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1. **Director’s Report**

The 2006 year has been an interesting one for the Centre for Water and Waste Technology with a number of staff and role changes. The year started with Professor David Waite on study leave from March until December 2006. During this time Associate Professor Richard Stuetz was acting Director of the CWWT. Professor Waite returned from study leave to the news that Professor Nicholas Ashbolt had resigned as Head of School for Civil and Environmental Engineering and was taking leave from UNSW for a 2 years position at the USEPA in Cincinnati. In February Prof Waite commenced preparation for taking over as Head of School. This has resulted in Associate Professor Stuetz becoming Director CWWT.

During a very busy and productive year in 2006, the CWWT continued its program of innovative yet applied research into environmental aspects of natural and engineered systems, with the year characterised by high productivity and ongoing grant success. Of particular note was the award of the first stage of a large collaborative project with Feedlot Services Australia, funded by Meat & Livestock Australia Limited, a project to examine the environmental impact and sustainability of cattle. The project brings together aspects of all of the CWWT disciplines together in one project, and is one that is supported by the strong teamwork ethic of the Centre.

Other projects commencing in 2006 included two ARC discovery grants on the “Absorption and removal of pharmaceutically active compounds by membrane processes used in water treatment and wastewater recycling” (Dr Khan and Dr Le-Clech) and “Membrane fouling in submerged hollow fibre membrane bioreactor systems: theory, modelling and fouling control” (Prof Waite, Dr Chang and Dr Le-Clech). These projects provided support for two new Centre Research Fellows, Dr Xiaomao Wang and Dr James McDonald. Dr Pierre Le-Clech was also awarded a three year NewSouth Global Post-doctoral Research Fellowship in collaboration with UNESCO Centre for Membrane Science and Technology to investigate “Fouling of organic materials in membrane bioreactors”. Dr Le-Clech has also been instrumental in establishing two 250 L pilot-scale MBR systems at Malabar STP in collaboration with the UNESCO Membrane Centre and industry partners.

In February, the Centre hosted the “1st IWA Australian Young Water Professionals Conference” which attracted 120 delegates from industry and universities throughout Australia. The conference included keynote presentations by Emeritus Prof Nancy Millis AC MBE and Ross Young (Water Services Association of Australia) and was sponsored by GHD, CRCWQT, CSIRO, CH2M-Hill and Maunsell. The conference presentations included a wide range of themes and provided a national forum for YWP to showcase current research being undertaken in Australia and also included a YWP mentor workshop in collaboration with Australian Water Association. CWWT also hosted its annual “IWA workshop of Odour Assessment and Treatment” in June and which was attended by 14 industry participants, the 3rd odour workshop is planned for December 2007.
With Professor Nicholas Ashbolt on study leave during 2007, Dr David Roser will become programme leader of the Environmental Microbiology and Pathogen Program. Prof David Waite will remain leader of the Physical & Chemical Processes Programme while he is Head of School. Dr Stuart Khan is taking leadership of the new program on Trace Organics. Dr Greg Peters continues as leader of the Life Cycle Assessment and Sustainability Program and Associate Professor Richard Stuetz remains the leader of the Environmental Odours and Atmospheric Emissions Program.

2007 is expected to be an exciting year with the hosting the 3rd AWA Water Reuse and Recycling Conference in July 2007 supported by Sydney Water, Veolia Water and CH2Mhill. This premier national water conference will include keynote presentations by Associate Professor Jörg Drewes and Prof Takashi Asano, the 2001 Stockholm Water Prize recipient. 2007 will also unfortunately see the departure after 9 years of Mrs Lyn Menzies as CWWT Business Manager.

I thank the group for their excellent efforts during 2006 and look forward to the challenges of improving the calibre of science and innovation that is undertaken by the Centre research staff.

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, Deputy Director and Business Manager together with a number of internally appointed Discipline 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 within the School of Civil and Environmental Engineering. Members of this Committee are:

- Assoc. Professor Richard Stuetz Deputy Director CWWT (Chair), Acting Director, 2006
- Professor David Waite Director, CWWT
- 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
- Ms Karrene Irvine School Senior Administrative Officer (by invitation)
- Mr Brett Miller Manager, WRL (by invitation)
- Mrs Lyn Menzies Business Manager, CWWT (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 2006 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 Stuetz.

During 2006 the programs and their leaders were:

- **Environmental microbiology and pathogen risk assessment**  
  Professor Nicholas Ashbolt

- **Physical-chemical processes**  
  Professor David Waite

- **Sustainability assessment**  
  Dr Greg Peters

- **Odour and atmospheric pollutant assessment and management**  
  Assoc Professor Richard Stuetz

- **Trace organics**  
  Dr Stuart Khan

4.1 **Environmental microbiology and pathogen risk assessment**

**Program Leader 2006: Professor Nicholas Ashbolt**  
**Current Program Leader: Dr David Roser**

National and international risk management-based water guidelines released by the World Health Organization and the National Health and Medical Research Council are starting to impact on how we manage water systems. CWWT researchers have played a significant role in the development of these guidelines for recreational waters, drinking water, and most recently water reuse guidelines. The principal factor promoted to harmonise priorities across all water exposures (for drinking, reuse and recreational waters) is that of tolerable disease burden – estimated by epidemiologic and quantitative risk assessment studies. CWWT continues to play a leading role in the development of methods for the latter.

As a consequence of the new guidelines, less emphasis is being placed 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
been emerging as the principal method that provides both target values for pathogens at control points, as well as what latitude there is for their control.

Major CWWT-lead projects through the CRC for Water Quality and Treatment (CRC-WQT), American Water Works Association Research Foundation (AwwaRF) and the European Union (via support from DEST) have provided and are continuing to provide critical data for assessing pathogen risks from catchments-to-taps and are also aiding in the uptake of the hazard analysis critical control point (HACCP) risk management approach. To facilitate its use we are also developing QMRA management tools that will allow the industry to estimate on a systems level, pathogen risks and integrate that information with economic, social, engineering and life cycle assessment tools, as promoted in the Sustainability Framework: Methodology for Evaluating the Overall Sustainability of Urban Water Systems (developed by the CWWT-lead team for the Water Services Association of Australia).

Highlights and important findings from recent projects include:

• Publication of the Australian Sustainability Framework: Methodology for Evaluating the Overall Sustainability of Urban Water Systems.

• Completion of recreational water management plans for local councils that utilise the water safety planning approach of the NHMRC (2005) guidelines, and hence use of microbial risk assessment to aid sanitary survey interpretation and target setting for safe swimming periods.

• Virus transport within un-saturated soils and groundwaters and the subsequent human health risks are able to be modelled in two dimensions (with HYDRUS-2D) following a collaborative project with leading Dutch researchers.

• Fate and transport of Cryptosporidium, E. coli and various viruses from faecal sources over land have led to several key findings, including the role of riparian vegetation in impeding Cryptosporidium but its minor role for bacteria and its insignificance for virus transport.

• Pathogens appear to be readily inactivated in faecal pats and soils during summer but not during cold periods. Furthermore, they are largely mobilized as single entities – important findings for modelling.

• Data summarizing the range of key pathogens, indicators and surrogates in drinking water tributaries across southern Australia during baseflow conditions and rain events is now available to aid risk assessments.

• Fully protected catchments provide in excess of the equivalent in pathogen reduction to that of water filtration. In contrast, septic-impacted catchments may result in 100 to > 10,000 fold increases in pathogen risks when extracting drinking water from rivers or small reservoirs.

• Legionella pathogens that develop with amoeba within domestic hot water pipe biofilms have been shown to be partly resistant to chlorination and heat (80°C) treatments through protection in amoeba cysts.

• Publication of the final report and book chapter on our collaboration with the Swedish group (funded by the Swedish Urban Water MISTRA program) that led to system life-time models for pathogen risks associated with a variety of urban water
and wastewater alternatives. Examples studies included urine-separation and its use in agriculture, domestic greywater reuse, and vacuum blackwater digestion and reuse for wastewater streams; and raw water supply to households with point-of-use treatment for domestic use.

- Completion and publication of the final EU report by researchers in CWWT to the MicroRisk (European Union and DEST project), which will be released as a guidebook for catchment-to-customer microbial risk assessment for drinking water systems by the World Health Organization and the International Water Association.

For further information please contact Dr David Roser: djroser@civeng.unsw.edu.au

### 4.2 Physical-Chemical Processes, Contaminated Sediments and Groundwaters

**Program Leader: Professor David Waite**

The Physical – Chemical Processes discipline area within the Centre for Water and Waste Technology conducts research into physical and chemical aspects of both the natural aquatic environment and engineered water and wastewater treatment systems. The areas of principal activity through 2005 included research into membrane fouling and advanced oxidation and redox technologies, investigation of contaminant transport from coastal regions underlain by acid sulfate soils, continuing investigation of factors influencing the bioavailability of iron in marine systems and the role of iron in stimulating the growth of toxic cyanobacteria in coastal waters.

Australian Research Council support has been particularly important in enabling appointment in 2005 of Dr Andrew Rose to a project focussed on investigation of the role of iron in influencing the growth of the cyanobacterium *Trichodesmium* in waters of the Great Barrier Reef and Dr Richard Collins to studies of contaminant transport to adjacent waterways from regions affected by acid sulfate soils. ARC grants also support doctoral students Quan Sun who is refining our understanding of the oxidative behaviour of nanosized zerovalent iron particles, Suvinai Santiwong and Peter Kovalsky who are studying the fouling behaviour of compressible cakes formed during membrane filtration of waters and wastewaters and Adele Jones who is working with Richard Collins, Associate Professor Mike Melville and Professor Waite in studies of iron and aluminium in coastal acid sulfate soils affected catchments. ARC support has also enabled the appointment of APAI student Mark Bligh to continue our investigations into factors inducing growth of the toxic cyanobacterium *Lyngbya majuscula* in coastal waters in collaboration with colleagues from the University of Queensland.

New ARC projects in the area of membrane filtration were awarded in late 2005. In particular, support has been obtained for detailed studies of the behaviour of fouling
layers on submerged membranes used in membrane bioreactors. This project will be lead by Professor Waite and Dr Sheng Chang, a previous Centre employee who is now working for Zenon Corporation in Canada. Funds are available for appointment of a research fellow to this project in 2006. A second project in the area of membrane fouling is focussed more on fouling prevention through vibration of submerged membrane systems and builds on studies initiated by our Israeli colleague Dr Gregory Genkin. Funding enabling appointment of two doctoral students and a postdoctoral fellow has been provided by the Australian Research Council.

As mentioned in my Director’s report, Dr Andrew Feitz, the previous leader of the Physico-Chemical Processes Program has accepted a Humboldt fellowship and will be taking up this position at the University of Karlsruhe in the group led by Professor Fritz Frimmel. While Andrew will no longer be based within CWT, we expect there will be ongoing interaction with our “delegate to Europe”, particularly in areas related to zero valent iron.

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

4.3 SUSTAINABILITY ASSESSMENT

PROGRAM LEADER: DR GREG PETERS

Life Cycle Assessment (LCA) is a method developed to model and evaluate the mass and energy balance of inputs and outputs of systems and to organise and convert those inputs and outputs into environmental themes with regard to resource use, human health and ecological sustainability. LCA takes into account environmental impacts over the entire life cycle of a product or service, from the extraction of raw materials, through to the consumption and final disposal of the product. In other words, it is a method for determining the 'environmental burden of a product from its design through to production and then final disposal'.

Research & Consulting Projects

Intensive research is undertaken in the areas of

- Sustainability assessment
- Life Cycle Assessment
- Life Cycle Costing
- Triple-Bottom-Line reporting
- Sustainable planning frameworks
- Input-Output Analysis
The above methods have a wide application in the water industry, waste management, food and manufacturing industry, clean technologies and tourism sector. Projects have been carried out for clients from industry and governmental organisations.

**Research links with teaching**

Since 2003, Sven Lundie, Greg Peters and other staff in the Program have been active in educating the next generation of engineers in waste management technologies and sustainability assessment in general. One highlight is a final year elective for students of environmental engineering which was designed to improve their “soft skills” (project management, communication, teamwork) as future engineering professionals. In 2005, students in Environmental Engineering Practice 4a (CVEN4727) compiled a Triple Bottom Line Report of the University of New South Wales in order to establish UNSW at the forefront of sustainable development of Higher Education Organisation. Based on pathfinding work by students in this class in 2004, and collaboration with UNSW managerial staff, the students were able to put together a “Pilot Sustainability Report on UNSW” which would rival anything produced by commercial sustainability consultancies. In 2006 and 2007 we focussed this subject on actual sustainable water cycle management projects involving collaboration with local councils.

**National and international Collaborations**

- **Australian Life Cycle Assessment Society (ALCAS):** Greg Peters is the Vice President of ALCAS, which is developing 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 Devison 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.

For further information please contact Dr Greg Peters at: g.peters@unsw.edu.au or Associate Professor Sven Lundie at: s.lundie@unsw.edu.au

### 4.4 Odour and Atmospheric Pollutant Assessment and Management

**Program Leader: Dr Richard Stuetz**

Odorous emissions from environmental sources (such as waste facilities, wastewater treatment plants, agricultural practices and transport infrastructure) are areas of increasing public 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 on public health (for example, road tunnel emissions). To improve the management of these emissions, new knowledge on the identification and generation of environmental emissions is required. The mission of the research group is to provide international leading research and training through the application of different analytical techniques for the measurement of environmental emissions and the development of novel treatment systems for the abatement of odours and odorants.

The group continues to develop its skills in the application of olfactory – mass spectroscopy (GC-MS-O). The GC-MS-O allows for the integration of olfactory analysis with GC-MS for solving complex odorants (Figure 1), this is achieved through the separation of annoyance odorants and their identification as individually compounds via mass spectroscopy analysis. During 2006, our Markes Unity thermal desorption system was upgraded with addition of an autosampler, which increases the analytical capacity of the group GC-MS for more automated VOC analysis. The Unity autosampler also allows for automated conditioning of our sorbent tubes. These new analytical systems will compliment existing technical expertises:

- Sampling and measurement of odours from different field sources;
- Sampling and 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 treatment and abatement.

**Current research areas / projects include:**
- Chemical analysis of odorants from Poultry facilities
- 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
- Corrosion and odours in wastewater collection systems

The group undertook a number of technical reviews for industry including a Water Environment Research Foundation (WERF) report on odours formation and corrosion in sewer systems with 14 other research partners, that will be published in 2007 as well as submitting several research proposals to the Australian Research Council, and the Poultry CRC. CWWT hosted its annual IWA workshop on Odour Assessment and Control in June 2006 which was attended by 14 industry participants, the 3rd odour workshop is planned for December 2007. The workshop aims to promote a wider understanding of the current issues in the assessment and management of environmental emissions and odours and consist of lectures and practical demonstration of odour sampling and measurement including dilution olfactometry testing.

The olfactory services continue to expand its contract based research activities and undertook a number of analytical assessments, odour measurement surveys, impact assessments and odour control product evaluations for clients.

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

Figure 1: GC-MS-O system
4.5 Trace Organics

Program Leader: Dr. Stuart Khan

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

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

A particular strength is the range of analytical capabilities in the use 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 close working relationship with the UNSW Biomedical Mass Spectroscopy Facility (BMSF) has significantly expanded the range of analytical equipment that may be utilised for CWWT research and consultancy projects.

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 both Australian and European water recycling guidelines particularly focusing on risk assessment techniques for trace organic chemicals.

A number of risk assessments were conducted during the year for Sydney Water. One of these was a human health risk assessment for their ‘Replacement Flows’ water recycling proposal and another for the risks associated with beneficial reuse of biosolids.

The Trace Organics Program is closely involved with the newly established ‘pilot hall’ facility at UNSW, which 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.

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

### 5.1 Overview

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Key Project Proponents</th>
<th>Research Topic</th>
<th>Granting Organisation</th>
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<td>An environment rating scheme for air conditioning and refrigeration systems using life cycle assessment methodology</td>
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<td>Microbial risk assessment - a scientific basis for managing drinking water safety from source to tap in collaboration with KIWA (Netherlands)</td>
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<td>Development of an integrated sustainability framework for best management practice of urban water systems</td>
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<td>T.D. Waite M. Melville I. White (ANU) R. Bush (USC) R. Collins</td>
<td>Reducing export of acid sulphate soil products (particularly iron, aluminium, phosphorus and organic carbon) as contaminants to coastal waters</td>
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<td>Predicting Lyngbya blooms: impact of iron transformation kinetics on flux, distribution and rate of uptake of bioavailable iron and phosphorus</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>
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<td>N. Ashbolt C. Davies</td>
<td>Challenge testing of UV treatment at Rouse Hill Recycled water plant</td>
<td>Sydney Water</td>
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<td>R. Stuetz</td>
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<td>T.D. Waite A. Feitz J. Guan</td>
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<td>C. Ferguson (Ecowise) N. Ashbolt C. Davies</td>
<td>Pathogen modelling in Watersheds</td>
<td>AWWARF through CRCWQT 202111</td>
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<td>2006/22</td>
<td>G. Swarbrick R. Stuetz S. Deaver (PGH)</td>
<td>Former camide landfill, Horsley Park: Landfill gas drainage &amp; biofiltration trial</td>
<td>CSR PGH</td>
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<td>T.D.Waite Xiaomao Wang S. Chang</td>
<td>Membrane fouling in submerged hollow fibre membrane bioreactor systems: theory, modelling and fouling control</td>
<td>ARC DP0665515</td>
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<td>2006/24</td>
<td>N. Ashbolt, G. Peters, D. J. Roser S. Khan, C. Davies</td>
<td>Managing the contaminants in feedlot waste products (Flot 333) with Feedlot Services Australia</td>
<td>Meat and Livestock Australia Ltd</td>
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<td>N. Ashbolt, C. Davies C. Kaucner</td>
<td>Riparian and water quality protection by influencing livestock movements.</td>
<td>Sydney Catchment Authority</td>
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<td>2006/26</td>
<td>N. Ashbolt, D. J. Roser, C. Davies, S. Petterson</td>
<td>Estimating the Relative Risk from Sewage Treatment Plant Effluent</td>
<td>Sydney Catchment Authority</td>
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<td>2006/27</td>
<td>A. Sharma</td>
<td>Climate change and its impacts on water supply and demand in Sydney with CSIRO, Metropolitan Water Directorate, NSW Greenhouse Office</td>
<td>The Cabinet Office (NSW)</td>
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<td>$200,000</td>
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<td>2006/28</td>
<td>N. Ashbolt C. Davies S. Petterson C. Kaucner</td>
<td>Quantifying stormwater recycling risks and benefits</td>
<td>Victorian Government Smart Water Fund Monash University sub-contract</td>
<td>$6,000</td>
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<td>2006/29</td>
<td>S. Khan J. McDonald</td>
<td>Absorption &amp; removal of pharmaceutically active compounds by membrane processes used in water treatment &amp; wastewater recycling</td>
<td>ARC DP0557085 (transferred from University of Wollongong)</td>
<td>$101,959</td>
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<td>R. Stuetz</td>
<td>Atmospheric emissions management workshop</td>
<td>Various</td>
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<td>2006/31</td>
<td>R. Stuetz, P. LeClech M. Storey (Sydney Water)</td>
<td>AWA Young Water Professionals Conference</td>
<td>Australian Water Association</td>
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<td>Feedlot Services Australia</td>
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<td>G. Peters, H. Rowley</td>
<td>Environmental Life Cycle Assessment of Biosolids Applications</td>
<td>NSW Biosolids Taskforce through Australian Water Association</td>
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<td>G. Peters, H. Rowley</td>
<td>Life Cycle Assessment for Christies Beach WWTP Upgrade</td>
<td>South Australia Water Corporation</td>
<td>$19,329</td>
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<td>G. Peters</td>
<td>Sale of Gabi 4 Lean LCA software including the Australia specific database</td>
<td>Environ Pty Ltd</td>
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<td>N. J. Ashbolt, D. Roser</td>
<td>Designing and prioritising water quality monitoring</td>
<td>Parramatta City Council</td>
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<td>2006/38</td>
<td>D. J. Roser, C. Davies, A. Feitz</td>
<td>Sustainable water treatment processes research</td>
<td>UNSW Foundation</td>
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<td>D.J. Roser, N.J. Ashbolt, C. Davies, S. Petterson S. Khan S. Petterson R. Signor</td>
<td>Health Risk Assessment of the use of treated effluent for environmental flows</td>
<td>Sydney Water Corporation</td>
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<td>2006/40</td>
<td>D.J. Roser</td>
<td>Assessment of risks arising from urban development especially sewage/on site septic waste overflows and transport</td>
<td>Queensland Department of Natural Resources, Mines &amp; Water</td>
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<td>Physical Chemical Processes program</td>
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<td>T.D. Waite</td>
<td>Provision of expert advice to the Lyngbya Scientific Working Group</td>
<td>Moreton Bay Waterways and Catchments Partnerships</td>
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<td>R. Stuetz, X. Wang, J. Guan</td>
<td>Odour Laboratory analyses</td>
<td>various</td>
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<td>Odour assessment at Warriewood STP</td>
<td>Clayton UTZ</td>
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<td>2006/46</td>
<td>R. Stuetz, X. Wang, J. Guan, A. Feitz</td>
<td>Assessment of ozonation for the destruction of odour from alumina refinery digestion condensate</td>
<td>Australian Aluminium Council</td>
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<td>Olfactometry analyses</td>
<td>Sydney Water</td>
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<td>2006/49</td>
<td>R. Stuetz, R. McLaughlan (UTS)</td>
<td>Collaborative research to support Nida Seelsaen PhD studies</td>
<td>UTS</td>
<td>$2,000</td>
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<td>2006/50</td>
<td>R. Stuetz, J. Guan</td>
<td>Method development for determination of unreacted residual monomer in finished polymer coated flat products</td>
<td>James Hardie P/L</td>
<td>$5,930</td>
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<td>2006/51</td>
<td>G. Chattopadhyay</td>
<td>Development of indoor air quality indicators and methodology for inclusion in Green Globe 21 benchmarking program</td>
<td>CRC Sustainable Tourism subcontract with UNSW Faculty of the Built Environment</td>
<td>$6,009</td>
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<td>S. Khan, J. Guan, R. Stuetz</td>
<td>Trace organics assessments</td>
<td>various</td>
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<td>S. Khan, J. Guan</td>
<td>Fouling diagnosis study</td>
<td>Veolia Water Systems through NSGlobal J070020</td>
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<td>2006/54</td>
<td>R. Stuetz</td>
<td>Membranes for Hydrogen Sulphide Odour Abatement</td>
<td>Faculty of Engineering</td>
<td>$14,000</td>
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</table>
5.2 Project Summaries

Summaries of selected projects that were either completed or were active during 2006 are provided below:

**Project 2006/28: Quantifying stormwater recycling risks and benefits**

**Funding Body:** Victorian Smart Water Fund, sub-contract with Monash University.

**Research Team:** ISWR, Monash University - Grace Mitchell (project leader), Ana Deletic, Tim Fletcher, Justin Lewis and Peter Poelsma, CWWT, School of Civil & Environmental Engineering, University of New South Wales - Prof Nicholas Ashbolt, Dr Cheryl Davies and Dr Susan Petterson University of Melbourne: Dr Louisa Flander City of Melbourne - Caroline Chandler

**Project Duration:** 2006-2008

With funds obtained under the Victorian Government initiative Smart Water, researchers from The Institute for Sustainable Water Resources, Monash University, UNSW Centre for Water and Waste Technology, and Melbourne University are undertaking a collaborative evaluation of three existing stormwater treatment systems, and the risks involved in non-potable reuse of treated urban stormwater.

The three sites, located in Melbourne at Royal Park, Altona Green, and Monash University, provide a range of barriers including UV disinfection, biofiltration, a constructed wetland, and retention ponds. Recycled water from each of these systems is used for open space irrigation. Funds are also currently being sought to study an additional site at Victoria Markets where recycled stormwater is used for hosing down market floors, and toilet flushing.

The specific objectives of the two-year project are to:

- Quantify the human and environmental risk associated with current stormwater recycling practices (particularly with respect to microbiological

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<tr>
<th>Project No.</th>
<th>Key project proponents</th>
<th>Research Topic</th>
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<td>2006/56</td>
<td>A. Rose</td>
<td>The influence of Environmental Variables on Extracellular Superoxide Production by Marine Microorganisms</td>
<td>Faculty of Engineering</td>
<td>$19,600</td>
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</table>
water quality parameters and heavy metals and performance at systems’ critical control points);

• Critically assess the performance of three diverse stormwater recycling systems, with particular reference to the appropriateness of collecting, treating and reusing stormwater for non-potable purposes (such as open space irrigation and toilet flushing);

• Quantify the amount of potable substitution achieved in comparison to design estimates and provide recommendations on design refinements required to maximise system performance; and

• Create a database of water quality and flow data which can be used for future integrated urban water management studies.

The study includes dry and wet weather monitoring of each system, as well as challenging each of the barriers with pathogen surrogate microorganisms.

Biofilter at the Monash University site

Project 2006/21: Pathogen modelling in Watersheds
Funding Body: CRCWQ&T with contributions from The American Water Works Association Research Foundation (AwwaRF)
Research Team: Ecowise - Dr Christobel Ferguson
UNSW - Professor Nicholas Ashbolt, Dr Cheryl Davies, Christine Kaucner.

A process based mathematical model was previously developed to predict the generation and export of pathogen loads in Sydney’s drinking water catchment
(Christobel Ferguson, PhD, University of New South Wales). Whilst some quantitative data was available for input to the model, a lack of data for certain inputs meant that some assumptions had to be made. For example, mobilisation rates of pathogens from animal faecal deposits were estimated according to the shape, size and consistency of the faeces. Sensitivity analysis carried out on the model indicated that the rate of mobilisation was an important parameter for predicting pathogen loads in catchments.

Funds were obtained from the American Water Works Association Research Foundation and the CRCWQT to further refine and develop this model, as well as an existing hydro-meteorological model (developed by Shane Haydon, Melbourne Water), to provide a flexible two-tiered approach that will allow for users with different levels of supporting data. Under a sub-contract, CWWT is responsible for provision and incorporation of quantitative data on pathogen mobilisation rates from animal faeces that would enhance the predictive capabilities of the models. The end products will be web user interfaces that can be accessed by AwwaRF subscribers.

Experiments carried out to quantify the impact of raindrops on pathogen release from the faecal matrix, and their transport in overland flow for the faeces of several animals types that are prevalent in Australian catchments, are now complete. The data will be incorporated into the models, and the refined models applied to a number of catchments in Australia, USA, and UK, using historic data to test the outputs.

**Project 2006/24: Managing the contaminants in feedlot waste products (Flot 333) with Feedlot Services Australia**

**Funding Body:** Meat & Livestock Association  
**Research Team:** (1st row) Robyn Tucker, Nicholas Ashbolt, David Roser, (2nd row) Cheryl Davies, Hazel Rowley, Greg Peters, Peter Watts, Stuart Khan and Richard Stuetz. FSA consulting: Robyn Tucker & Peter Watts.  
**Project Duration:** 2006 - 2008
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.

The new MLA research 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 2006, the project team was engaged in extensive data-gathering, including a literature review, inspections of feedlots from western Victoria to central Queensland and meetings with key researchers in the United States from Iowa to Texas. The ideas and information have been summarised in a report to the client, and will facilitate quantitative risk assessment and the development improved management guidelines for the reuse of feedlot byproducts.

**Project 2006/16: Life Cycle Analysis of the grass fed red meat industry with Feedlot Services Australia**

**Funding Body:** Meat and Livestock Association  
**Research Team:** CWWT - Greg Peters, Hazel Rowley, Matthias Schulz  
FSA Consulting – Robyn Tucker, Steve Wiedemann  
**Duration:** 2005-2007

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 2006, the project team visited farms in three states and collected life cycle inventory (LCI) data on their operations. We also examined the feasibility of using traditional LCA indicators for modelling the potential impacts associated with these operations, and proposed ways of examining issues of interest to meat producers. This information was presented at a workshop with the client, enabling the project team to identify the most promising directions for the remainder of the project.

**Project 2006/09: Development of an integrated sustainability framework for best management practice of urban water systems**

**Funding Body:** ARC Industry Linkage, with Water Services Association Australia and Total Environment Centre

**Research Team:** CWWT - Nicholas Ashbolt, Elizabeth Lai, Sven Lundie, Hazel Rowley, Greg Peters

CIT Urban Water, Chalmers University, Sweden - Erik Kärmen

Sustainable Water Division of NSW Department of Commerce, Sydney - John Anderson and Jennifer Blaikie,

**Duration:** 2004-2007

Over the last decade, water cycle management has become an increasingly challenging marketplace of ideas. Citizens have demanded increasingly higher environmental performance from their water service providers, while governments demand greater financial efficiency and the service providers cope with population and climatic pressure. To use Sydney’s systems as an example of this, Sydney Water has been required to reduce nutrient discharges, entailing many different kinds of large infrastructure investment. The government has forced Sydney Water to trade as a corporatised business, shed staff and improve its profitability. In the last ten years, the organisation has added half a million customers and experienced one the worst droughts on record, which climatologists believe to be related to global climate change. To cope with the pressures bearing on Sydney Water, particularly population growth and higher standards, capital works expenditure by the organisation reached almost four billion dollars in that time period. These examples of pressures on Sydney’s water cycle management are typical of the Australian water industry as a whole.

At the same time, the range of practical information tools and planning approaches available to water cycle managers has expanded, including strategic environmental tools such as life cycle assessment, health risk methodologies like quantitative microbial risk analysis, cost assessment techniques like life cycle costing and approaches to public engagement like choice modelling. Under these circumstances
in which the variety of practical, political and intellectual influences on water cycle planning has grown, managers are looking for clarity on the best ways to plan for the future development of their water, sewerage and stormwater systems. This means taking a holistic, multidisciplinary approach.

The CWWT joined with the Sustainable Water Division of the NSW Department of Commerce and CIT Urban Water at Chalmers University, Gothenburg, to provide a Sustainability Framework for the Water Services Association of Australia. This was delivered in 2005. During 2006, the research team has been engaged in dialogue with stakeholders about a detailed case study which will illustrate how the Framework can operate in practice. We also engaged in dissemination activities to industry including publication in the Australian Water Association’s journal Water and preparation of a paper and presentation for the Ozwater conference.

**Project 2006/06: Development of a novel ecological footprint for environmental reporting of companies**

**Funding Body:** ARC Industry Linkage grant with Sydney Water to Sydney University, sub-contract with Sydney University.

**Research Team CWWT:** Sven Lundie, Gregory Peters, Hazel Rowley, Henry Hu.

Ecological footprint (EF) calculation is a method of sustainability assessment made popular by Mathis Wackernagel. EF has captured the public imagination because of its relatively concrete indicator metric – a hectare of land – and the energetic communication activities in which Wackernagel and others have engaged. Most people can imagine an area of land 100 metres along each side, so describing the number of hectares required by an organisation supplying drinking water, or the hectares disturbed by the organisation, is more meaningful to the general public than saying how many kilograms of carbon dioxide are emitted by the organisation. The key issue with ecological footprints is the extent to which environmental impacts can be quantitatively converted to hectares. This conversion will, by mathematical definition, always mean more assumptions need to be made than would be the case if we were happy to only tell Joe Public about his impacts in more abstract terms, but if scientists are to engage with the public and government policy, more assumptions may be better than more precision.

This project has developed a revised methodology for calculating ecological footprints. It considers anthropogenic disturbances at a finer level of geographical disaggregation than previous methods – instead of a single national land area it considers 1408 smaller regions. It also addresses a previous gap in disturbance-based ecological footprint calculation – the exclusion of ecotoxic emissions. In 2006 we submitted an article to an international journal on this method and described it using a case study. The resulting ecological footprint is larger than previous calculations, but it avoids a current methodological problem in which the energy used to treat exhaust gases or wastewaters increases the ecological footprint of communities without any corresponding benefit associated with reduced emissions to the environment.
Project 2006/10: Reducing export of acid sulfate soil products (particularly iron, aluminium, phosphorus, and organic carbon) as contaminants to coastal waters.

Funding Body: Australian Research Council industry linkage with, Tweed Shire Council and the NSW Canegrowers Association

Chief Investigators: UNSW, Professor David Waite, Associate Professor Mike Melville, ANU, Professor Ian White and SCU, Dr Richard Bush

Research Team: Dr Richard Collins, Senior Research Associate, Ms Adele Jones, PhD Scholar, Ms Francisca Alvarez, Honours Scholar, Ms Le Thi Minh Hue, Honours Scholar, Dr Marty Hancock, TSC Floodplain Officer

Duration: April 2005 – June 2008

Objectives

The overall objective of this project is the development of innovative, yet practicable floodplain management techniques designed to reduce the impacts of acid sulfate soil (ASS) drainage products on estuarine and coastal waters quality. These ASS drainage products include metals such as iron, aluminium and manganese as well as phosphorus and natural organic matter. These products are important drivers of emerging coastal water quality problems including metal toxicity and oxygen depletion to aquatic organisms as well as stimulating the growth of harmful algal blooms.

r groundwater levels and chemistry in acid sulphate soils and how they respond to rainfall events and tidal fluctuations. The soils in the region seem to have a large capacity to quickly absorb rainfall (minutes to hours) but drain laterally very slowly (days to weeks) to the drains. The latter characteristic is of considerable practical interest as this suggests that subsurface migration of ASS contaminants is slow and, on the contrary, that salt intrusion (from the tidal flushing of drainage lines) should be an effective acid neutralising management strategy. These results are, however, perplexing in that the source of acid generating contaminants in the drains of ASS is not evident. As such, field monitoring and sampling is ongoing to unravel the biological, physical and chemical processes contributing to the transfer of ASS contaminants from the soil to the drain and eventually to the Tweed River. It is anticipated that these findings will be incorporated into a predictive hydrogeochemical model that can be used to ascertain the success of innovative floodplain management Research Program

The research program is approaching the objectives of the project by:

(1) water quality and weather monitoring to determine the temporal and spatial changes of water flow as well as assist in determining the soluble chemical forms of iron and aluminium as they are transported from the soil to the surrounding aquatic systems (e.g. drainage, estuary and coastal systems).

(2) determining in the field and laboratory, the hydrologic and hydraulic characteristics of the various ASS materials and profiles, and how they change; and

(3) determining the physico-chemical parameters controlling solute (and contaminant) transport in ASS soil profiles.
Field monitoring equipment has been installed at field sites in the Tweed River Floodplain to monitor techniques before they are implemented.

Field determination of ASS drain chemistry on the Tweed River floodplain (October 2006).

**Project 2006/23:** Membrane fouling in submerged hollow fiber membrane bioreactor (SHFMBR) systems: theory, modelling and fouling control

**Funding Body:** Australian Research Council discovery project funding

**Research Team:** David Waite, Pierre Le-Clech, Sheng Chang, Xiaomao Wang

**Project Duration:** 2006-2008

Membrane bioreactor (MBR) is a promising process for wastewater treatment and water reclamation, although membrane fouling, which decreases membrane permeability and increases operation cost, remains a major deterrent to its wider application. For decades, a main focus of MBR study has been on the identification, characterization, mechanism investigation and modelling of membrane fouling. Notwithstanding the vast numbers of investigations on membrane fouling, it seems that there is lack of some common understanding on this subject. The main reasons are related to the complexity of the MBR system and the poor comparability between various investigations.

In the present project, a comprehensive investigation of the influence of biological process conditions will be carried out to develop a fundamental understanding of membrane fouling. Three identical MBR (Fig. 1) will be constructed and operated in parallel to minimize the influence of the fluctuation of sludge characteristics with time. The studied biological conditions include sludge retention time (SRT)/organic loading, sludge concentration, dissolved oxygen (DO) concentration, nutrient (N)
concentration and mineral metal (Ca$^{2+}$) concentration. These biological conditions can greatly influence sludge characteristics such as extra-cellular polymeric substances (EPS) and soluble microbial products (SMP) contents, which were demonstrated by many investigations to be the most impacting factors of membrane fouling.

Based on the monitored results, relations between membrane fouling behaviours, EPS/SMP characteristics and biological conditions can be correlated. The biological conditions that significantly influence membrane fouling can be determined. A deep and comprehensive insight is expected to be formed on membrane fouling. Thereafter, the fouling layer modelling and simulation will be done to describe the evolvement of membrane fouling and establish a comprehensive fouling theory. The structure and development of the fouling layer are the main foci of modelling in the present project. The ultimate goal of this project is to find some feasible methods to control or minimize membrane fouling.

The project aims to:

- understand factors controlling membrane fouling in SHFMBR for wastewater treatment through comprehensive theoretical and experimental studies in which interrelationships between membrane fouling, extracellular polymeric substances (EPS) properties and biological process parameters will be established;

- investigate and model the structure and transport characteristics of the gel layer formed on the membrane surface through rigorous simulation and advanced image morphological processing and, in so doing, develop a novel theory to describe the relationship between structure parameters and transport mechanism within the gel layer;

- apply the above findings to optimization of design and operation of the membrane processes in SHFMBR systems.
Project: 2006/38: Solar and Photocatalytic Inactivation Rates of Micro-organisms in Drinking Water
Funding Body: UNSW Foundation, - Sustainable water treatment processes research
Research Team: David Roser, Cheryl Davies, Andrew Feitz, Nicholas Ashbolt
Project duration: 2005-2007

Solar-assisted thermal disinfection of drinking water has been proposed for ‘point of use’ disinfection in tropical regions under the banner of ‘SODIS’. The objective of this study was to measure natural sunlight-driven inactivation in a wet (1100 mm rainfall.y-1), middle latitude location (33oS), under optimised reaction conditions and assess its potential for use in such climatic zones. Water containing Enterococcus faecalis, spores of Clostridium sporogenes, and PRD1 bacteriophage, (final concentrations ca 1 x 105 mL-1 was exposed to sunlight in 22-L reaction vessels. The results showed that on sunny days, disinfection would be effective all year round (3.0-7.8 log10.d-1 reduction of C. sporogenes, and PRD1 (10th percentile)). The disinfection effectiveness was reduced with coloured water (140 colour units) but not with turbid waters (900 NTU). Performance was compromised by short and overcast days, but storage for three days could greatly mitigate this. Reactor area requirements (0.015 m2.L-1) were significant but not prohibitive. The use of TiO2-coated tiles failed to enhance disinfection. Importantly for more temperate regions, inactivation by solar irradiation alone appears sufficient for effective disinfection under optimised conditions. Overall, the data indicated the potential for applying the SODIS concept more widely, providing the performance periods are managed properly.

Project 2006/29: Adsorption and Removal of Trace Organic (pharmaceutical) Compounds by Membrane Processes used in Water Treatment and Wastewater Recycling
Funding Body: Australian Research Council Discovery Fund
Research Team: Stuart Khan, Pierre Le-Clech, and Menachem Elimelech
Project Duration: 2005-2007

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.

Dr James McDonald was employed as a full-time research associate on this project in October 2006. James’ role has been focusing on developing and refining analytical methods for the determination of a range trace organic chemicals including pharmaceutically active compounds, endocrine disrupting chemicals and flame retardants.

Initial investigations have examined the effects of the operating conditions including feed water chemistry and membrane fouling on the retention of trace organics by a loose nanofiltration membrane. Trace organics with functional groups having pKa values in the environmental pH range and outside the environmental pH range were selected for investigation under a variety of conditions. Results indicate 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 (Nghiem & Khan, 2006). These observations may be explained by electrostatic interactions between the solutes and the membrane surface and by the speciation of the ionisable compounds. Membrane fouling has also been shown to exert some considerable impact on the retention of trace organics (Nghiem et. al, 2007). The underlying mechanisms however remain unclear and are the subject of current investigations.

**Project 2006/04: Microbial risk assessment - a scientific basis for managing drinking water safety from source to tap**

**Project Participants:** Nicholas Ashbolt, Susan Petterson, David Roser and Ryan Signor in collaboration with KIWA water research, Netherlands (led by Dr Gertjan Medema through the European Union MicroRisk project [www.microrisk.com] involving UNSW with the 10 European partners)

**Funding Body:** Department of Education Science and Training (DEST)

International Science Linkages Program; established under the Australian Government’s innovation statement Backing Australia’s Ability.

**Duration:** 2003 - May 2006

MicroRisk is a collaborative research project with the objective of developing and evaluating a harmonised framework for quantitative assessment of the microbiological safety of drinking water in the EU member states. Australia was involved through a DEST collaborative grant.

The component reports of the project comprised the following:

1. QMRA: its value for risk management
2. Intestinal illness through drinking water
3. Pathogens in drinking water sources, literature review
4. Pathogens in source water, source water assessment
5 Efficacy of water treatment processes
6 Contamination during distribution
7 Estimation of the consumption of cold tap water for microbiological risk assessment
8 QMRA methodology
9 How to implement QMRA? Estimate Baseline and Hazardous Event Risks with Management End Uses In Mind

CWWT was responsible for parts 8 and 9. The project was completed in May 2006; for the complete project refer to www.microrisk.com.

**Project 2006/52: Risk Assessment and Health Effects Studies of Indirect Potable Reuse Schemes**

**Funding Body:** Local Government Association of Queensland

**Research Team:** Stuart Khan and David Roser

**Project Duration:** December 2006

The outcome of this project was a literature review examining existing studies that have been undertaken to investigate the health effects of planned indirect potable reuse of municipal effluents.

Planned potable reuse of municipal wastewater refers to the purposeful augmentation of a potable water supply (surface water or groundwater) with highly treated reclaimed water derived from conventionally treated municipal effluents. In ‘indirect’ potable reuse schemes, the mix of reclaimed and traditional source waters receives additional treatment prior to distribution to customers.

Municipal wastewaters contain a complex mixture of chemicals and microbiological organisms. As a result, they pose particular challenges for assuring the safety of their use as sources of potable water. These challenges have been addressed by the incorporation of Advanced Water Treatment processes that provide a level of treatment that is not normally used in either existing sewage treatment plants currently discharging into Australia’s rivers and oceans or drinking water treatment plants currently operating on water abstracted from Australia’s rivers or dams.

Planned indirect potable recycling schemes have been implemented and assessed in terms of their human safety in the USA since the 1960s. A number of major case studies were presented in the report including:

- Montebello Forebay Groundwater Recharge Project (California)
- Potomac Estuary Experimental Water Treatment Plant (Washington DC)
- Denver Direct Potable Reuse Demonstration Project (Colorado)
- San Diego Total Resources Recovery Project (California)
- Tampa Water Resource Recovery Project (Florida)
- Singapore Water Reclamation Study “The NEWater Study”
The planned indirect potable recycling schemes provided different levels of advanced water treatment, ranging from simple filtration and disinfection in the early studies conducted on the Montebello Forebay, through to granular activated carbon (GAC), reverse osmosis (RO) and ozonation used in schemes located in Colorado and Florida. Notwithstanding this, the health-effects studies from each project are extremely encouraging in terms of the potential safety of planned potable water recycling in Australian cities. In spite of comprehensive investigations, no clear deleterious effects have been identified. Furthermore, waters treated in preparation for recycling were routinely shown to be of equal or greater quality than traditional potable water sources. This applies to both microbial and chemical water quality. Risks associated with indirect potable reuse (while never zero) are successively decreased with increasing levels of treatment.

While studies undertaken overseas bode well for the safety of recycled water generally, exactly how effectively these studies can be translated to potential Australian schemes is less clear. Water sources will differ and water treatment processes will differ. Furthermore, environmental barriers (surface water or groundwater environments) may differ significantly from scheme-to-scheme. Therefore, in order to ensure the full protection of public health, a comprehensive health assessment should be undertaken specifically for any planned Australian scheme. Australian health risk assessment guidelines such as those published by Queensland Health Council provide guidance on how such risk assessments should be undertaken. More specific guidance is anticipated in Phase 2 of the National Guidelines for Water Recycling which is undergoing development during 2007.


Funding: Upper Parramatta River Catchment Trust

Research Team: David Roser, Cheryl Davies, Stephen Wyllie (WRL) and Nicholas Ashbolt

Project Duration: 2004-2007

Lake Parramatta is a decommissioned drinking water reservoir located approximately 3 km north of the city of Parramatta. The Lake has a surface area of 10.5 hectares and holds when full 450 megalitres of water. It was created by damming the Hunts Ck valley. The reservoir is 13 metres deep at the dam wall reducing to ca 2 m in its upstream reaches. The Lake’s foreshores are largely comprised of coastal bushland overlying Narrabeen/Hawkesbury sandstone typical of many coastal parts of the Sydney Basin.

The Upper Parramatta River Catchment Trust determined in 1997 to implement work leading to the Lake having good enough microbial water quality to be ‘swimmable’ once again for visitors. An initial target date of 2005 was established under the banner ‘Swim Toward 2005’. To this end it has undertaken several monitoring and environmental studies. In discussions with the Trust, CWWT proposed a project of 3 stages to collect microbiological and related data needed to understand the severity and sources of water borne pathogens with a view to remediating the catchment and
minimising the exposure of recreators to water borne pathogens. This new risk based management approach was proposed in line with new NHMRC(2005) recreation guidelines. The three stages were:

1. Evaluation of Lake microbial water quality based on readily available historical data and an initial Sanitary/Reconnaissance Survey of contamination (Roser and Ashbolt 2004b, 2004c);

2. Assessment of microbial water quality and health risk during Dry Weather (Roser et al. 2005) and identification of management actions which might lead to primary recreation being viable;

3. An assessment of microbial water quality and health risks arising due to Hazardous Events (principally high rainfall/run-off) and assessment of management strategy viability.

Provisionally at the end on 2006 it had been concluded that in regard to recreation:

Conclusions

1. Suitability of the Lake for Recreation

2. During dry weather the Lake appeared to correspond to NHMRC(2005) recreation Suitability Classification A or B and hence was suitable for primary contact recreation based on these guidelines.

3. However during Wet Weather the Lake appears to correspond to NHMRC(2005) recreation Suitability Classification B to D depending on the size of the event and the time elapsed since run-off has finished and immediately after Wet Weather the Lake is not considered suitable for primary contact recreation based on these guidelines.

4. A recovery period following wet weather of 1 to 5 days is required.

General Recommendations:

1. That management of pathogens in Lake Parramatta be based on the development of a Water Safety Plan for Recreation which exploits the findings of the Lake Parramatta project and previous related studies.

2. That this be part of a larger water recreation management plan.

3. That the Water Safety Plan be developed irrespective of whether primary contact recreation is introduced as there already appears to be significant secondary contact recreation and the plan is also applicable to this being undertaken safely.

4. Management of primary contact through a proposed ‘Swimming Club’ is strongly recommended as it provides a means for developing appropriate hygiene arrangements and a channel for communication of risk information to would be users.

5. That personal hygiene rules similar to those pertaining at municipal chlorinated swimming pools be promoted to minimize the potential for shedding (e.g. sick people discouraged from swimming; washing before bathing).

This project was nearing completion at end of 2006.
As part of the Western Sydney Recycled Water Initiative (NSW Metropolitan Water Plan 2006) it has been proposed that tertiary-treated effluent from the Penrith, St. Marys and Quakers Hill sewage treatment plants (STPs) undergo advanced treatment via Microfiltration (MF) and Reverse Osmosis (RO) to produce water suitable for replacing environmental flows to the Hawkesbury-Nepean River (Figure I). As part of the planning process, Sydney Water was requested to undertake a human health risk assessment of the proposed Replacement Flows project.

Sydney Water commissioned the University of New South Wales’ Centre for Water and Waste Technology (UNSW-CWWT) to undertake a desk-top screening-level risk assessment of the potential impact on human health of releasing highly treated wastewater into the Hawkesbury-Nepean River immediately downstream of the Penrith Weir. The study considered potential risks to humans arising from waterborne pathogens and chemicals, and the potential for cyanobacterial (blue-green algal) blooms arising from the proposed flow replacement releases under different flow regimes in the river.

No additional risk from pathogens was identified for the pathways examined from the introduction of highly treated wastewater to the Hawkesbury-Nepean River during effective operation of the MF-RO treatment process.

In regard to chemicals, no additional risk was identified for the majority of chemicals investigated (108 out of 111 chemicals) from the introduction of the highly treated replacement flows during effective operation of the MF-RO treatment process. A marginal risk was shown for three of the chemicals by one exposure pathway only. This risk is likely to be overestimated, however.

The impact on cyanobacterial risk levels by the implementation of the Replacement Flows project was seen as positive.

Commenced in 2006, this project is aimed at estimating the contribution of sewage treatment plants (STPs) and other point and diffuse sources of pathogens entering receiving waters in the SCA area of operation to health risks arising from exposure of human populations to waterborne pathogens; Using selected sub-catchment case studies develop methodologies, estimate ‘Baseline’ and ‘Hazardous Event’ risks and
STP Critical Limits needed to achieve acceptable drinking water and bathing exposure.

Expected Outcomes include:

1 for Drinking Water Consumption: Estimates of consumer infection rates, and the quality of STP discharges and operating conditions needed to achieve tolerable levels of pathogen exposure; Identification of major barriers to infection and the variability in their effectiveness and the contribution of different sources to infection rate estimates.

2 for Recreational Contact: Site by Site Assessment of current Recreation Suitability overall and in terms of water and sanitary quality; identification of key contamination sources under Baseline and ‘Event’ conditions. Contribution of STPs and other sources to site contamination based on application of NH&MRC scheme and exposure modelling.
### 6 CWWT Supported Research Students

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

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<td>Mark Bligh</td>
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<td>PhD</td>
<td>D. Waite</td>
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<tr>
<td>Christopher Duesterberg</td>
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<td>D. Waite</td>
</tr>
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<td>Aurelie Godrant</td>
<td>Iron uptake by Trichodesmium: impact of superoxide production.</td>
<td>PhD</td>
<td>D Waite &amp; A Rose</td>
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<tr>
<td>Adele Jones</td>
<td>The Transport and Transformation of Aluminium (Al) and Iron (Fe) from Acid Sulfate Soils (ASS)</td>
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<tr>
<td>Christine Kaucner</td>
<td>Surface properties of Cryptosporidium oocysts.</td>
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<td>N. Ashbolt</td>
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<td>Peter Kovalsky</td>
<td>Effect of mixing on hydraulic properties of compressible cakes formed in membrane filtration</td>
<td>PhD</td>
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<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>
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<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>
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<td>Kate Murphy</td>
<td>Seawater tracers and their application to verifying mid-ocean ballast water exchange.</td>
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<td>D. Waite, W. Dunsmuir</td>
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<td>Gavin Parcsi</td>
<td>Chemical analysis of Odorants from Poultry Facilities</td>
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<tr>
<td>An Ninh Pham</td>
<td>Generation and Transformation of Iron and Manganese in Lake Burragorang.</td>
<td>PhD</td>
<td>D. Waite</td>
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<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>
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<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>Ryan Signor</td>
<td>Quantitative microbial hazard and risk assessment for urban drinking water systems.</td>
<td>PhD</td>
<td>N. Ashbolt</td>
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<tr>
<td>Eric Sivret</td>
<td>Nitrous Oxide Monitoring for Nitrification Process Control</td>
<td>PhD</td>
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<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 &amp; A. Feitz</td>
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6.1 Research Student Project Summaries

Rebecca Barnes

Title: Planning for sustainable water and sanitation interventions in rural developing communities

Supervisors: David Roser, Paul Brown, Richard Stuetz

Funding: Women in Engineering Scholarship

Background: Bec grew up in Tamworth and escaped without a love for country music. Since age 9 she has wanted to work in a developing region, motivated by a realisation of what Jesus did for her. In preparation for this work, she studied Enviro Eng at UNSW (2001-2004) with industrial training in India. After taking 6 months to work in the ghettos of Washington DC, she returned to begin a PhD. Her field work is in the Philippines – the country that first inspired her to Christian mission work 13 years ago.

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. The fact that many countries, such as India, are covered with abandoned infrastructure from well-meant interventions implies decision-making which:

a. fails to consider cultural or societal preferences;

b. employs a ‘recipe’ or repeated intervention and fails to recognise differences between communities;

c. focuses on implementation of a particular technology rather than meeting a need or desired performance; or

d. focuses on short-term rather than long-term improvement.

This research project aims to:

1. determine the extent to which all five key principles of sustainability (human health, environmental, economic, socio-cultural, technical) are considered in the decision-making methods used for water and sanitation interventions;

2. establish links between deficiencies in decision-making and common premature failure mechanisms or abandonment of water and sanitation systems; and determine ways in which planning processes can be improved in order to reduce the incidence of early water and sanitation project failure.

3. Investigation has been undertaken using a case study in mountain villages of Northern Luzon, The Philippines.
Mark Bligh

Project:  Fate and transformation of Iron and Phosphorus in Coastal Waters – Implications for Bloom Forming Benthic Cyanobacterium, Lyngbya majuscula.

Supervisor:  Prof. David Waite

Funding body:  ARC Linkage Project

Industry Partner:  Moreton Bay Waterways and Catchment Partnership

Project Aims:

- Modelling of major geochemical processes controlling Fe (and P) bioavailability (to Lyngbya)
- Incorporation of key biogeochemical processes into larger (temporal and spatial) scale models

Project Summary:

Release of Fe and P from bottom sediments in the Moreton Bay has been identified as a likely major source of Fe (and P) during bloom periods. Compared to surface waters, there is less understanding of the likely chemical transformations of Fe from subsurface environments on discharge to an estuarine environment. This pathway of nutrient supply forms the focus of investigations in this project.

Oxidation of porewater containing ferrous iron (Fe\textsuperscript{II}) in the presence of natural organic matter (NOM) will result in two forms ferric iron (Fe\textsuperscript{III}) – 1) Organically complexed Fe\textsuperscript{III} and 2) Fe\textsuperscript{III} oxide particles. While Fe oxides are generally considered to be unavailable to organisms, freshly precipitated oxides are initially reactive and potentially bioavailable. Reactivity of oxide particles is expected to decrease with age, with both the initial reactivity and aging process being affected by the presence of NOM and the oxyanions phosphate and silicate. The formation of Fe oxide particles also has implications for the fate of phosphorus (P) also contained in porewater since P is strongly bound by Fe oxides especially when present during oxide formation.

Differentiating organically complexed Fe from oxide particles is difficult when the particles are small and reactive. A technique based on the differing reactivity of the two pools of Fe to a strong Fe complexing molecule desferrioxamine B (DFB) has been used. The formation of the Fe-DFB complex has been modeled as the double exponential decay of two pools of Fe enabling the calculation of the initial sizes of the two pools as well as their respective rates of reaction with DFB. (Figure XX.)

Figure XX. Composition of oxidation products resulting from the oxidation of Fe\textsuperscript{II} (1µM) in the presence of Suwanee River fulvic acid (SRFA) after 15 minutes. The proportion of Fe\textsuperscript{III}-SRFA complex is expressed as a percentage of the total Fe\textsuperscript{III} in the system. The remainder of the Fe\textsuperscript{III} is oxide particles. The two pools of Fe have been measured by differing reactivity to a strong Fe complexing molecule desferrioxamine B (DFB).
Aurelie Godrant

**Project:** Role of superoxide in iron acquisition by marine phytoplankton.

**Supervision:** D. Waite (Australia) and P. Tréguer (France).

**Funding:** Australia: ARC Discovery Project: Mechanism of iron acquisition by Cyanobacterium *Trichodesmium* in coastal waters
France from 2007: Lavoisier funding, Egide (French government of foreign affairs)

**Background:** Aurélie graduated from the University of Tours, a city located in the centre of France in general chemistry and biology (2002). Then, she travelled to different places in France to study and gain more experience in environmental sciences.

She arrived in Sydney in 2004 for a training period with D. Waite, A. Rose and S. Garg. Then, after 8 months training, she started her PhD (Sept 2005) in collaboration between France and Australia.

**Project outline:** Marine phytoplankton are a principal player in primary production, fixing almost half the carbon on Earth. Therefore, the abundance and the state of these organisms have an important influence on the greenhouse effect phenomenon. In addition, being the basis of the food chain, their abundance affects the prosperity of all the other marine organisms such as zooplankton or fish, etc. Also, several marine cyanobacteria can fix nitrogen, and thus, represent an important source of nitrogen in the oceans. Because nitrogen is an essential nutrient, the abundance of these organisms plays a critical role in the global cycle of carbon.

Typically, the growth of marine organisms is limited by the availability of nutrients (such as trace metals, which are often essential nutrients because of their presence as cofactors in certain enzymes) This is then, a critical factor for the presence of these organisms in marine waters. However, the uptake of these nutrients and maintenance of other favourable conditions is not straight forward and often requires utilisation of complex biochemical systems.

One of these essential nutrients is iron which, because of low solubility of its thermodynamically stable state Fe(III), is found in very low concentration in the oceans. More than 90% of this iron is complexed by organic ligands in marine waters. The exact role of these molecules is not yet well understood, but it would appear that they are produced by organisms and that they increase iron solubility.
Phytoplankton has different ways to absorb iron from sea water such as direct absorption of dissolved iron, absorption via membrane complexes, assimilation of complexed iron with organic molecules (siderophores), or even reduction of the iron at the subsurface of the phytoplankton membrane to the more soluble Fe(II). This reduction can occur by photochemical processes, via enzymes linked to the cell surface, or even via the release of reducing components in the environment such as superoxide. The major objective of this project is to understand how this last process works.

The aims of this project are:

- the development of a method for analysing the rate of production of superoxide from cyanobacteria such as (*Trichodesmium erythraeum*) in an iron depleted environment (e.g. open ocean).
- to characterize the growth limiting conditions in parallel to the iron concentration in the environment.
- to characterise how the production of superoxide is linked or influenced by environmental conditions (Fe depletion, light intensity, cell concentration, etc.), and the impact of this production on the availability of iron.
- to apply the superoxide detection method in the field (e.g. on the Great Barrier Reef).

At the present time, most studies have been conducted on *Trichodesmium erythraeum* cultures. These have shown a decrease in growth rate while the iron concentration has been decreased from 400 nmol/L to 10 nmol/L in the medium. The study on their physical changes is not yet finished, but it appears the cell size is changing in iron-depleted medium. Also, a new method is in development to detect the production of superoxide from this organism.

**Adele Jones**

**Project:** The Transport and Transformation of Contaminants from Acid Sulfate Soils (ASS)

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

**Funding body:** ARC Linkage with Tweed Shire Council and NSW Canegrowers Association

**Project summary:**

- To provide insight into the major chemical speciation of contaminants (predominantly iron and aluminium) discharged from ASS to neighbouring flood drains and then to the main estuarine water body
- To examine the transformation of these contaminants from source (soil) to sink (estuary).
- To examine the kinetics of selected transformations of certain species of Fe and Al and develop a model that satisfactorily describes these transformations.
- To assess the benefits of certain remediation methods such as tidal flushing of drains.
High concentrations of iron (Fe) and aluminium (Al) are able to be exported from acid sulfate soils to neighbouring estuarine environments. This presents a significant threat to the health of the neighbouring estuary as both Fe and Al release latent acidity upon hydrolysis. Inorganic Al species, particularly the polymeric species, are also highly toxic to marine life.

Analyses performed on pore water from soil collected from the Tweed region demonstrate that a large portion of the Fe released is in the ferrous form, and appears to undergo oxidation to form various mineral forms as it diffuses from the lower soil profile to the upper soil profiles. Of the remaining Fe in the dissolved phase, between 3 and 100 % may be complexed to dissolved organic matter (DOM). As expected, peak Al concentrations are measured in the transition and acidic zones of the soil profile, and at most only 10 % of this is complexed to DOM.

Preceding flooding considerable concentrations of DOM have been reported in literature, predominantly as a result of vegetation decomposition, resulting in severe de-oxygenation of floodwaters. The release of such high concentrations of DOM may considerably enhance the amount of Al and Fe complexed to organic matter, which in turn may enhance the off-site movement of Al and Fe by preventing loss due to precipitation. The use of the competing ligand method, using desferrioxamine (DFB), to measure the dissociation rate of ferric iron and DOM within drain water from the region have demonstrated that the ferric-DOM complexes formed are relatively stable (log K = 9.9). The use of a cation-exchange resin/ICP-MS technique to measure the rate of Al-DOM complex dissociation has demonstrated that the Al-DOM complex is not very strong in comparison to known stable species, such as Al-EDTA. Therefore, Fe may transported large distances off-site as compared to Al.

I have recently investigated the sunlight-mediated reduction of ferric to ferrous Fe. Field data collected to date suggests this is occurring. There is also a large amount of hydrogen peroxide produced, as a result of DOM photolysis, which may also impact the health of estuarine life.

The plotting of field data against thermodynamic speciation curves suggests that Al most likely precipitates as Jurbanite, Al(SO₄)(OH)₂H₂O. Further studies into the reactivity of Jurbanite are planned.
Karen Jury

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

**Supervisors:** Dr Richard Stuetz and Prof. Nick Ashbolt

**Co-Supervisors:** Dr Tony Vancov and Dr Paul Gill

**Funding:** This PhD project is funded by an ARC Discovery grant

**Background:** I emigrated to Australia from England in 1999. Prior to that, I spent 13 years working at the Food Research Institute in Norwich as a Higher Scientific Officer. My research duties focused on manipulating genes and pathways within cheese starter bacterial cultures. Between 1995 and 1997 I came to Australia on a career break and carried out research for Mauri Labs in the Dept. of Biotech at UNSW. I then went back to England and in 1999 married an Australian living in Ballina (near Byron Bay) in Northern NSW which is where we live now. I have spent 7 years (between having children) at the Dept. of Primary Industries working on projects associated with environmental microbiology (developing and employing molecular techniques for microbial soil community analysis). In 2006, as an external student, I started my PhD project investigating the transfer of antibiotic resistance genes within sewage bacteria.

**Project Introduction:** Over exploitation and inappropriate use of antimicrobial agents, particularly in medical and agricultural practises, have led to a proliferation of multi-resistant bacteria. Besides triggering major public health concerns, these practises have provoked fervent debate amongst the various governing and scientific bodies regarding when, where and how antimicrobial are to be used. Antimicrobials kill sensitive bacteria thus producing a selective pressure for resistant strains which are able to survive and multiply. Resistance maybe an inherent trait such as point-mutations in the ‘targeted’ gene(s) or can be acquired by horizontal gene transfer. Horizontal gene transfer is the major route for widespread dissemination of antibiotic resistance amongst bacteria. 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 and involving point of source transfer in their natural habitats.

**Project Outline:** This study focuses on one ‘hotspot’ area; the waste water treatment plant (WWTP). Bacteria previously exposed to antimicrobials in hospitals, households, animal husbandry and agriculture all flow into WWTPs alongside low levels of excreted antibacterial agents, the latter providing a selective pressure for lateral resistance gene transfer. The synthetic antimicrobial Sulfamethoxazole has been selected for this study. To date three genes responsible for sulphonamide resistance have been discovered, predominantly in gram negative bacteria; Sul1, Sul2 and recently the Sul3 gene.
Low levels of sulfamethoxazole will be added to two pilot-scale WWTP biological reactors; a traditional activated sludge (AS) reactor and a membrane bioreactor (MBR) which is an emerging technology for waste water treatment. The MBR is a suspended growth activated sludge process whereby the effluent is effectively filtered through submerged tubular membranes leaving large molecules behind, primarily the microorganisms, and thus producing high quality effluent ready for recycling. This withholding of microbes creates a more stable bacterial community and less sludge waste, but at the same time raises the question as to whether it could potentially be creating favourable conditions for lateral transfer of resistance genes and thereby be considered a ‘point of source’ for multi-resistant environmental bacteria.

Comparative studies will be performed on samples from the two reactors’ biomass. Samples will be cultured which will give a small snapshot of the bacterial population within each reactor, revealing information pertaining to antimicrobial resistance patterns, Sul resistant levels and bacterial morphology. Total DNA will be extracted from each and further characterised using molecular techniques including DGGE and LH-PCR (DNA fingerprinting) and realtime-PCR (gene quantification).

**Aims:** To compare Sulphonamide resistance levels within the bacterial community of two pilot WWTP secondary reactors: a traditional activated sludge reactor and the emerging membrane bioreactor before and after addition of sulfamethoxazole.

- Are the Sul resistance genes increasing in number?

If so, how? Is it clonality or acquired resistance by horizontal gene transfer?

**Achievements in 2006:**

- I have optimised a quick, cheap method of extracting DNA from bioreactor samples which is pure enough for downstream techniques such as PCR.
- Antibiotic screen-Of the culturable Sul resistant colonies there were typically 2-7 multi-resistance traits. Of the 107/ml culturable colonies, a high proportion (105) showed Sul resistance. The MBR always presented a higher percentage of resistance to each antibiotic compared to the AS, which was presumably due to the increased retention time, thus allowing the bacteria to proliferate. Of all the antimicrobials under investigation, the highest level of microbial resistance was recorded against ampicillin in both reactor designs, whilst tetracycline and ciprofloxacin were the lowest.
- Molecular methods such as LH-PCR give a much more accurate view of the bacterial population dynamics compared to culturing. Statistical analysis of the
data has shown that the MBR population is more stable than the AS community, presumably because of the longer retention time within the MBR reactor.

- The sampling baseline for each reactor is near completion prior to the addition of the antimicrobial (sulfamethoxazole) next month.

Christine Kaucner

Project: Factors influencing overland mobility of Cryptosporidium oocysts  
Supervisors: Prof. Nicholas Ashbolt (CVEN, UNSW), Dr Cheryl Davies (CWWT)  
Background: Christine Kaucner is a part time Master of Science student at the CWWT, while she is a research assistant associated on Centre pathogen research. She has 17 years experience in the water industry as a microbiologist and is currently a member of the Australian Standards for Water Microbiology committee. She was employed full-time during 2006 on various CWWT and CVEN projects. Her Masters project involves a study of the surface properties of Cryptosporidium oocysts, the environmentally stable stage of the enteric pathogen Cryptosporidium, which is shed in the faeces of various mammals. Her Masters thesis was submitted for examination in January 2007.

Project summary: The mechanisms responsible for overland transport of faecal pathogens, particularly Cryptosporidium oocysts, from animal sources to water bodies are not fully understood. Surface properties of microbes, such as electrostatic charge and hydrophobicity, are thought to contribute to their aggregation and attachment to solid surfaces. There is conflicting evidence that methods used to purify Cryptosporidium oocysts from faecal material may affect the oocyst surface, leading to biased conclusions from transport studies. By studying oocyst surface properties, aggregation and soil attachment, Christine addressed whether oocyst purification methods influence overland transport studies, and whether oocysts are likely to be associated with particles during overland transport.

When using the microbial adhesion to hydrocarbon (MATH) assay with octane, oocyst hydrophobicity was shown to be method and isolate dependent, with oocysts displaying moderate to high hydrophobicity in 0.01 M KNO₃. There was no observed attachment, however, to the hydrophobic octyl-Sepharose™ bead ligands when using the same suspension solution. Oocyst age did not appear to influence their hydrophobicity. A small but statistically significant proportion of oocysts displayed a net negative surface charge as observed by their attachment to an anion exchange ligand (DEAE). There was no difference in hydrophobicity or surface charge observed between purified oocysts and oocysts that had been extracted without the use of harsh chemicals and solutions with dehydrating properties.

Purified oocysts did not aggregate at pH values between 3.3 and 9.0, nor in solutions lower than 0.59 M in ionic strength at a pH 2.7 which is approaching the reported isoelectric point of oocysts. This finding suggests that oocysts may not form aggregates under general environmental conditions. The association of purified oocysts with soil particles was observed in settling columns. Attachment to soil particles was not conclusive since the settling of the soil particles may have
Entrained single oocysts. Nonetheless, approximately 27% of oocysts were estimated to be unbound to soil or associated with small soil particles. Hence models for oocyst overland transport should consider a significant fraction as single entities or associated with soil particles less than about 3 μm in size.

Eli Lai

**Project:** Development of an integrated sustainability assessment framework for best practice management of urban water system

**Supervisors:** Assoc. Prof Sven Lundie, Prof Nicholas Ashbolt

**Sponsor:** Water Services Association of Australia (WSAA), Total Environmental Centre (TEC)

**Background:** Elizabeth graduated from UNSW in 2004 with BE (Environmental) with First Class Honours majoring in water engineering. As a Co-op Scholarship student in her undergraduate years, she worked for Sydney Water Corporation and Collex Pty Ltd, undertaking analytical projects for sustainable urban water planning and business strategic planning. Prior to joining the LCA team in CWWT, she was a project engineer in the private wastewater service sector, managing multiple wastewater treatment equipment installation projects and serving as a liaison officer between the designer, manufacturer and contractor.

**Project summary:** The conventional approach to make decisions on the selection of urban water system is generally based on economic cost-benefit analysis. However, thinking in terms of economic costs and benefits is no longer sufficient; social, health, and environmental aspects have to incorporated into the decision making process. Typically, reporting practice tends to divorce the environment and economy from society, and effectively displaces the latter. The narrow focus adopted contrasts with the broad definition of sustainability. The challenge is to incorporate meaningful sustainability assessment in the decision making process that addresses the conflicting criteria underpinning the definition.

**Progress to date:** A new approach is developed based on the concept of trade-off sacrifice level in pairwise comparisons between criteria, modelled using fuzzy logic control. The decision makers’ preferences are expressed by five levels of trade-off sacrifice between pairs of criteria. The decision makers can assign their preferences of sacrifice level by linguistic assessment and the output trade-off weight (TOW), a measure of a decision maker’s perceived trade-off level modelled by the rule-based fuzzy logic control system. The final analysis shows the performance for each sacrifice class for each case, to aid decision making.

A new method is also developed to measure social receptivity towards water and sanitation in rural community is developing country, which incorporate the Theory of Planned Behaviour, a model that predicts human behaviour. Elizabeth is currently conducting a case study to test the methodology in South Africa. The results from the social receptivity study will be included in the trade-off sacrifice decision-aiding approach, modelled using fuzzy logic control.
Nhat Le-Minh

**Project:** The Removal of Antibiotics (Sulfomethoxazole and Trimethoprim) in Wastewater using Activated Sludge and Membrane Bioreactor  
**Supervisors:** A/Prof. Richard Stuetz & Dr. Stuart Khan  
**Funding:** University International Postgraduate Award (UNSW Engineering Faculty Scholarship)

**Project Summary**

**Aims:**
- To develop the reliable and precise analytical method for determining the trace concentration of antibiotics in the wastewater and other aqueous media
- To understand the removal mechanisms of the conventional activated sludge and membrane bioreactor for the selected antibiotics and compare the treatment performance of these biological systems
- To investigate the impact of elevated concentration of antibiotics on the performance and recovery of these treatment systems
- To assess the potential maintenance and development of the antibiotics resistant strains and its public health implications

There are the increasing concerns about the emerging and maintenance of antibiotic resistance in bacterial strains due to the occurrence of antibiotic residues in the environment. The incomplete elimination during the treatment processes at the wastewater treatment plant may introduce pharmaceutical compounds in general and antibiotics in particular to the surface water and hence exposure the risk to humans. Therefore, the removal mechanisms for antibiotics in the treatment plant should be well understood to enable any future upgrading which will improve treatment efficiency.

Liquid Chromatography – Tandem Mass Spectrometry (LC-MS-MS) is adopted as a technique to determine the concentration of antibiotics. Aqueous component and biosolids are separated from wastewater samples. Microwave solvent extraction is used to dissolve the compounds of interest from biomass into aqueous phase. The samples are cleaned up and enriched with Water Oasis HLB solid phase extraction cartridges before the analysis. Deuterated compounds of the interested antibiotics are used as the surrogate standards to compensate the matrix effects. The further method development still goes on in order to improve the detection limit of the analysis.

The pilot plant study with a small scale activated sludge system and a membrane bioreactor is conducted to model the removal of antibiotics by these two biological treatments. The reactors are currently stable and are going to be spiked with antibiotics at low doses over time. The effects of antibiotic input on the performance of the biological systems are investigated.

Concurrently, samples from North Head STP are analysed to determine the existence and trace concentrations of sulphonamide and trimethoprim in domestic wastewater. The elimination efficiency of the membrane bioreactor at North Head STP is determined and will be used as the basis to compare with those of the pilot scale reactors.
Kate Murphy

**Project:** Seawater tracers and their application to verifying mid-ocean ballast water exchange.

**Supervisors:** Prof. David Waite, Prof. William Dunsmuir

**Funding body:** Smithsonian Environmental Research Center, USA

**Project Aims:** Identify naturally-occurring chemicals in seawater (trace elements and dissolved organic matter) that can be used to tracer ballast water sources and verify mid-ocean exchange.

**Project Summary:**

Ballast water is used by trading ships to maintain stability when the ship is not carrying a full load of cargo. When foreign ballast water is released by ships undertaking cargo maneuvers, non-native species are released sometimes with harmful consequences to biodiversity, fisheries or human health.

Quarantine laws in Australia and the USA require that coastal (i.e. high-risk) ballast water be replaced with oceanic (i.e. low-risk) ballast water prior to discharge in port. This process is called ballast water exchange (BWE). Enforcement of BWE requires a reliable method of distinguishing between ballast water from coastal and oceanic sources. My project aims to identify and evaluate such tools.

**Organic matter tracers**

Coastal seawater contains chromophoric dissolved organic matter exported from terrestrial environments. This material fluoresces when excited by UV and visible light. Using parallel factor analysis (PARAFAC), I am characterizing the fluorescent organic matter components in seawater and evaluating their utility for tracing sources of ballast water.

**Trace elements**

Coastal seawater contains many trace elements, nutrients and radioactive isotopes derived from weathering of the earth’s crust. To qualify as ballast water tracers, however, they must exhibit three basic properties (1) stability in ballast tanks over time; (2) agreement between concentrations in ballast tanks and concentrations in the ocean where the ballast originated (fidelity); and (3) measurement predictability following the implementation of BWE. In this component, I am examining the suitability of three trace elements (Ba, P and Mn) for tracing ballast water sources.
Gavin Parcsi

**Project:** Chemical Analysis of Odorants from Poultry Facilities
**Supervisors:** A/Prof. Richard M. Stuetz and Dr Stuart Kahn
**Funding Body:** The Australia Poultry Cooperative Research Centre (P-CRC)
**Background:** Gavin gained his BE (Mechatronics) and BSc (Chemistry) from the University of Sydney in 2005 and commenced his PhD in Environmental Engineering in 2006.

**Project Summary:** Population growth has an increased demand upon primary industries to produce greater quantities of food stuffs to satisfy the consumers. Associated to the population growth is an expansion of established cities that leads to rural encroachment, this rural encroachment results in a decline in the chief barrier against rural malodours, that of distance. Intensive livestock practices are one of the most effective ways to produce the quantity and consistent quality of livestock produce that is in increasing demand from the general population, however they also have a significant impact on the local environment with respect to dust and odour emissions. The Australian P-CRC is funding a significant project that is investigating the odour and dust emissions from typical mechanically (tunnel) ventilated poultry houses; one of the aspects of this project is the analysis of non-methane volatile organic compounds.

The analysis of the emissions from poultry houses around Australia NMVOC analysis will be performed by collecting pumped sorbent tubes and subsequent assay using thermal desorption – gas chromatography – mass spectrometry (TD-GC-MS) and also thermal desorption – gas chromatography – mass spectrometry and olfactometry (TD-GC-MS/O.). The simultaneous detection using mass spectrometry and olfactometry allows for the odorants within the matrix to be identified and subsequently prioritised.

The Markes Unity Thermal Desorber (pictured right, with UltrA Autosampler) preconcentrates and focuses the analytes from the sorbent tubes (pictured below) before subsequent injection into the gas chromatograph.
The compounds within the emissions are then separated within the gas chromatograph before being simultaneously detected by the mass selective detector (MSD) and the olfactory detection port (ODP) (illustrated below left) this allows for two data sets to be collected, the first being the mass spectral data, and the second being the olfactometry chromatogram, which allows for the identification and prioritisation of the compounds responsible for the odour (illustrated below right).

Nida Seelsaen

Title of project: Stability of Recycled Organic Materials in Urban Stormwater Runoff Treatment

Student/supervision team: The PhD supervisor and co-supervisor are A/P Richard Stuetz, Stephen Moore, and Dr Robert McLaughlan from University of Technology, Sydney.

Student background: Nida graduated with BEng (Environmental Engineering) from the Khonkaen University (Thailand) in 1998 and MEng (Environmental Engineering) from Chulalongkorn University (Thailand) in 2002. Nida worked as a lecturer at Faculty of Engineering, Mahasarakham University, Thailand before commenced PhD study at UNSW in July 2003.

Project summary: Urban stormwater runoff associated with heavy metal contamination have adverse effect to receiving water, human and ecosystem resulting in heavy metal removal has become a great concern as a part of wastewater treatment. Due to small concentration of heavy metal in urban run off comparing to industrial wastewater, commercial sorbent which is expensive is not cost-effectively to apply in urban run off treatment. Prior research suggests that low-cost sorbent which is a by-product or waste from industrial or agricultural operation could be alternative sorbent as a result of their low cost of application and disposal also overall efficiency is satisfying. This research focuses on application of a range of compost, zeolite, ash, recyclable waste in urban runoff treatment especially heavy metal removal. The PhD thesis will combine two aspects; experimental and management aspect to fulfil the holistic approach of environmental system management. Experiment includes sorption, leaching and desorption test using such sorbents to compare performance and design the best mixing sorbent for heavy
metal removal in urban runoff treatment. Material accounting tools such as Material Flow Analysis (MFA) and Substance Flow Analysis (SFA) has been performed in the Upper Parramatta River Catchment, Sydney to demonstrate how different sorbent, ranges of heavy metal concentration in runoff and flow of heavy metal in system affect each other.

Laboratory works to assess efficiency of various ROMs both in batch and column test have been finished. MFA of copper in the Upper Parramatta River Catchment has been performing to depict flows of copper in stormwater runoff. This case study shows relationship of copper, sorbent and urban stormwater runoff in the system boundary.

Quan Sun

Title: Contaminant Degradation Using Nanosized Zero Valent Iron Particles

Supervisors: Professor David Waite and Andrew Feitz

Funding: APA(I)

Project Outline: The aim of the project is to examine the possibility of extending the applicability of zero valent iron (ZVI) to degradation of organic contaminant in waters by inducement of oxidative (rather than reductive) process and, develop new ZVI particles that could make groundwater remediation using reductive nZVI commercially viable (lowering the price from $66 to $9/kg) and possibly widen the technology to oxidative treatment.

Many research found successful removal of organic contaminants through Fenton oxidation, which generates radicals to oxidize contaminants. Dissolve Fe$^{2+}$ and H$_2$O$_2$ (so-called Fenton reagents) were commonly added to generate strong oxidants: hydroxyl radical (OH$^-$). However, this type of system requires continuous addition of Fe$^{2+}$/H$_2$O$_2$.

Instead of direct application of expensive oxidant -- H$_2$O$_2$ and Fe$^{2+}$, an innovative approach is to provide a cost effective way to induce fenton’s oxidation as shown in the following reaction:(Joo, Feitz and Waite, 2003)

$$O_2 + Fe^0 + 2H^+ = Fe^{2+} + H_2O_2$$

Use of ZVI to induce Fenton oxidation has two advantages beyond addition of Fe$^{2+}$/H$_2$O$_2$, which are as follows (Berendahl and Thies, 2004):

- ZVI is able to attach or coat on large particle such that ZVI adsorbed media could treat passing through contaminated water in sand filter or various type of filtration system.
- ZVI injected through wells could be mobilized in and attached to soil grains in contaminated aquifers.

However there is a need to reduce the cost of ZVI as the current synthesis approach (Wang and Zhang 1997) use expensive sodium borohydrite. The less costly ZVI synthesis method is currently evaluating.
## 7. **Staff**

### Staff in the Centre for Water and Waste Technology

<table>
<thead>
<tr>
<th>Staff Member</th>
<th>Position</th>
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<td>Research Associate</td>
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</tr>
</tbody>
</table>

*To commence PhD studies in 2007

** Academic staff of School of Civil & Environmental Engineering.

*** To leave in 2006
8. **CWWT Publications 2006**

**BOOKS**


**BOOK CHAPTERS**


**JOURNAL ARTICLES (REVIEWED)**


**JOURNAL ARTICLES (NOT REVIEWED)**


**CONFERENCE PAPERS (REVIEWED)**


CONFERENCE PAPERS (NOT REVIEWED)


TECHNICAL REPORTS


9. **Financial Statement**

9.1 **Income and Expenditure for 2006**

The following summary of income and expenditure for the activities of the Centre for Water and Waste Technology is based on actual and accrued figures:

<table>
<thead>
<tr>
<th>Description</th>
<th>2006</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue generated by Centre activities, from invoicing and grant funding:</td>
<td>2,383,763</td>
<td>1,778,388</td>
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<tr>
<td><strong>Income earned and accrued from the above:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARC discovery &amp; linkages</td>
<td>$706,871</td>
<td>543,820</td>
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<tr>
<td>Other Commonwealth funding</td>
<td>$22,505</td>
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<td>Co-operative Research Centres</td>
<td>$242,161</td>
<td>233,099</td>
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<td>Industry &amp; Government corporations</td>
<td>$395,206</td>
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<td>Overseas organisations</td>
<td>$4,141</td>
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<td>Other non CWWT UNSW funds</td>
<td>$15,915</td>
<td>11,258</td>
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<td>Consulting</td>
<td>$350,659</td>
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<td>Workshop</td>
<td>$11,381</td>
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<tr>
<td><strong>Total Income earned and accrued:</strong></td>
<td>$1,804,419</td>
<td>1,590,299</td>
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**Expenditure:**

**Direct project expenses:**

<table>
<thead>
<tr>
<th>Description</th>
<th>2006</th>
<th>2005</th>
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<td>Payroll</td>
<td>834,343</td>
<td>735,507</td>
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<td>Additional staff termination and leave preservation</td>
<td>3,000</td>
<td>5,570</td>
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<td>Scholarship payments</td>
<td>240,675</td>
<td>195,210</td>
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<tr>
<td>Non-person expenditure</td>
<td>455,852</td>
<td>470,916</td>
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<tr>
<td><strong>Total project expenses</strong></td>
<td>1,533,870</td>
<td>1,407,204</td>
</tr>
</tbody>
</table>

Payroll Administration Staff less direct project input         | 120,704   | 112,655   |
Payroll Project Staff not covered by project income             | 0         | 0         |
Additional staff termination and leave preservation             | 1,490     | 2,500     |
Scholarship contribution                                       | 16,208    | 3,025     |
Equipment and equipment maintenance: 9,564 8,856
Other Material expenses: 27,349 28,661
Travel: 0 2,118
Bad debt: 0 19,914
Total Administration Expenses: 175,315 177,729
Total Operating Expenses: 1,709,184 1,584,932
Operating Result: 95,235 5,367
Operating Surplus (Deficit) bfwd from previous year: (125,210) (130,577)
ACCUMULATED operating SURPLUS (DEFICIT)  (29,975) (125,210)

Research income yet to earn from cash received (exclusive of unpaid invoices):
Cash Balance of funds received at end 2006: 591,410
Termination preserved: (97,140)
Operating deficit: (29,975)
Work in progress from funds received: 464,295

9.2 COMMENT ON 2006 INCOME AND EXPENDITURE

The CWWT receives project income from a wide variety of sources and dependent upon the grant body providing the research funds and as such, the funds are granted in combinations of the following: as up front grants, quarterly payments on receipt of invoices, monthly payments from invoiced expenditure recovery, on milestone report acceptance or on project completion.

While the central financial system of the University records all transactions made on CWWT projects, the figures are interpreted to provide a more accurate picture of CWWT activities. For example, where internal transfers are made between projects, expenditure recovery from projects outside CWWT are treated as income into the centre and transfers between CWWT projects are treated as expenditure recovery. There sometimes are variations with the central system depending on the manner of treatment of these transfers on the central system.

Rather than stating cash received by the Centre as income, and in order to track the progressive financial performance of the Centre against budget and to provide a true sense of profit and loss, the income earned from projects is calculated progressively on a monthly basis throughout the year. Up front funds may have been received but
until the research is completed these funds cannot be considered as earned and similarly, if funds are not to be received until the end of the project it is necessary to track the income earned within the project budget against expenditure incurred until the cash is received. For each project, a monthly track of income earned, from time spent and other budgeted items of direct expenditure, is maintained throughout each year. A proportion of projects, depending on their funding source allow for the direct charging of administration and other overhead costs and forms part of the income earned on projects.

Great success was again achieved in the level of high calibre research projects underway and the successful completion of their studies of a number of Centre project funded post-graduate students.

The income accrued/earned by research projects and other activities during 2006 amounted to $1,804,419. The accrued project income for 2006 was 20.4% lower than the income budgeted at the beginning of 2005 of $2,266,968. The lower than expected result was due to later than expected commencement of a number of research projects. Project expenditure of $1,533,870 was also lower by 24.1% than the projected budget expenditure of $2,022,095. Overhead / administration expenditure of $175,315 was 12.3% lower than the budgeted $200,010. The lower than budgeted figure was assisted by the decision to sell the Centre car as it was found not to be an economic proposition to continue its maintenance. Vehicles were hired when required.

The CWWT recorded an operating profit of $95,235 for 2006 from the earned income, with the accrued operating deficit of $29,975 to be carried forward to 2007. For the past 5 years expenditure recorded has included an accrued amount for the termination allowance and preserved leave that may be payable at the end of salary contracts. The amount costed and preserved for 2006 was $4,490 bringing the total expensed and preserved for termination at the end of 2006 to $97,140.

The UNSW financial system recorded a budget balance of $1,504,208 from established projects for the CWWT at the end of 2006, and an unadjusted cash balance of $899,949. Together with the new project approvals already received for 2007 the continued earning capacity of the Centre is assured. The invoices that were recorded as unpaid at the end of 2006 have since largely been paid. There were no bad debts recorded for 2006.

During 2006, the CWWT employed 11 research staff, 2 part time administration staff and a number of short term casual staff. Through its projects the CWWT supported 15 post graduate research students. The CWWT works with 4 School of Civil and Environmental Engineering academic staff members and accommodated 2 research
staff employed by the Membrane Centre in the School of Chemical Engineering as part of an on-going collaborative arrangement.

The overhead administration included the Business Manager and a Secretary/Administration assistant. Lance Bowen, a former senior public servant (now retired) and later a consultant with the centre, continued to provide valuable assistance to the CWWT library on a voluntary basis, for which the staff of the Centre were most grateful.