Cyanobacteria in Australia -

Bloom Management, Research and Future Options

Abstracts from the meeting held
2 & 3 August, 2010, Melbourne, Victoria

WQRA
water quality research australia

A Victorian Government initiative

State Government Victoria

Cyanobacteria in Australia – Bloom Management, Research and Future Options

Abstracts from the second National Cyanobacterial Workshop

2-3 August 2010, Melbourne Victoria

This National Cyanobacterial Workshop was hosted by the Department of Sustainability and Environment, Victoria; the Department of Health, Victoria; and Water Quality Research Australia.

Attending the workshop were people involved in the management of public health, water resources and water supplies, and core cyanobacterial research.

The workshop was organised by **Louisa Davis**, Project Officer, Water Industry Governance, Department of Sustainability and Environment Victoria, **Vanora Mulvenna**, Senior Policy Officer, Water Policy Section, Department of Health Victoria and **Luc Richard,** Department of Health Victoria

together with an organising committee comprising:
Dr Lee Bowling - NSW Office of Water
Dr Will Buchanan – Barwon Water, Victoria
Dr Daniel Mainville - Department of Sustainability and Environment, Victoria
Greg Smith - Goulburn-Murray Water
Dr Michele Akeroyd – Water Quality Research Australia
Mark Vanner – Murray Darling Basin Authority
Angela Gackle – Water Quality Research Australia

*Cover photographs, of 2010 algal blooms on the Murray River, kindly supplied by **Vanora Mulvenna**, Senior Policy Officer, Environmental Health Unit, Health Protection Branch, Department of Health, Victoria.*

*Book of abstracts compiled by **Angela Gackle**, WQRA, Adelaide SA.*

2nd National Cyanobacterial Workshop Program

Rendezvous Hotel, 328 Flinders Street, Melbourne

Workshop Program – Day 1 – Monday 2nd August 2010

8:40 – 9:00	Registration, tea and coffee			
9:00 – 9:10	Welcome and housekeeping			
9:10 – 9:30	Keynote address	Toxic Cyanobacteria – where now?	**Ian Falconer**	
Session 1 – Source Water Management and Treatment – Chair: Margaret Leonard				
				Page #
9:30–9:50	**Gayle Newcombe** AWQC	The development of Australian and international guidance manuals for the management of cyanobacteria		6
9:50–10:10	**Mike Burch** AWQC	Controlling cyanobacteria: Alternative and innovative methods for algal control		8
10:10–10:30	**Jared Koutsoukos** Dept of Health, WA	Key issues in the management of Western Australia's draft 2009 harmful algal bloom response plan for recreational waters		10
Morning Tea – 10:30 – 11:00				
11:00-11:20	**Rita Henderson** UNSW Water Research Centre	Size, strength and structure of micro-algae flocs during water treatment		12
11:20–11:40	**Anas Ghadouani** U of WA	Engineering solutions for the reduction and removal of toxin-producing cyanobacteria from waterways		14
11:40–12:00	**Feng Qian** U of Melbourne	Dewatering of cyanobacteria-rich sludge		14
12:00–12:20	**Lionel Ho** AWQC	Optimising water treatment processes for the removal of cyanobacteria and their metabolites		16
12:20–12:40	**Natasha Ryan** NSW Office of Water	New South Wales algal management strategy: A review		18
Lunch – 12:40 – 13:40				
Session 2 – Guidelines for Managing Cyanobacterial Risks – Chair: Lee Bowling				
13:40–14:00	**Heather Bishop** NHMRC	Revision of the *Australian Drinking Water Guidelines*		20
14:00–14:15	**Bruce Gray** DEWHA	Revision of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* and the *Australian Guidelines for Water Quality Monitoring and Reporting*		22
14:15–14:35	**Vanora Mulvenna** Dept of Health, Vic	Summary of state and territory-based guidelines and management frameworks		22
Afternoon Tea 14:35 – 15:00				
15:00–17:00	Facilitated Discussion: ❖ Research priorities ❖ National consistency ❖ Cyanobacterial management issues			
17:00–18:00	Networking drinks			

Workshop Program – Day 2 – Tuesday 3rd August 2010

Session 3 – Distribution, Monitoring and Testing – Chair: Will Buchanan

			Page #
8:30–8:50	**Andrew Humpage** AWQC	Cyanosurvey – A national update on the distribution of toxic cyanobacteria	24
8:50–9:10	**Thang Nguyen** RMIT	Using an algal online analyser for detecting the presence of cyanobacteria in biologically treated effluent	26
9:10–9:30	**David Waite** UNSW	Impact of iron species transformations on growth and toxicity of cyanobacterial *Microcystis* species	28
9:30–9:40	**Tim Malthus** CSIRO Land & Water	Potential of the enhanced spectral and spatial features of the WorldView-2 satellite sensor for monitoring blooms in inland waters	28
9:40–9:55	**Nagur Cherukuru** CSIRO Land & Water	Estimating water quality and bloom status using hyperspatial optical measurements: A case study in lake Burley Griffin, Canberra	30
		Morning Tea – 9:55 – 10:20	
10:20–10:40	**Elke Reichwaldt** UWA	Cyanobacterial toxin dynamics: What can we learn from spatial and temporal variability?	32
10:40–11:00	**Brad Sherman** CSIRO	Cyanobacterial bloom dynamics – some lessons from the Nineties and the Noughties	34
11:00–11:20	**Yoshi Kobayashi** Dept of Env, Climate Change & Water, NSW	Cyanobacteria in inland floodplain wetlands	36
11:20–11:40	**Felicity Roddick** RMIT/**Andrew Humpage** AWQC	Using test strips to detect microcystin in lagoon-treated wastewater	38
11:40–12:00	**Kumar Eliezer** ALS Environ Water Resources Group	Developing a rational basis to meet operational needs in the management of nuisance cyanobacterial occurrences in water sources	40
		Lunch – 12:00 – 13:00	

Workshop Program – Day 2 – Tuesday 3rd August 2010

Session 4 – Toxin production and uptake – Chair: Barbara Sendall

Time	Speaker	Title	Page #
13:00–13:20	**Glenn McGregor** Qld Dept of Environment and Resource Management	A new potentially toxic cyanobacterium from Australian freshwaters: First report of the cyanotoxins cylindrospermopsin and deoxy-cylindrospermopsin from *Raphidiopsis mediterranea (Cyanobacteria/Nostocales)*	42
13:20–13:40	**Philip Orr** Seqwater	Production dynamics of cylindrospermopsins by an Australian strain of *Cylindrospermopsis raciborskii* isolated from a drinking water storage reservoir in SE Qld	44
13:40–14:00	**Larelle Fabbro** CQU	Taxonomy and ecology of toxin-producing *Limnothrix*	46
14:00–14:20	**Suzanne Froscio** AWQC	Novel toxic activity associated with the cyanobacteria *Limnothrix*: Use of screening assays for detection	48
14:20–14:40	**Michele Burford** GU, Australian Rivers Institute	Factors promoting the dominance of the toxic freshwater cyanobacterium *Cylindrospermopsis raciborskii*	50
Afternoon Tea – 14:40 – 15:00			
15:00–15:20	**Ian Stewart** Queensland Health Forensic and Scientific Services	Mullet are efficient bioaccumulators of nodularin. Field investigation of a toxic *Nodularia* bloom in SE Qld, and the public health implications of dietary exposure to nodularin	52
15:20–15:40	**Jackie Myers** RMIT	Uptake and depuration of nodularin in seafood species: A human health risk assessment	54
15:40–16:00	Wrap up of presentations		
16:00 Workshop close			

Keynote Address: Toxic Cyanobacteria - Where Now?

Ian Falconer, Honorary Visiting Fellow in Pharmacology, Faculty of Medical Sciences, University of Adelaide

With the ongoing increase in world population, and rising average temperatures, the problems presented by toxic cyanobacteria can be expected to also progressively increase. Eutrophication of lakes and rivers relates directly to nutrient input and water temperature and neither component is easily managed. Negative human health impacts from cyanobacterial contamination of drinking water have been observed in Africa, Asia and South America, where large populations do not have adequately treated drinking water.

There are substantial gaps in both knowledge and practice with respect to management of toxic cyanobacteria. In Australia we have a long record of cyanobacterial problems exhibited as livestock deaths, and an increasing number of toxic species identified as the cause. Our research on all aspects of toxic cyanobacteria is world class, yet during the last two years we saw hundreds of kilometres of our main southern rivers contaminated to the extent of towns receiving health warnings from presence of blooms of toxic cyanobacteria.

As long as there is no flow out of the Murray Darling system to the sea, cyanobacterial eutrophication is inevitable.

Two of the major areas needing attention here are monitoring and management of water resources. Cell counts are quite inadequate proxies of toxicity and direct toxicity measurement is needed. Not all the toxins have yet been identified, so relying on cell identity, or even chemical identity is not sufficient. Management needs to include land use practices, as well as water management, and both need implementation.

Our national Guidelines for water quality are as accurate as possible with present knowledge, but they have no legal weight. Not even within one State do the Guidelines have direct enforcement.

The research challenges can be seen from the papers at this conference, and the revisions of the water Guidelines will bring up to date the application of the increasing knowledge. The more difficult part will be the implementation.

The Development of Australian and International Guidance Manuals for the Management of Cyanobacteria

G Newcombe[1], W Harding[2], N Dugan[3], P Baker[1], M Burch[1], J House[1], L Ho[1], J Brookes[4], T Hall[5], G Gruetzmacher[6], H du Preez[7], A Swanepoel[7] and F Schulting[8]

[1] Australian Water Quality Centre, SA Water Corporation, Water Quality Research Australia, email: gayle.newcombe@sawater.com.au
[2] DH Environmental Consulting, South Africa, email: bill@dhec.co.za
[3] USEPA, USA, email: dugan.nicholas@epamail.epa.gov
[4] University of Adelaide, Australia, email: justin.brookes@adelaide.edu.au
[5] WRc, UK, email: tom.hall@wrcplc.co.uk
[6] KompetenzZentrum Wasser Berlin gGmbH, Germany, email: gesche.gruetzmacher@kompetenz-wasser.de
[7] Scientific Services, Rand Water, South Africa, email: hdupreez@randwater.co.za
[8] Global Water Research Coalition, email: gwrc@iwahq.org

The management of cyanobacteria, in source water and by treatment, has been an ongoing focus of water industry research and over several decades hundreds of journal articles, reports and fact sheets have been published on these topics. Several years ago, a research project was developed through the Cooperative Research Centre for Water Quality and Treatment to consolidate that wealth of knowledge into a practical, user-friendly manual that could be used by Australian water quality managers and operators to help manage cyanobacteria in source waters. During the following years, manuals with similar aims were developed in South Africa and Europe.

Cyanobacteria is one of the priority issues of the area **Water and Health** of the joint research agenda of the Global Water Research Coalition (GWRC), an alliance of fourteen of the leading water industry research organisations worldwide (GWRC 2004). In 2007 a GWRC expert workshop was held in South Africa, which was attended by those responsible for the development of the three regional manuals, with the aim to consolidate the available knowledge and know-how and to develop an international guidance manual incorporating the most important aspects of the different manuals to enable its application worldwide.

This presentation will provide a brief introduction into the content and application of the Australian, and GWRC International, Guidance manuals.

Notes

Controlling Cyanobacteria: Alternative and Innovative Methods for Algal Control

Mike Burch[1], Peter Hobson[1], Sandy Dickson[1], Lyudmila Tsymbal[1] & Jenny House[1], Justin Brookes[2]
[1] mike.burch@sawater.com.au Australian Water Quality Centre, SA Water, Adelaide
[2] University of Adelaide

SA Water continues to experience significant source management issues with cyanobacterial blooms and has traditionally controlled algae using copper sulphate. It is recognised however that copper-based algicides are not an effective long-term solution to algal problems and there is a need to find a more environmentally acceptable long-term management strategy for nuisance algal and cyanobacterial blooms. A new joint project between Water Quality Research Australia (WQRA) and the Water Research Foundation (WRF) aims to address this issue. This paper describes the approach to be adopted in the project, which has been underway since March 2009.

The project will evaluate a range of alternative and innovative techniques for control of algae and cyanobacteria that have potential for application in drinking water reservoirs. The study will consider a range of commercial products and some other techniques that are available in the US and Australia but have differing degrees of acceptance and testing within the water industry. Most of these options have not had rigorous and scientifically valid testing with evaluations published in peer-reviewed scientific literature.

The project has adopted the following approach:

- Evaluate the cost, toxicity, feasibility, and environmental friendliness
- Use copper sulphate as a benchmark for the effectiveness, cost, and ease-of-use
- Test selected alternatives in natural water samples
- Address downstream consequences and implications to water treatment utilities.

The options being tested include: Alternative Algicides - hydrogen peroxide compounds; Algistats – alum, lime and modified clay for phosphorus binding and removal; Mixers - lake surface circulators for algal and cyanobacterial growth reduction; Ultrasound - low energy *in situ* ultrasound transducers for algal inhibition; Hybrid Ultrasound/Ozone algicide systems – a novel device based around treatment with a combination of ultrasound and ozone.

The paper will present results to date with a focus on the comparison of copper sulphate with a copper chelated algicide and a stabilised hydrogen peroxide chemical tested using laboratory bioassays with a range of cyanobacteria and green algae. Results from a trial of a surface circulator tested in a reservoir in the US will also be presented.

The project has strong collaborative team including the Australian Water Quality Centre (AWQC); the University of Adelaide; Department of Civil and Environmental Engineering, Virginia Tech, USA; the Department of Environmental Engineering, National Cheng Kung University, Taiwan. Utility partners include the Water Corporation (Western Australia), SA Water and the Western Virginia Water Authority, Roanoke, Virginia, USA.

The project will provide rigorous testing of the effectiveness, applications potential and cost of the alternatives to copper sulfate. The experimental testing is also designed to assess the mechanisms of action of the algal control methods.

Notes

Key Issues in the Management of Western Australia's Draft 2009 Harmful Algal Bloom Response Plan for Recreational Waters

Jared Koutsoukos, Department of Health, Western Australia

There are a number of water bodies monitored for cyanobacteria and other phytoplankton species in Western Australia (WA). Monitoring generally occurs for environmental purposes; however the focus of the draft 2009 WA Harmful Algal Bloom (HAB) response plan is recreational waters. Some monitored waterways are also used for irrigation purposes.

The WA response plan for HAB in recreational waters is based on a joint agency approach involving the Department of Health, Department of Water, Department of Environment and Conservation, Swan River Trust, Department of Fisheries, Water Corporation and respective local government authorities.

The response framework delineates the roles, responsibilities and response for each agency in the event of a harmful cyanobacterial or algal bloom event.

WA's Department of Water (DOW), is the key agency that undertakes cyanobacterial and algal monitoring in WA's waterways. The monitoring frequency varies for different waterways depending on available funding, its historical significance and regional location. The Department of Health (DOH), WA oversees public health communication and action resulting from cyanobacterial and algal monitoring.

The Peel-Harvey Inlet, the Serpentine and Murray Rivers in the Peel region which are approximately 55-70km South of Perth, and the Wilson Inlet between Denmark and Albany in the Southwest seasonally tend to develop the greatest number of cyanobacterial events requiring management and response interventions of governing authorities.

One of the key issues or challenges in the response framework is the interpretation of alert levels in accordance with the National Health & Medical Research Council (NHMRC), 2008, *Guidelines for Managing Risks in Recreational Water.*

The environmental sampling methodology, irregularity of sampling frequency and the administration of appropriate and timely public advice also present a considerable challenge to manage cyanobacterial bloom events in accordance with the response plan and NHMRC Guidelines.

The interpretation of sampling results for phytoplankton species that potentially may impact upon shellfish in the absence of a defined toxin analysis program for recreational waters is problematic.

Notes

Size, strength and structure of micro-algae flocs during water treatment

Rita Henderson[1], Stephanie Harguindeguy[1,2] and Bruce Jefferson[3]

[1] UNSW Water Research Centre, The University of New South Wales, Sydney
[2] School of Engineering, The University of Poitiers, FRANCE
[3] Centre for Water Science, Cranfield University, UK

Coagulation-flocculation (C-F) of algae is a crucial stage in the removal of microalgae in drinking water treatment plants. However, C-F is a complex process that can be difficult to optimise, resulting in unsatisfactory cell removal efficiencies. The aim of this research was to improve understanding of how algal floc properties vary under different C-F conditions, and thus lend insight into process optimisation. This was achieved by investigating the impact of varying coagulant dose and flocculation time on the resultant floc size, strength and structure for *M. aeruginosa* cells and other micro-algae such as the Chlorophyte, *Chlorella vulgaris*. The results were compared with those obtained for inert particulate and colloidal material such as clay (kaolin) and natural organic matter (NOM). The experiments were performed using bench scale jar testing with lab cultivated cells. The coagulant utilised was aluminium sulphate and pH was kept constant at pH 7. Floc structural properties were monitored using a Malvern Mastersizer 2000 while floc charge was determined via zeta potential measurements using a Malvern Zetasizer.

It was determined that when coagulating *M. aeruginosa* and *C. vulgaris* cells under charge neutralisation flocculation conditions, flocculation was not initiated until 7 minutes after coagulant addition. Maximum floc size was not achieved in some instances until 25 minutes had passed. In comparison, under equivalent conditions, flocculation of inert material such as clay and NOM commenced after a 1 minute lag time and steady-state floc size was achieved in 5 minutes or less [1-2]. For algal cells, floc growth rate increased with higher coagulant doses such that when operating under what would be considered “sweep flocculation” conditions, growth rate was more similar to that observed for inert materials. The implications of these findings are that if insufficient time is available for flocculation of algal cells, even if adequate coagulant has been added, flocculation may not occur if the retention time is too short or if short circuiting occurs. This will have particular impact when large flocs are required for sedimentation processes or when DAF processes are operated with flocculation retention times of less than 10 minutes.

1. Sharp, E.L., Jarvis, P., Parsons, S.A., and Jefferson, B., The impact of zeta potential on the physical properties of ferric-NOM flocs. Environmental Science and Technology, 2006. **40**(12): p. 3934-3940.

2. Henderson, R., Sharp, E., Jarvis, P., Parsons, S., and Jefferson, B., Identifying the linkage between particle characteristics and understanding coagulation performance. Water Science and Technology: Water Supply, 2006. **6**: p. 31-38.

Notes

Engineering solutions for the reduction and removal of toxin producing cyanobacteria from waterways

Anas Ghadouani, Aquatic Ecology and Ecosystem Studies, School of Environmental Systems Engineering, The University of Western Australia, 35 Stirling Highway, M015, Crawley, Western Australia, 6009

Cyanobacterial blooms constitute a serious threat to the sustainability and the safety of water resources around the world. Excessive growth of toxin-producing cyanobacteria and long lasting episodes of blooms are believed to have increased in frequency and magnitude in the last decade due to increased nutrient loading from watersheds to lakes, reservoirs, rivers and estuaries. Long term and sustained effort focused on the reduction of point and non-point source nutrient export have only resulted in a relatively small reduction in eutrophication in some areas in the world. It is essential that more direct action is taken to apply active treatment to reduce and remove algal blooms and their toxins especially in key waterways such as drinking water supplies or fish rich waters, among other environments. In this talk, a series of experiments will be presented to demonstrate the short term benefit from the application of an *in situ* treatment to control internal loading of phosphorus. In contrast, a more active treatment consisting of the controlled addition of hydrogen peroxide, a low cost technology, is presented to show a net reduction in the occurrence of cyanobacteria and their toxins. An overview of the advantages, including rapid reaction and low cost, and the limitations of such treatments will be discussed.

Dewatering of Cyanobacteria-rich Sludges

Feng Qian[a], Peter J Scales[a], David R Dixon[a], Gayle Newcombe[b]
[a]Particulate Fluids Processing Centre, Department of Chemical and Biomolecular Engineering, The University of Melbourne, Victoria 3010
[b]Australian Water Quality Centre, GPO Box 1751, Adelaide SA 5001

fqian@unimelb.edu.au

Cyanobacteria are now recognised as a serious water quality problem for drinking water supplies in Australia. They generate a number of metabolites that are responsible for the disagreeable earthy or musty taste and odour in water, or are toxins that pose health threats to human and animals. The fate of cyanobacteria in water treatment processes is not well understood, particularly how to manage cyanobacteria-rich sludge to maximize drinking water recovery. Recovery and reuse of this water is of increasing importance due to the continuing drought in south east Australia. This study aims to determine the fate of the cyanobacteria cells (specifically *Microcystis aeruginosa*, *Anabaena circinalis* and *Cylindrospermopsis raciborskii*) in conventional water treatment processes. These three species were cultivated in the laboratory to produce artificial alum sludges that mimic those produced in water treatment plants in the presence of cyanobacterial blooms. Metabolite release was monitored during coagulation, sedimentation and filtration in order to identify the processes responsible for their release. The dewatering characteristics were also examined and compared to a range of biological and non-biological materials to identify the ease with which water can be recovered.

Notes

Optimising water treatment processes for the removal of cyanobacteria and their metabolites

Lionel Ho and Gayle Newcombe

lionel.ho@sawater.com.au Australian Water Quality Centre, South Australian Water Corporation, 250 Victoria Square, Adelaide, SA 5000

Cyanobacteria are a concern for Australian water authorities as their persistence in water supplies causes numerous problems for water treatment plants. These include exertion of an additional demand on chemicals and clogging of filters, resulting in reduced filter run-times and increased backwash frequencies. However, the major problem caused by cyanobacteria is the metabolites they produce, in particular, cyanotoxins and taste and odour (T&O) compounds. These metabolites not only account for a large number of consumer complaints due to aesthetic issues, but can also compromise human health.

One of the major species of cyanobacteria which plague Australian water bodies is *Anabaena circinalis*, which can produce geosmin (a T&O compound) and saxitoxins (potent neurotoxins). Other cyanobacterial species of concern in Australian waters include *Cylindrospermopsis* and *Microcystis*, which have the ability to produce the hepatotoxins, cylindrospermopsin and microcystin, respectively.

With the increasing frequency of cyanobacterial detection in Australian water supplies, coupled with the changing climate and drought, it is imperative that water authorities employ and optimise successful treatment strategies for the mitigation of cyanobacteria and their metabolites. The Australian Drinking Water Guidelines (and more recently the Water Safety Plans) stipulate that it is important to utilise multi-barrier treatment options to ensure these contaminants do not reach the customer tap.

This presentation will provide new insights into optimising conventional water treatment processes for the removal of cyanobacteria and their associated metabolites. In addition, more advanced treatment regimes, including membrane and biological filtration processes will also be discussed with respect to their capacity to successfully remove these contaminants. Moreover, this presentation will highlight the best management practices that water authorities can apply in water treatment plants for the mitigation of cyanobacteria and their metabolites.

Notes

New South Wales Algal Management Strategy: A Review

Natasha Ryan, A/Team Leader Statewide Resource Condition, NSW Office Of Water, Department of Climate Change and Water, PO BOX 2213 Dangar NSW 2302 natasha.ryan@water.nsw.gov.au

The NSW Office of Water (the Office) and its predecessors have been instrumental over the years in co-ordinated, whole of government response to the occurrence of blue-green algal blooms in the State's rivers and storages. The establishment of the NSW Algal Management Strategy and its supporting programs, a response of the formation of the 1992 Blue-Green Algal Task Force, a direct result of algal blooms in the Darling River. That five year program included establishment of the nine Regional Algal Co-ordinating Committees (RACC) and a range of incentives and programs that included nutrient control works, education and the stock and domestic bore subsidy.

The recent NSW policy platform has moved toward water reforms and the implementation of water sharing plans and restructuring within the NSW government natural resource management agencies to meet new state and federal NRM and Water drivers. Nevertheless the Office continued to support water quality programs and algal management.

The resilience of the NSW Algal Management Strategy for the previous eighteen years highlights the importance to government of managing the risk posed by algal blooms. Within NSW in the early millennium the coastal RACCs also took on management of risk imposed by marine algal blooms following cabinet decisions with respect to biotoxin management.

During these past eighteen years post 1992 Darling Bloom, three large contentious blooms have proven the resilience of the framework and enabled monitoring, evaluation, reporting and continued improvements of algal management. These were the Myall Lakes blooms of 1999-2001, a coastal RAMSAR listed lake of 10,000 hectares north of Newcastle with a commercial fishing and prawning industry, houseboat industry, national park camping and ecotourism resort facilities. This bloom also occurred in a period leading up to local government elections which added a level of complexity to the issue. Precautionary fishing closures for the commercial and recreational fishing industry were also enacted.

The other two contentious regional scale blooms were the 2009 and 2010 Murray River Algal blooms on the border of New South Wales and Victoria for 6 to 8 weeks covering up to 1000 river kilometres. The 2009 bloom invigorated interest in blue-green algal management, requiring an interstate multi-level, whole of government and water management agency regional response with federal government interest in the management. After this the Murray RACC stakeholders and the Office undertook a critical evaluation of the management response, produced an evaluation report and recommendations to continually improve the management of risk imposed by blue-green algal blooms in both the Murray River and NSW proper.

Some of the recommendations included, but were not limited to, re-affirming government support for the process and formalising governance arrangements for the strategy, reviewing the State Advisory Group Structure and Role, improving the communications strategy (media releases, web links, algal information line, stakeholder communication lists), improving the availability of spatial information to facilitate more effective management responses, streamlining reporting, training new staff and building more capacity for algal management, improving database management, ensuring adequate sampling supplies and training, engaging with stakeholders, managing stakeholder expectations, updating and modernising contingency planning documentation and undertaking a socio-economic analysis of the Murray Algal Blooms.

For more information you can download the report at www.water.nsw.gov.au and click on the algal alerts icon.

Notes

Update of the *Australian Drinking Water Guidelines*

Heather Bishop, NHMRC

The *Australian Drinking Water Guidelines* (ADWG) are a joint initiative of the NHMRC and the Natural Resource Management Ministerial Council (NRMMC). Given the size of the Guidelines, undertaking a review of the complete Guidelines concurrently is too large a task. They therefore follow a rolling-revision process which allows specific issues to be reviewed in a timely manner. This ensures that the Guidelines continue to present the latest scientific evidence.

As a means of informing the current revision of the ADWG and determining the priority issues, meetings were held with significant stakeholders.

In April 2007 the NHMRC established the Water Quality Advisory Committee (WQAC) to provide expert advice on health issues relating to water quality. Membership comprises representatives from the scientific community, consumers, medical profession, government health and environment departments, experts within recycling systems, health risk assessment, and the broader water management industry. The work was divided into five areas including monitoring, organics, inorganics, microbiology and disinfection byproducts. The revision work was supported by additional experts in the relevant fields.

The four existing cyanotoxin fact sheets were revised to include the latest studies as follows:

1. *Cylindrospermopsin* - Apart from the existing major pathological effects of cylindrospermopsin, including liver, kidneys, stomach and vascular system, the revised fact sheet identifies lungs, heart, adrenal glands and the lymphatic system as being susceptible.

   Additional information has been included about when to provide health authorities with initial notification (when numbers of *C. raciborskii* reach 30% of the density equivalent to 1 µg/L. Alert when cell numbers are equivalent to 1 µg/L cylindrospermopsin)

2. *Microcystins* - The revised fact sheet has additional information on the general description, noting that microcystins are extremely stable chemically and remain potent even after boiling, though they are subject to biodegradation by a range of aquatic bacteria.

   A more comprehensive discussion is also included on the effects on the human liver, determined as a result of an accidental poisoning incident in Brazil in 1996, in which 76 people died.

3. *Nodularin* - Very minor amendments to update references

4. *Saxitoxins* - Minor amendments to include information on detection via immunoassay procedures

The public consultation period was extended in recognition of the size of the document and resulted in 55 submissions which were considered and incorporated where appropriate.

The final draft was circulated to State and Territory Regulators to verify that their concerns had been addressed. This was followed by a teleconference as an additional consultative process. State and Territory water regulators advised of their support of the final draft which went to Council on 16 July.

The ADWG have been forwarded to Natural Resource Management Standing Committee with a letter of request from Council for it to be forwarded out of session to the Natural Resource Management Ministerial Council for approval.

Notes

Revision of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* and the *Australian Guidelines for Water Quality Monitoring and Reporting 2000*

Bruce Gray, Department of the Environment, Water Heritage and the Arts

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* (ANZECC and ARMCANZ 2000a), and the *Australian Guidelines for Water Quality Monitoring and Reporting 2000* (ANZECC and ARMCANZ 2000b), are key source documents for managing water quality and protecting aquatic ecosystems in both Australia and New Zealand. These Guidelines form part of the National Water Quality Management Strategy (NWQMS). Individual Guideline documents, and the Strategy as a whole, are jointly endorsed by the Environment Protection and Heritage Ministerial Council (EPHC), the Natural Resource Management Ministerial Council (NRMMC), and / or the National Health and Medical Research Council (NHMRC). The National Water Quality Management Strategy aims to achieve sustainable use of water resources by protecting and enhancing their quality while maintaining the economic and social development of Australian and New Zealand communities.

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000*, and the *Australian Guidelines for Water Quality Monitoring and Reporting 2000*, employed in conjunction with the *Australian Drinking Water Guidelines 2004* (NHRMC and NRMMC 2004) and the *Guidelines for Managing Risks in Recreational Water 2005* (NHMRC 2005), form the national “benchmark” Guidelines for the management, monitoring and reporting of Blue-Green and other algal blooms in fresh, coastal, and marine waters. These benchmark Guidelines directly inform state / territory, local government, and regional algal management processes.

The NHMRC and NRMMC are currently finalising their revised *Australian Drinking Water Guidelines 2010*. Complementing this, the EPHC, NRMMC, and NHMRC are also undertaking a joint review of the Australian *and New Zealand Guidelines for Fresh and Marine Water Quality 2000* and the *Australian Guidelines for Water Quality Monitoring and Reporting 2000*. This revision work is likely to have implications for the way Blue-Green Algae and associated toxins are monitored and reported into the future, and is likely to result in revised guideline levels for Primary Industries and, potentially, a closer alignment with other NWQMS documents (such as the NHMRC’s *Guidelines for Managing Risks in Recreational Water*).

For more information on the review of National Water Quality Management Strategy Document 4: *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000*, please visit the EPHC Website www.ephc.gov.au or contact Haemish Middleton or Ian Newbery from the National Environment Protection Council Service Corporation on (08) 8419 1200, hmiddleton@ephc.gov.au or inewbery@ephc.gov.au. In New Zealand, contact Todd Krieble, Ministry for the Environment, Phone 64 4 4397640, Todd.Krieble@mfe.govt.nz. For information on the Australian Drinking Water Guidelines please contact Heather Bishop from the National Health and Medical Research Council (heather.bishop@nhmrc.gov.au).

Summary of state and territory based cyanobacterial guidelines and management frameworks in Australia

Vanora Mulvenna, Senior Policy Officer, Department of Health, Victoria

Government agencies across Australia’s states and territories have developed frameworks to coordinate the management of, and response to, cyanobacterial blooms. Numerous guidelines and fact sheets have also been published by these agencies in relation to cyanobacterial blooms in water used for drinking, recreation, irrigation, and livestock.

A summary of state and territory based guidelines and management frameworks will be presented, demonstrating the importance of effective risk communication and coordination in the management of risks posed by cyanobacterial toxins.

Notes

CyanoSurvey - A National Update on the Distribution of Toxic Cyanobacteria

Andrew Humpage, Virginie Gaget & Suzanne Froscio, AWQC.

Toxic cyanobacteria remain a major risk factor for drinking water quality in Australia, but integrated up-to-date information about the distribution of problem cyanobacteria is lacking. Instead we have disjointed local knowledge held within disparate organisations. The last large scale survey (of the Murray-Darling Basin only) was done in 1991, and we know that species distributions have changed considerably since then. In addition to the well-known toxin producers, new toxigenic species have been identified since the 1991 survey, but little is known of their geographic distribution or the rate of occurrence of toxigenic strains. These newly identified toxic species include *Aphanizomenon ovalisporum, Aph. flos-aquae, Lyngbya wollei, Anabaena lemmermannii, Raphidiopsis curvata*, and *Limnothrix* species. There is also uncertainty about *Microcystis flos-aquae* because although it was historically considered non-toxic, it now appears that it can be toxic on occasions. However, the taxonomy of the cyanobacteria is currently undergoing major revision due to improved genetic typing methods, and it is unclear whether some of these names represent truly separate species or simply morphological variants of the same species. These new genetic techniques have now been developed to the extent that they can be used to help refine morphological identification, which remains the mainstay of monitoring throughout most of Australia. We also have new rapid toxin detection methods such as ELISAs and field tests which need to be validated on a wide range of natural samples before they can be recommended to the industry. This requires comparison with established analytical methods and also with bioassays based on the toxic mechanisms involved.

The CyanoSurvey project started in December 2009. It will replicate the 1991 survey and use the comparison with the current situation to make predictions about likely on-going impacts of climate change. But it will also expand the scope of that survey nationally with help of 14 Water Quality Research Australia (WQRA) member organisations plus a number of other organisations that have volunteered to provide cyanobacterial samples from their critical drinking water sources. Information gathered will include cyanobacterial species composition and presence of toxic species, toxin and toxicity analyses by both ELISA and functional assays (with positives characterised by LC-MS). Water chemistry analysis will aid our understanding of the drivers of species distribution patterns. Individual species/strains will be isolated into culture to confirm toxin production, and for comparison of morphological and genetic classifications. A DNA library of strains and species will be established that can support further work in this area.

The outcome will be a unified collection of national data linking the occurrence of toxic cyanobacteria to water quality preferences and genetic typing. This will provide the basis for a greater understanding of the drivers of distribution changes, which will help predict future trends, and also provide a valuable benchmark as the basis for future climate change studies. The project will also conduct a cross-validation of a range of analytical methods for species identification and toxin production.

An outline of the project will be provided, and opportunities for Water Industry and Researcher collaborations will be highlighted.

Notes

Using an Algal Online Analyser for Detecting the Presence of Cyanobacteria in Biologically Treated Effluent

Thang Nguyen, T Doan, L Fan and FA Roddick
School of Civil, Environmental and Chemical Engineering
RMIT University, GPO Box 2476, Melbourne, 3001.

Western Treatment Plant (WTP) treats approximately 52% of Melbourne's sewage using a combined activated sludge-lagoon process. After passing through the activated sludge ponds, the effluent is clarified, passed through a series of lagoons and then held in the holding pond referred to as Head of Road Storage (HORS) before release as Class A (with disinfection) or Class C (without disinfection) recycled water. The lagoon system is subject to periodic cyanobacterial blooms (usually *Microcystis aeruginosa*) during the warmer months, thus precluding use of the treated water for recycling.

The response of the Algal Online Analyser (AOA) located at WTP to the presence of known concentrations of *M. aeruginosa* and a green alga (*Euglena gracilis*) was investigated to determine its effectiveness in detecting potential cyanobacterial blooms within the system. The AOA uses fluorescence excitation of chlorophyll *a* as a means of detection. The presence of other pigments in the different algal classes, and their interaction with chlorophyll *a,* results in a specific excitation spectrum for the different algal taxonomic classes. Suspensions of laboratory-grown cultures of known concentrations of the organisms were prepared in HORS water and the response of the AOA in terms of chlorophyll *a* concentration determined in three different experiments.

There was a strong linear correlation between cell count and chlorophyll *a* for both *M. aeruginosa* (30,000-65,000 cells/mL, biovolume of 0.003-0.007 mm^3/mL) and *E. gracilis* (650-3400 cells/mL, biovolume of 2-10 mm^3/mL). The influence of the presence of the two algal species on the response of the AOA for both classes varied with test run.

This study demonstrated that the AOA could be used as an alert system for cyanobacterial blooms at WTP. Furthermore, it was shown that regular cleaning was a major factor which affects the performance of the instrument.

Notes

Impact of Iron Species Transformations on Growth and Toxicity of Cyanobacterial Microcystis Species

T David Waite[1], Manabu Fujii[1], Cuong Dang[1], Rali Alexova[2] and Brett Neilan[2]

[1]School of Civil and Environmental Engineering and [2]School of Biotechnology and Biomolecular Sciences, The University of New South Wales, Sydney, NSW 2052

It has been purported that the growth and toxicity of some cyanobacterial species is influenced by the bioavailability of the trace nutrient iron. New evidence based on batch culture studies with toxic and non-toxic strains of *Microcystis aeruginosa* is presented which provides insight into the role of iron in growth and toxin production by this organism. The presence of organic matter and light has a dramatic influence on iron bioavailability and kinetics of iron uptake by *Microcystis aeruginosa*. Iron bioavailability influences both organism growth and toxin production with growth rate reduced under iron limiting conditions but toxin production increased. The presence of the toxin appears to give an advantage to microcystin-producing cyanobacteria in the early stages of exposure to severe iron stress and may protect the cell from reactive oxygen species-induced damage.

Potential of the enhanced spectral and spatial features of the WorldView-2 satellite sensor for monitoring algal blooms in inland waters

Tim Malthus[1], Nora Egli[2], Nagur Cherukuru[1], Brad Sherman[3], Arnold Dekker[1], Ken Gillan[4]
1. Environmental Earth Observation, CSIRO Land and Water, GPO Box 1666, Canberra ACT 2601. (tim.malthus@csiro.au)
2. Remote Sensing Group, University of Zurich – Irchel, Winterthurerstrasse 190, CH-8057 Zurich, Switzerland
3. Catchment Biogeochemistry and Aquatic Systems, CSIRO Land and Water, Canberra, ACT 2601
4. Sinclair Knight Merz, Armidale, VIC

Remote sensing methodologies may provide complementary information to conventional *in situ* sampling of bloom forming algal groups and other water quality parameters; the ability to provide spatial maps of surface inland water quality from airborne and satellite data is already well demonstrated. The keys to the approach are robust, physically driven analytical algorithms to quantify algal concentrations and other optical water quality parameters and perhaps to identify key algal groups (e.g. cyanobacteria). The spatial resolution of the sensors also needs to be such that accurate maps of the spatial distribution of blooms are obtained that are useful for management purposes for a range of water body sizes.

We present here the preliminary results of a study into the feasibility and potential of using DigitalGlobe WorldView 2 sensor data for mapping blooms and other optical water quality parameters in Lake Burley Griffin during the first half of 2010. This sensor, launched in late 2009, provides high spatial resolution (1.8 m) and enhanced spectral resolution (8 bands) at high temporal frequency (up to 2.5 day revisit time). The study represents an integration of *in situ* optical, fluorescence and conventional water quality sampling with laboratory optical characterisation of the waters, combined with optical modelling and image analysis. We test the ability of the additional spectral information in WorldView2 to better map water quality parameters across the lake and even to distinguish individual phytoplankton types more precisely, and specifically cyanobacteria.

Notes

Estimating water quality and bloom status using hyperspectral optical measurements: A case study in Lake Burley Griffin, Canberra

Nagur Cherukuru, Tim Malthus, Nora Egli, Arnold Dekker, Brad Sherman

GPO Box 1666, CSIRO Land and Water, Canberra.
Email: nagur.cherukuru@csiro.au

Lake Burley Griffin (LBG) is an artificial lake in the centre of Canberra. The lake is an ornamental body and its surrounds, consisting mainly of parklands, are popular with recreational users. For this reason it is important to monitor and maintain the water quality in this lake. Blue green algal blooms and high levels of turbidity are common factors that affect the water quality in this lake. Currently the National Capital Authority regularly samples the water at various locations, issues warnings to the public and occasionally closes the lake during intense (and potentially toxic) bloom periods.

Given sufficient resolution, remotely sensed data could provide spatial overviews of the biogeochemical status of the lake providing valuable information to complement more laborious *in situ* single point measurements. The spectrum of reflectance emanating from a water body contains the signature of various optically active substances. With a knowledge-based optical model it is possible to retrieve and quantitatively map the distributions of substances such as phytoplankton, suspended sediments and coloured dissolved organic matter.

With the aim of developing an optical model for the lake we have surveyed LBG through the first months of 2010, to measure the concentrations of phytoplankton pigments, suspended solids, and coloured dissolved organic matter, inherent optical properties such as absorption and backscattering and apparent optical properties such as radiance irradiance, reflectance and remote sensing reflectance.

Based on the field measurements, we will present the nature of particulate and dissolved substances in LBG, their specific inherent optical properties and bio-optical relationships. Next we will introduce the bio-optical model that is capable of simulating the remote sensing signature. Finally, we discuss the applications of this model in both biogeochemical modelling and remote sensing algorithm development, particularly in the context of cyanobacterial bloom detection.

Notes

Cyanobacterial toxin dynamics: What can we learn from spatial and temporal variability?

Elke S Reichwaldt and Anas Ghadouani

School of Environmental Systems Engineering
The University of Western Australia,
Email: elke.reichwaldt@uwa.edu.au and Anas.Ghadouani@uwa.edu.au

Toxic cyanobacterial blooms threaten the safety of water resources around the world and their occurrence is thought to increase even further in the future as a consequence of climate change. Our understanding of the dynamics of cyanobacterial blooms is not well enough developed to allow for the implementation of efficient management of this serious water quality problem. All attempts to permanently control nuisance blooms have failed so far. The predictions of bloom occurrence and variability are still highly inaccurate due to the lack of understanding of the environmental triggers that control blooms and their variability. The progress of managing toxic cyanobacterial blooms successfully is hindered by the fact that many ecosystems exhibit marked thresholds in their dynamics making them nonlinear systems that are highly unpredictable. Even more unreliable are predictions of toxin dynamics as the fate of cyanobacterial toxins in aquatic systems is still largely unknown.

In this presentation we will show how cyanobacterial blooms and their toxins co-vary over time and space. We will discuss how this information can be used to inform our management strategies based on intense data collection from a population of lakes in Western Australia. In addition we will outline some of the knowledge gaps which need to be addressed in order for us to improve our predictive ability of algal blooms and especially the toxin producing ones.

Notes

Cyanobacterial bloom dynamics - some lessons from the Nineties and the Noughties

Brad Sherman, Ian Webster, Phil Ford - CSIRO Land and Water

The massive 1991 blue green algal bloom in the Darling River led to a concerted effort to study and better understand the various factors affecting algal bloom dynamics in Australia. Studies in Maude Weir Pool, Chaffey Dam, Fitzroy Barrage and Myponga Dam revealed some important consistencies across systems.

In each of these thoroughly studied systems, the onset of persistent stratification leading to a shallow surface mixed layer (SML) depth:euphotic depth ratio (Z_{sml}:Z_{eu} < 2-3) preceded the onset of cyanobacterial blooms. This typically occurs when Z_{sml} becomes smaller due to local meteorological conditions and has even been observed to occur in the depths of winter (e.g. Chaffey Dam). It may also occur when an initially turbid water column stratifies and clears as particles sink out of the water column thereby increase Z_{eu} (e.g. Fitzroy Barrage). Persistent shallow surface mixing layers allow buoyant algae such as *Microcystis* and *Anabaena* (and motile phytoplankton such as the dinoflagellate *Ceratium*) to thrive whereas non-buoyant and non-motile algae sediment out of the euphotic zone thereby reducing competition for nutrients.

In many cases, the algal *populations* grew at rates determined by the available light in the SML until such time that macronutrient limitation (typically phosphorus) prevented any further accumulation of algal biomass. Typically, nutrient concentrations were not observed to limit algal growth rates (i.e. cell division rates). At Chaffey Dam, artificial destratification reduced internal loading of phosphorus by up to 85% leading to a corresponding reduction in algal biomass although cyanobacteria still dominated the population because of their ability to maintain position within the euphotic zone relative to other species.

Despite a theoretical capability to exploit light-nutrient separation, the buoyant cyanobacteria species *Anabaena* and *Microcystis* were not observed to continue growing within the SML once nutrients had been depleted there despite an ample supply of bioavailable phosphorus located just a metre or two below the SML. In general the populations of these species were redistributed within the SML each night following convective mixing with little or no movement to depths below the SML.

From an algal bloom management perspective these observations lead to the conclusion that avoidance of *Microcystis* and *Anabaena* requires Z_{sml}:Z_{eu} ≥ 3. We know enough about mixing in rivers and reservoirs to enable us to assess the susceptibility of a system to buoyant algal bloom formation using commonly available flow and weather data. Unfortunately, it is not easy to engineer Z_{sml}:Z_{eu} ≥ 3 in medium-large reservoirs in much of Australia. In smaller storages (<10,000 ML e.g. Timor Dam, Coonabarabran NSW) it may well be possible to light-limit cyanobacterial growth using surface mixers (e.g. WEARS) or other means of artificial destratification (e.g. bubble plumes). Nutrient load reduction by artificial destratification or direct oxygenation can be used to effectively reduce algal biomass in storages where internal nutrient loads are a major component of the annual nutrient budget.

Notes

Cyanobacteria in inland floodplain wetlands

Yoshi Kobayashi
Rivers and Wetlands Unit, Waters and Coastal Science Section
Department of Environment, Climate Change and Water NSW
Email: Yoshi.Kobayashi@environment.nsw.gov.au

There are communities of cyanobacteria in inland floodplain wetlands, even though these wetlands have been affected by prolonged periods of drought, river regulation and water extraction. Environmental flow waters to the wetlands may affect the wetland cyanobacteria, by transporting a range of riverine cyanobacterial species at high concentrations into the floodplains, particularly during summer. I will present the current species compositions of cyanobacteria and their cell densities in some of the most significant floodplain wetlands in NSW. I will also discuss environmental and human factors affecting them. I recommend that cyanobacteria in inland floodplain wetlands need to be monitored, especially where grazing and human-related activities occur. Information about the wetland cyanobacteria provides a framework to assess cyanobacterial blooms across a range of inland water bodies, including rivers, lakes and reservoirs.

Notes

Abraxis Strip Test for Microcystins - Validation for use with Lagoon-treated wastewaters

Andrew Humpage, Suzanne Froscio, Melody Lau, Australian Water Quality Centre, Adelaide.

Felicity A Roddick, T Nguyen and L Fan, School of Civil, Environmental and Chemical Engineering, RMIT University, Melbourne

Judy Blackbeard & Danny Murphy, Melbourne Water Corporation

Melbourne Water's Western Treatment Plant (WTP) treats 52% of the wastewater from the metropolitan area of Melbourne and 72% of the industrial wastewater to Class A recycled water standard. However, periodic blooms of potentially toxic *Microcystis aeruginosa* compromise this quality and so a rapid method for microcystin detection was sought. Rapid tests for the microcystins have recently become available that are designed to be able to be used in the field. The tests provide a semi-quantitative result within a limited response range and are available with detection limits relevant for drinking water and recreational water compliance testing (1 µg/L and 10 µg/L, respectively). The RMIT and AWQC teams have independently assessed the applicability of these tests for the determination of microcystin-related toxicity in effluent waters from WTP as well as a number of other waters.

The projects assessed:

- Accuracy of the tests to quantify microcystin-LR within the concentration detection range claimed by the manufacturer.
- Precision to reliably produce the same result when repeatedly tested with the same microcystin concentrations.
- Cross-reactivity of the range of available purified microcystins.
- Matrix effects caused by chemical constituents of real waters and *Microcystis* cells.
- The reliability of the Abraxis QuikLyse cell lysis method.
- Inter-operator and band density variability effects on scoring the test results.
- A preliminary comparison was made between the drinking water and recreational water tests.

Conclusions from the project for the recreational water test strip (<1 to 10 µg/L) were:

- The claimed mLR concentration response range of the test was confirmed within reasonable limits. The false negative and false positive rates were unacceptably high for spike concentrations below 2.5 µg/L. This concentration should therefore be considered the Limit of Detection of the assay.
- Inter-operator variability was reasonably high and this was worse in untrained scorers. Contributing to this was significant inter-assay variability in test band intensity. However, this variability was minor in terms of the response range of the assay and is unlikely to lead to false negatives.
- The test strips responded to all 8 analogues tested and also to a mixture of another 7 analogues contained in the Certified Bloom Material. Cross-reactivity was generally similar to cross-reactivities published for the Abraxis ELISA for Microcystins, and never less than 50%. Based on the published data, the test is expected to over-estimate toxicity but this will most likely rarely exceed 2-fold. However, this assessment must remain provisional due to the lack of toxicity and cross-reactivity data for the majority of described microcystins.
- Matrix effects due to the test waters or to cyanobacterial cell material were also relatively minor, being on the order of 2-fold at the maximum. Chlorinated then quenched waters samples did not adversely affect the assay. The QuikLyse method proved to be a rapid and reasonably effective way of releasing intracellular microcystin from *M. aeruginosa* for the measurement of total microcystin by both the strip test and HPLC.
- A limited comparison of the Drinking Water Strip Test and the Recreational Water Strip Test suggests that the former is slightly more accurate.

Notes

Developing a rational basis to meet operational needs in the management of nuisance cyanobacterial occurrences in water sources

Kumar Eliezer & Lisa Stephenson, Biology Laboratory ALS Environmental Water Resources Group,

The initial step in the management of a potential cyanobacterial incident in water sources is the identification of the offending cyanobacteria. The next step is to enumerate the offending organisms to enable the making of a reasonable risk assessment with regard to public health and water quality. A key element in this process is to get the results back as quickly as possible to the water engineers to enable early operational decision-making.

Methods to reach these dual objectives are well-established and have been in use by all NATA accredited Biology laboratories. The basis of these methods is microscopy and requires trained staff to have not only well developed skills in microscopy, but also well-developed taxonomic skills with respect to cyanobacteria and algae in general.

In addition to using cell numbers, biovolume measures have been increasingly used by water authorities in making risk assessments.

Aimed at facilitating the attainment of the latter objective, biovolume measurements and biovolume calculators have been prepared by state authorities and are currently in use.

While agreeing with this broad approach, some time-saving and rational changes to the “Biovolume” approach are proposed.

The reasoning behind this rationalisation is explained and critical comment on the suitability of the proposed approach is invited.

Notes

A new potentially toxic cyanobacterium from Australian freshwaters: First report of the cyanotoxins cylindrospermopsin and deoxy-cylindrospermopsin from *Raphidiopsis mediterranea* (Cyanobacteria/Nostocales)

Glenn B. McGregor[1] and Barbara C. Sendall[2]

[1]Queensland Department of Environment and Resource Management, 120 Meiers Road Indooroopilly Qld 4068 glenn.mcgregor@derm.qld.gov.au

[2] Queensland Health Forensic and Scientific Services, 39 Kessels Road, Coopers Plains Qld 4108, Australia.

In Australia the cyanotoxin cylindrospermopsin (CYN) and its natural epimer deoyx-cylindrospermopsin (deoxy-CYN) has been associated with both planktonic and benthic cyanobacteria. The most common and widespread CYN-producing cyanobacterium in Australia is *Cylindrospermopsis raciborskii*. Due to its morphological plasticity *C. raciborskii* has often been confused with other morphologically and ecologically allied Nostocalean species including *Raphidiopsis mediterranea* Skuja. This confusion is frequently compounded by reports of concurrent toxin production.

We studied a filamentous cyanobacterium isolated from the plankton of a eutrophic reservoir in Queensland which, based on morphological features, was putatively identified as *R. mediterranea.* Strain FSS1-150/1 was screened by HPLC MS/MS for a number of common cyanotoxins and was shown to produce both CYN and deoxy-CYN at concentrations of 917 and 1065 $\mu g\ g^{-1}$ dry weight respectively. Evidence for CYN synthesis by strain FSS1-150/1 was further supported by PCR amplification of a fragment of the *pks* gene involved in CYN biosynthesis. Subsequent phylogenetic analyses using a partial sequence of the 16S rRNA gene confirmed its identification and showed that strain FSS1-150/1 was closely related to a group of *Raphidiopsis* sequences including representatives of both *R. mediterranea* and *R. curvata*.

These results provide the first confirmation of the production of CYN and deoxy-CYN by *R. mediterranea* and the second species of the genus *Raphidiopsis* known to produce these potent cyanotoxins. It adds to the number of potentially toxic cyanobacterial species known from Australian freshwaters which should be considered when assessing the risk to public and ecosystem values.

Notes

Production dynamics of cylindrospermopsins by an Australian strain of the tropical cyanobacterium *Cylindrospermopsis raciborskii* (Woloszynska) Seenayya et Subba Raju isolated from a drinking water storage reservoir in south-east Queensland

Philip T. Orr[1], Michele A. Burford[2] and Geoffrey K. Eaglesham[3]

[1] Seqwater, PO Box 16146 City East, Qld 4002, Australia
[2] Australian Rivers Institute, Griffith University, 170 Kessels Road, Nathan, Qld 4111, Australia
[3] Queensland Health Forensic and Scientific Services, 39 Kessels Rd, Coopers Plains, Qld 4108, Australia

Toxic cyanobacteria present one of the highest risks to water supply for any water authority. Seqwater is responsible for sourcing, storing and supplying safe potable drinking water to more than 2 million people in southeast Queensland. Understanding the processes that drive development of toxic cyanobacterial blooms and production of cyanotoxins is an important tool in water cycle management.

Cylindrospermopsis raciborskii is the most abundant potentially toxic species found in Brisbane's 3 main water storage reservoirs. In Australia, *C. raciborskii* produces 2 potent cylindrospermopsins – 7-epi-cylindrospermopsin (7-epi-CYN) and deoxy-cylindrospermopsin (deoxy-CYN). We grew a clonal but non-axenic strain of *C. raciborskii* isolated from Lake Samsonvale near Brisbane in P-limited batch cultures to study the dynamics of cylindrospermopsin production. We measured changes in filament length (μ_{fil}), total biomass (μ_g) and intracellular ($\mu_{i\text{-}CYN}$) and total (intracellular plus extracellular) 7-epi-CYN and deoxy-CYN concentration ($\mu_{CYN's}$) throughout the cell cycle to test the hypothesis that cylindrospermopsin production is a constitutive process related to cell division and/or growth.

We cannot rule out biodegradation of dissolved CYN's by bacteria. However, μ_{fil} and μ_g were positively correlated (1:1) with $\mu_{i\text{-}CYN's}$ and $\mu_{CYN's}$ suggesting that cylindrospermopsin production is related to growth and cell division in *C. raciborskii*. One interesting outcome was the finding of a peak *C. raciborskii* filament length of up to 300m (filament) mL^{-1} culture during stationary phase.

Notes

Taxonomy and ecology of toxin producing *Limnothrix*

Larelle Fabbro[a], Catherine Bernard[a,b], Rebecca Campbell[a,b], Paul Monis[b], Suzanne Froscio[b], Andrew Humpage[b].

[a] Centre for Environmental Management, CQ University, Rockhampton, Queensland, Australia.
[b]Australian Water Quality Centre, GPO Box 1751, Adelaide SA 5001, Australia.

A new toxin produced by a *Limnothrix* was discovered while screening cyanobacterial samples for the presence of known and unknown toxins as part of an Australian Coal Association Research Project. It is the first time that a toxin-producing freshwater *Limnothrix* has been described.

The features of this cyanobacterium in both field and pure cultures were consistent with the cyanobacterial species *Geitlerinema unigranulatum* as well as with the earlier Australian descriptions of *Limnothrix* cf. *planctonica.* However, genetic analyses closely group this cyanobacterium with the commonly occurring temperate species *Limnothrix redekei*.

Limnothrix may occur as solitary planktonic trichomes, mats on the bottom or within the water column, or in balls floating on the surface. A fine mucilage, often confused with a sheath, may cover older trichomes. The long, thin trichomes may glide into coils, may flex and are not attenuated at the ends. The cylindrical cells are 1.6-2.0 μm wide and 5.0-6.5 μm long. Constriction at the cross walls is generally not observed and cross walls are often indistinct. Refractile granules are present in the cells - near the cell walls and sometimes distributed within the cells.

Limnothrix often co-dominates with *Cylindrospermopsis raciborskii* in both temperate and tropical environments. In the Fitzroy River system, it is often found just above the level of the thermocline. However, toxin producing material has also been isolated from water sampled from major pipelines within the Central Queensland region.

Notes

Novel toxic activity associated with the cyanobacteria *Limnothrix:* Use of screening assays for detection.

Suzanne Froscio[a], Han Min Lau[a], Catherine Bernard-Pattinson[b], Larelle Fabbro[c] and Andrew Humpage[a]
[a] Australian Water Quality Centre, GPO Box 1751, Adelaide SA 5001, Australia.
[b] Centre for Environmental Management, CQ University, Rockhampton, Queensland, Australia and Australian Water Quality Centre, GPO Box 1751, Adelaide SA 5001, Australia.
[c] Centre for Environmental Management, CQ University, Rockhampton, Queensland, Australia.

Development of biochemical screening assays for cyanobacterial toxins allows identification of toxins based on known activity. While this may be diagnostic for the toxin or toxin class that the assay has been designed for (e.g. microcystins, cylindrospermopsins) there is also potential to pick up new, unidentified toxins.

In this example, screening cyanobacterial samples for the toxin cylindrospermopsin led to the identification of novel toxic activity from the cyanobacterium *Limnothrix.*

The cell-free protein synthesis assay was inhibited by the *Limnothrix* extract as would be expected when cylindrospermopsin is present. However analysis by immunoassay (ELISA) and analytical techniques (HPLC, LC-MS) could not detect cylindrospermopsin itself. PCR amplification of genes associated with cylindrospermopsin production was also absent.

Further characterisation revealed that the toxic responses induced by the *Limnothrix* extract could not be attributed to other known cyanobacterial toxins. Distinctive toxic effects of the *Limnothrix* extract in mammalian cells include significant ATP depletion and marked granulation of cells as observed by both microscopy and flow cytometry. Current work aims to identify and characterise the toxic agent present.

This case highlights how biochemical screening assays can complement analytical techniques for the identification of toxic activity in cyanobacterial samples. Adequate validation of such techniques is required.

Notes

Factors promoting the dominance of the toxic freshwater cyanobacterium *Cylindrospermopsis raciborskii*

Michele Burford[1], James Udy[2]

[1]Australian Rivers Institute, Griffith University, Nathan, QLD 4111, Australia, Email: m.burford@griffith.edu.au
[2]Seqwater, 240 Margaret St, Brisbane, 4002, Australia

The cyanobacterium *Cylindrospermopsis raciborskii* is becoming increasingly prevalent in reservoirs, lakes and weir pools throughout the world. Early reports showed that this species dominated in warmer waters in the tropics and subtropics, e.g. reservoirs in Brazil and Australia. However, in recent years it has been reported in substantial densities in summer months in many temperate areas of the world, e.g. northern Europe.

Toxin production occurs in Brazil and Australia, and is less common in other areas of the world. Research conducted in southeast Queensland reservoirs over the last seven years suggests that there are a few key strategies utilised for this species to out-compete other algal species. These include the ability to: scavenge phosphorus in low phosphorus environments; alternate nitrogen fixation with dissolved nitrogen utilisation, and the ability to optimise growth under low light.

Managing blooms is, therefore, likely to be difficult, as nutrient reduction and artificial mixing strategies are unlikely to yield benefits in the short to medium term. However, understanding factors promoting the dominance of this species will provide the information needed to improve predictive models.

Notes

Mullet (Mugilidae) are efficient bioaccumulators of nodularin. Field investigation of a toxic *Nodularia* bloom in SE Queensland, and the public health implications of dietary exposure to nodularin

Ian Stewart[1,2], Geoffrey K. Eaglesham[1], Glenn B. McGregor[3], Roger Chong[4], Alan A. Seawright[5], Wasantha A. Wickramasinghe[5], Ross Sadler[2], Steve Carter[1], Lindsay Hunt[1], Glenn Graham[1,6]

[1]: Queensland Health Forensic and Scientific Services, Coopers Plains, Qld; [2]: School of Public Health, Logan Campus, Griffith University, Meadowbrook, Qld; [3]: Dept of Environment and Resource Management, Indooroopilly, Qld; [4]: BioSecurity Queensland, Dept of Employment, Economic Development and Industry, Coopers Plains, Qld; [5]: University of Queensland, National Research Centre for Environmental Toxicology (EnTox), Coopers Plains, Qld; [6]: Faculty of Science, University of the Sunshine Coast, Maroochydore, Qld

Dietary transfer of cyanotoxins is an emerging public health issue. Many national and trans-national government agencies monitor and regulate seafood and shellfish for alert concentrations of several eukaryotic marine algal toxins such as saxitoxins, domoic acid and okadaic acid. While many of these same agencies have adopted guideline recommendations for certain cyanotoxins in drinking water and recreational waters, edible aquatic and marine animals are yet to receive a comparable degree of regulatory oversight for the presence of cyanotoxins. Public health workers from Scandinavia and northern Europe are concerned about nodularin entering the human food chain because of frequent and extensive *Nodularia* blooms in the Baltic Sea. Tissues of flounder and other teleosts, bivalve molluscs and eider ducks are intermittently investigated through research programs to measure nodularin levels. The highest reported concentration to date of nodularin in fish liver is 2.2 mg kg^{-1} dry weight from Baltic Sea flounder, and the highest reported concentration in any seafood product by natural exposure is 6.4 mg kg^{-1} wet weight in prawn viscera from the Gippsland Lakes, Australia.

We investigated mullet and other fish specimens (eel, bream and cod) retrieved from a fish kill at a small recreational lake that suffered a toxic *Nodularia spumigena* bloom. Nodularin was extracted from muscle and liver tissues with aqueous methanol and quantified by HPLC-MS/MS. Sea mullet (*Mugil cephalus*) median liver nodularin concentration was 12.0 mg kg^{-1}; (range 11.2 mg kg^{-1}, 13.2 mg kg^{-1}) wet weight; *n*=3. Dry weight equivalents calculated from lyophilised mullet livers were: median 43.6 mg kg^{-1} (range 40.8 mg kg^{-1}, 47.8 mg kg^{-1}). Nodularin was also found in the muscle of these fish: wet weight median = 13.6 µg kg^{-1} (range 10.0 µg kg^{-1}, 17.6 µg kg^{-1}). Dry weight equivalents from lyophilised muscle: median = 44.0 µg kg^{-1} (range 32.3 µg kg^{-1}, 56.8 µg kg^{-1}). Hepatic nodularin concentrations in the carnivorous fish were several orders of magnitude lower than those found in mullet. Further investigations at this study lake were therefore directed towards mugilids. Mullet captured by seine and gill nets at the index lake were again found to have ppm concentrations of nodularin in their liver and ppb concentrations in muscle tissue; livers were enlarged and discoloured, histology examination revealed evidence in some specimens of severe degenerative pathology.

Mullet have a specialised feeding strategy. They are detritivores and planktivores; their specialised mouthparts suck up surface sediments from which they extract and digest nutrients. We suspect that the feeding ecology of the Mugilidae and their consequently high exposure to *Nodularia* most likely explain this unusually high uptake of nodularin. *Nodularia*-prone estuaries in South Australia, Western Australia and Victoria support valuable commercial mullet fisheries, and mullet are important aquaculture and mariculture products. We will seek funding to conduct experimental research on uptake and elimination kinetics of cyanobacterial hepatotoxins in mugilids in order to explore further the food safety implications of dietary exposure to cyanotoxins.

Notes

Uptake and depuration of Nodularin in seafood species: A human health risk assessment

Jackie Myers[1,2,], Allinson, Graeme[2], Allinson, Mayumi[2], Allen, David[3], Rose, Gavin[3], Kaya, Kunimitsu[4], Nugegoda, Dayanthi[1],.

[1] School of Applied Sciences, RMIT University, Bundoora Campus, PO Box 71, Bundoora, Victoria, 3083.
[2] Future Farming Systems Research, Department of Primary Industries, DPI Queenscliff Centre, P.O. Box 114, Queenscliff, Victoria, 3225.
[3] Future Farming Systems Research, Department of Primary Industries, DPI Werribee Centre, 621 Sneydes Road, Werribee, Victoria, 3030.
[4] Graduate School of Life and Environmental Science, University of Tsukuba, Ten-nodai 1-1-1, Tsukuba 305-8572 Japan

Blooms of *Nodularia spumigena*. occur worldwide, mostly in salty or brackish waters, and typically in estuaries and coastal lagoons. The Gippsland Lakes in the south-east of Victoria, Australia have a long history of blooms of *N. spumigena*, which in recent years have become more frequent and intense. The most recent blooms in the Gippsland Lakes have seen a ban on the harvesting of shellfish and prawns, and the sale and consumption of finfish unless skinned, deheaded and filleted. Public warnings about the recreational use of the lakes have reduced tourism and further impacted vulnerable commercial ventures. This has led to concern about the impact of the bans on the region and the imprecise nature of the monitoring process for blooms

N. spumigena produces toxins, specifically nodularin (a cyclic pentapeptide hepatotoxin similar in structure and activity to the hepatotoxin microcystin produced by the cyanobacterium *Microcystis spp*.), that present a hazard to human health. Nodularin may be accumulated in some aquatic organisms, such as mussels and prawns, and be transferred to higher trophic levels such as fish. As part of a human health risk assessment of the toxin nodularin in Victorian waters and the review of trigger values for safe levels in seafood we investigated the uptake and depuration of nodularin in black bream (*Acanthopagrus butcheri*) and eastern king prawns (*Melicertus plebejus*) under laboratory conditions to determine how nodularin is taken up and into which organs. The uptake and depuration data, and its incorporation into risk assessment models for nodularin, will be discussed.

Notes

Poster: Cyanobacteria Treatment by a Novel DAF Process

Russell KL Yap[1], Bruce Jefferson[2], Simon A Parsons[2] and Rita K Henderson[1]

[1]UNSW Water Research Centre, The University of New South Wales, Sydney
[2]Centre for Water Science, Cranfield University, Bedfordshire, UK

The application of dissolved air flotation (DAF) in the treatment of algae laden waters is a popular method as algae has a naturally low density. Prior to DAF, it is required that algae are coagulated in order to minimise the negative cell surface charge and produce larger particles (flocs). In the contact zone, negatively charged micro-bubbles collide and adhere to near neutral floc particles which then float to the surface where they can be removed. However, coagulation of algal cells can be difficult to achieve, thus reducing removal efficiency. An alternative solution is to modify the bubble surface as opposed to that of the algal cell, potentially removing the need for coagulation. Specifically, as algae have a negative surface potential, by producing positively charged bubbles, effective removal could be achieved without the need for pre-treatment.

In this research, lab cultured *Microcystis aeruginosa* cells were utilised for flotation jar tests. A number of chemicals of differing characteristics were trialled for the modification of bubble surfaces. This was achieved by dosing varying concentrations into the saturator of the bench scale DAF unit. No pre-treatment was utilised. Removal efficiency was determined by cell counting and turbidity. Residual zeta potential was also monitored to ascertain the degree of chemical-particle interaction.

It was found that when bubbles were modified with polyDADMAC, highly effective clarification of *M. aeruginosa* was achieved. Under optimised conditions, removal efficiency was comparable with or exceeded that achieved when using conventional coagulation-DAF. In contrast, when using a metal coagulant as a bubble modifier, poor removal was achieved (1). Inefficient removal was also observed when utilising other algal species – *Chlorella vulgaris* and *Asterionella formosa*. This was attributed to differing cell character (2).

In continuation of this study, novel chemicals are being synthesised to enhance this adaptation with the aim of enabling the treatment of a much wider range of algal species. Pilot plant trials will be conducted in field locations. With success, the implementation of bubble modification could reduce or eliminate the use of flocculators while enabling the effective treatment of elevated concentrations of algae.

1. Henderson, R.K., Parsons, S.A., and Jefferson, B., *The potential for using bubble modification chemicals in dissolved air flotation for algae removal.* Separation Science and Technology, 2009. **44**(9): p. 1923-1940.
2. Henderson, R.K., Parsons, S.A., and Jefferson, B., *Polymers as bubble surface modifiers in the flotation of algae.* Environmental Technology, 2010. **31**(7): p. 781 - 790.

Poster: Phylogeny and toxicology of *Lyngbya wollei* (Cyanobacteria/Oscillatoriales) from north-eastern Australia

Barbara C Sendall[1], Glenn B McGregor[2]

[1]Queensland Health Forensic and Scientific Services, 39 Kessels Road, Coopers Plains Qld 4108
[2]Environment and Resource Sciences, Queensland Department of Environment and Resource Management, 120 Meiers Road, Indooroopilly Qld 4068. glenn.mcgregor@derm.qld.gov.au

Lyngbya wollei (Farlow ex Gomont) Speziale and Dyck is a benthic filamentous cyanobacterium which inhabits freshwater riverine habitats. To date two populations from south-east Queensland (Australia) have been putatively identified and found to produce the potent cyanotoxin cylindrospermopsin (CYN) and its analogue, deoxy-cylindrospermopsin (deoxy-CYN). *L. wollei* is also a known producer of the potent neurotoxic saxitoxins in the southern United States. There it is regarded as a nuisance weed organism forming massive infestations of both benthic and free-floating mats in shallow lakes and reservoirs.

To further investigate the phylogeny and toxicology of CYN and deoxy-CYN producing *L. wollei*, axenic strains were isolated from two Australian sites; a riverine site in south-east Queensland and a reservoir in central Queensland. To examine the mechanisms of CYN and deoxy-CYN production we sequenced a fragment of a *pks* gene involved in cylindrospermopsin biosynthesis. The PCR primers commonly utilised to amplify the *cyrC pks* gene from the Nostoclean-CYN producing cyanobacteria *Cylindrospermopsis raciborskii* and *Aphanizomenon ovalisporum* did not amplify the target gene from *L. wollei.* Instead, degenerate *pks* primers were used to amplify a *pks* gene from *L. wollei,* and species-specific *pks* primers designed from the PCR amplicon. The *pks* gene was successfully sequenced from the two strains of *L. wollei* and found to be invariant. The sequence of this gene showed a high level of similarity to the *cyrF pks* gene which is putatively involved in CYN biosynthesis. To confirm the identification and phylogenetic relatedness of the two Australian strains to other toxigenic *Lyngbya* species we analysed partial sequences of the 16S rRNA and *nifH* genes and the phycocyanin-intergenic spacer (cpcß-cpcα IGS).

The two Australian strains of *L. wollei* were almost identical in their 16s rRNA gene sequence and shared 96% sequence identity with a strain of *L. wollei* from Alabama that produces saxitoxins.

Poster: Effects of alkalinity and pH on the growth rate of *Cylindrospermopsis raciborskii*

Daryl P. Holland[1], Amanda Pantorno[1], Slobodanka Stojkovic[1], Philip T. Orr[1,2], John Beardall[1]

[1]Monash University, School of Biological Sciences, Clayton, VIC, 3800
[2]Seqwater, PO Box 16146 City East, Qld 4002

Blooms of the toxic cyanobacterium *Cylindrospermopsis raciborskii* (Woloszyńska) Seenya *et* Subba Raju are a frequent occurrence in many drinking water reservoirs around the world. Changing land and water use, and increasing atmospheric CO_2 and temperature associated with climate change can affect the availability of free-CO_2 and HCO_3^- (bicarbonate) for photosynthesis in those systems, and this can drive changes in phytoplankton dynamics.

The growth rate of a Queensland strain of *C. raciborskii* grown under different alkalinity and pH conditions was determined in two experiments: 1. Sealed batch cultures grown under low light (20 µmol photons $m^{-2}\,s^{-1}$); and 2. Continuous cultures (turbidostats), bubbled with air and grown under high light (100 µmol photons $m^{-2}\,s^{-1}$). Overall growth rates were considerably higher at high light compared with low; the maximum doubling time was 1 day and 5 days respectively. At low light, growth rates were positively correlated with free-CO_2 and negatively correlated with HCO_3^- concentrations, whereas at high light the opposite occurred. In both experiments growth continued when the pH was > 9 where no free-CO_2 is present.

These results suggest that *C. raciborskii* utilises both free-CO_2 and HCO_3^- as sources of dissolved inorganic carbon for photosynthesis but that the energy dependent carbon concentrating mechanism (CCM) necessary for efficient DIC usage appears not to function effectively at low light.

Poster – A field based comparison of toxin-producing *Aphanizomenon ovalisporum* and *Cylindrospermopsis raciborskii* as they approach overwintering

Sally Everson, Tweed Shire Council, Murwillumbah, NSW.

Two toxin-producing algae (*Aphanizomenon ovalisporum* and *Cylindrospermopsis raciborskii*) were studied as they approached an overwintering phase in Cobaki Lake (New South Wales, Australia). Each species was examined with respect to growth of specialised cells (heterocytes and akinetes), toxin production and the accompanying seasonal dynamics of the water body. Environmental conditions were linked with different behaviour in each species. Both *A. ovalisporum* and *C. raciborskii* produced specialised cells during the bloom, but quite different dynamics featured in each species. As the water chemistry changed, *A. ovalisporum* produced akinetes before experiencing a rapid decline in cell numbers. In contrast, *C. raciborskii* continued to bloom without producing detectable akinetes. Peak *C. raciborskii* cell concentrations (83,160 cells mL^{-1}) occurred in the late autumn, when surface water temperatures were 19.1 ˚C, and were accompanied by toxin concentrations exceeding 100 µg L^{-1}. This field study provides evidence that *C. raciborskii*, despite being traditionally considered as a tropical species, can be highly toxic in cooler waters. These data support laboratory studies showing that *C. raciborskii* produces optimal toxin production in cooler temperatures such as subtropical environments. This has serious implications for both water quality and human health risks in those subtropical climates where *C. raciborskii* is present.

Everson SR, Fabbro LD, Kinnear SG, Wright PJ, submitted 2010. A Field based comparison of toxin-producing *Aphanizomenon ovalisporum* and *Cylindrospermopsis raciborskii* as they approach overwintering. *Harmful Algae*.

Poster: Blue-green Algae web based BGA notification system

Louisa C Davis[1] and Louise Sullivan[1]

[1]Department of Sustainability and Environment, Water Industry Division, East Melbourne, VIC, 3002

The Department of Sustainability and Environment coordinates the management framework for Blue-green algae in Victoria. A large number of organisations, including Water Corporations, Councils, Catchment Management Authorities, Parks Victoria and private organisations notify DSE when blue-green algae levels in water become elevated.

The data provided by these organisations used to be sent via fax or email and then entered into a database by DSE. This had a number of disadvantages, including double handling of data, the format made the data difficult to analyse and the organisations that submitted the data couldn't check or use the database.

The DSE has addressed these issues by developing a web-based notification system for Blue-green algae. This system allows water managers to enter information on blooms via a secure website. The information on previous blooms is also stored on the website, to allow for analysis of the bloom data. Some examples of the functionality of the system are illustrated.

Poster: An introduction to new, cost effective satellite imaging technology for detection of cyanobacteria blooms, Chlorophyll-a, *E. Coli*, total vegetation coverage and septic leakage in inland waters

Scott Tucker, Clearwater Lakes and Ponds Pty Ltd.

An introduction to new satellite imaging technology used to detect the presence, location, and concentration (down to parts per billion) of early Cyanobacteria blooms in the world's lakes, streams, rivers, ponds, and reservoirs.

Early detection lowers chemical treatment costs and reduces damage to the water body. Satellite imaging can efficiently provide numerous data points as compared to conventional sampling methodology and as such is low cost by comparison. This technology has been ground truthed based on grants from NASA and NOAA in the US. Satellite imaging is key to improving the safety and quality of the world's drinking water supply and recreational use waters because it enables water body managers to view the status of the entire water body as opposed to point samples. This technology can also detect total Phosphorus on land and in water, Ch-a, *E. Coli*, total vegetation coverage, and septic leakage. Images have been archived since 1982, as such; a historical perspective of a water body can be obtained for trend analysis.

Poster: New Zealand new! - New Zealand's toxic cyanobacterial research and management

AgResearch	Dr Rex Munday
Cawthron	Dr Patrick Holland, Dr Lesley Rhodes, Dr Susie Wood, Andy Selwood, Lincoln Mackenzie
ESR	Dr Wendy Williamson
NIWA	Dr Ngaire Philips, Dr Sue Clearwater, Dr Mary de Winton, Karl Safi
University of Canterbury	Francine Smith, Dr Paul Broady, Dr Sally Gaw
Waikato University	Wendy Paul, Dr Andreas Rueckert, Prof David Hamilton, Prof Craig Cary
Victoria University	Mark Heath, Dr Ken Ryan

Over the past four-years targeted research programmes and reactive responses to animal and human poisonings have resulted in significant advancements in knowledge on New Zealand's toxin producing cyanobacterial species. Highlights have included; the identification of new toxin-producing species, new data on their spatial and temporal distribution, and the identification of variables linked to the regulation of toxin production. These data provided the basis for the development of national guidelines for managing toxic cyanobacteria in recreational water. This poster documents some of our recent toxic cyanobacterial research and management advancements and recognises the contribution of multiple New Zealand research organisations.

Highlights;

- Guidelines for managing toxic cyanobacteria in recreational waters released November 2009.
- Establishment and cryopreservation of a New Zealand cyanobacterial culture collection containing >100 strains. The collection includes corresponding genetic and toxin data.
- Identification of new toxin producers including internationally novel; saxitoxin, anatoxin-a and microcystin producers and a freshwater (non-*Nodularia* sp.) nodularin producer.
- Development of molecular tools for tracking toxin producing species and investigating cyanotoxin production.
- Demonstration that microcystin production is not constant during a *Microcystis* bloom.
- Detailed knowledge on spatial and temporal variability in anatoxin production in benthic species.
- New insights on the regulation of anatoxin-a production in benthic cyanobacteria.
- Effect of microcystins on the health of native freshwater mussels and crayfish, and development of toxicity thresholds.
- Development of SPATT for monitoring cyanotoxins.

Poster: Lake Hume integrated water quality, cyanobacteria presence/absence, physico-chemical and bathymetry simultaneous data capture pilot project

Kris Kleeman and Mark Vanner MDBA GPO Box 1801, Canberra, ACT
David Steer and Tristian Richter Sentinel Pty Ltd, Gladstone St, Fyshwick, ACT 2609

The risk of cyanobacterial blooms in Lake Hume increases as the storage levels decrease during the December to April period. Previous Lake Hume integrated water quality studies have recommended that increased monitoring should be implemented during periods of low storage levels. The project objective is to develop a method for the identification of 'Hotspots' and will be used to evaluate management options for the improved water quality monitoring in Lake Hume.

This pilot was an investigation into the viability of emerging technologies for the simultaneous data capture of bathymetry, water quality, and the presence and absence of cyanobacteria in a major water storage and in river channel downstream.

The pilot study used a remote controlled drone water craft, fitted with a Dual band echo sounder (bathymetry data capture), a Hydrolab MS5 (electrical conductivity, pH, turbidity, temperature) and Turner Cyclops-7 Fluorometer (presence / absence of cyanobacteria concentrations). The depth of the Hydro Lab and Flurometer sensor is directly dependant on the speed of the water craft. The reliability of data collection for the cyanobacteria presence or absence will have to be calibrated with sub samples. It is intended that this technology and methodology will be used to map the geomorphic and water quality parameters collected in a single spatial and temporal representation for subsequent cyanobacterial hotspots and water resource management.

The pilot study has proved the usefulness of the data collection methodology. The outputs of this study have been represented as thematic raster surfaces using a colour ramp to highlight the trends across the survey areas. The findings have confirmed the feasibility of the research methodology and the end result has been the production of an accurate spatial representation of cyanobacterial concentrations; geomorphic variation of the study areas and physical-chemical parameters collected.

Poster: Inter-Agency Response to the 2010 Cyanobacterial Bloom in the Murray River

Kris Kleeman[1], Mark Vanner[1], Chester Merrick[2] and Lee Bowling[3]

1. Murray Darling Basin Authority, GPO Box 1801, Canberra, Australian Capital Territory 2601
2. Office of Water, NSW Department of Environment, Climate Change and Water, PO Box 829, Albury, New South Wales, 2640, Australia
3. Office of Water, NSW Department of Environment, Climate Change and Water, PO Box 3720, Parramatta, New South Wales, 2124.

In early 2010, there was an extensive Cyanobacterial Bloom along the Murray River leading up to and including the Easter holiday period. The cyanobacterial bloom was most severe in the Murray River between Lake Hume and Echuca/Moama. It was first detected within Lakes Hume and Mulwala, and the section of river joining these two lakes, from sampling on 8th and 10th February, and subsequently spread downstream to Echuca/Moama by mid February.

The bloom extended down the Murray River from Echuca to just downstream of Mildura; however the bloom in this part of the river was much more ephemeral, persisting for less than a week at most locations. Weekly Blue-Green Algal alerts mapping suggested that the bloom was moving progressively downstream.

The bloom was dominated by *Anabaena circinalis*, which contributed between 85 and 98% of the total cyanobacterial biovolume at most locations at the onset of the bloom. The identity of this species was confirmed by full sequence 16S ribosomal PCR undertaken by the University of New South Wales. Although *Anabaena circinalis* was the dominant species, increasing amounts of *Microcystis aeruginosa*, *Microcystis flos-aquae*, *Cylindrospermopsis raciborskii* and non-toxic cyanobacterial species began to appear as the bloom declined. Toxicity and toxigenicity testing showed that toxin concentrations were always below detection in all samples tested, although the bloom displayed the genetic potential to produce saxitoxins, microcystins and cylindrospermopsin.

Inter-agency response to the bloom conducted by the Murray and Sunraysia Regional Algal Coordinating Committees (RACCS) was comprised of representatives from New South Wales, Victorian and Commonwealth agencies and other stakeholders. Activities in response to the bloom included coordinated increased monitoring & media releases, aerial imagery surveillance to determine the extent of the bloom and a bathymetric investigation into mapping the build-up of cyanobacterial biomass in Lake Hume.

These management activities will help agencies better understand the conditions leading to the formation of algal blooms and to better manage for these events in the future. Being able to predict in advance the build-up of cyanobacterial biomass in the upper Murray will allow a more pre-emptive coordinated agency response. The management objective is to mitigate or reduce the extent of cyanobacterial blooms in order to reduce the negative environmental, social & economic impacts associated with system-wide cyanobacterial blooms in the River Murray.

Poster: Treating algal taste & ODOURS - Learning the hard way

Brigid Creasey, Barwon Region Water Corporation
Email: brigid.creasey@barwonwater.vic.gov.au

Situated along the Great Ocean Road in Victoria, the Aireys Inlet Water Supply System supplies the townships of Aireys Inlet and Fairhaven. The self contained system is supplied from the 410 ML Painkalac Reservoir. In recent years, the Reservoir has suffered the effect of drought and low storage levels which has led to the emergence of algal blooms. In order to combat the development of blooms a range of control measures were implemented, including the installation of a Solar Bee unit, to provide circulation and destratify the reservoir.

Raw water from the Painkalac Reservoir is treated to potable standard at the Aireys Inlet Water Treatment Plant (WTP) which consists of MIEX pre-treatment followed by conventional treatment. During a previous outbreak the WTP was taken offline for extensive testing to confirm that the WTP was capable of removing algal toxins. During the test, treated water from nearby Anglesea was carted to residents as a precautionary measure.

Despite the implementation of several reservoir control measures, an algal bloom of *Anabaena circinalis* and *Microcystis* emerged in early 2010. Confident that the WTP was capable of removing algal toxins, the plant continued to supply residents. It was quickly recognised that taste and odours associated with the bloom were contributing a noticeable reduction in aesthetic quality. As such, the previously developed contingency plans were invoked and a Powdered Activated Carbon (PAC) dosing system was deployed.

Like many coastal communities in the peak of summer, the populations of Aireys Inlet and Fairhaven swell to several thousand. As such, a corresponding influx of taste and odour complaints was observed. This appeared to be a consequence of the brief time delay between identification of the problem and implementation of PAC system. A short time after implementation the complaints ceased.

A few weeks later, a fault with the PAC dosing system resulted in a single plant run whereby PAC was not appropriately dosed. The rapid deployment of the system did not leave sufficient time to organise the usual alarms to alert minor faults. Treated water from this plant run combined with approximately two weeks of supply in the clear water storage. The plant fault only lasted for a matter of hours; however, the consequences of the fault impacted customers for a fortnight.

It is recognised that only small concentrations of these compounds can impart significant taste and odours to the water supply. The learning gained from this experience is that even small faults or reductions in performance of PAC systems can have significant impacts on the quality of the water supplied to customers. Of particular note is that, depending on the supply system, even small traces of the offending algal metabolites may take considerable time to be removed from the reticulation system.

Poster: Assessment of the socio-economic impacts of Murray River algal blooms

Graham Carter, Brinta Nandy and Christine Hill
Socio-economics team, NSW Office of Water

The 2009 and 2010 algal blooms which affected the Murray River and tributaries from Lake Hume through to Euston have caused significant community concern. Substantial government (Federal, State and Local), private business and community resources have been invested to better prepare and co-ordinate management responses to these blooms. The social and economic impacts from these blooms, however, remain largely unquantified. To address this information gap the NSW Office of Water is currently undertaking a study to assess the socio-economic costs of these recent Murray River algal blooms.

The study has been divided into two stages. The first stage involves the social profiling and development of the data collection and assessment methodology. The second stage will involve the socio-economic impact data collection and assessment. The study is being designed to ensure that the data collected are representative of the geographic diversity of the Murray valley- Albury through to Mildura (and possibly Euston) and the wider areas from which tourist visits are sourced.

Stage one, which completed in June 2010 involved -

- Literature review of recent algal bloom cost impact studies and a media review to consider local, regional and national media reports on the blooms;
- Profiling of major impact sectors in the Murray River region, which will provide an outline of the regional distribution of water users, industries and impacts;
- Assessment of the geographical distribution of socio-economic impacts and confirmation of proposed study area boundaries;
- Development of the data collection methodology and draft survey design for Stage 2. This will provide recommendations on data collection and on case studies or use of data extrapolation methodology to ensure most cost effective and representative data sets are collected.

The second stage of the study is proposed to be completed by late 2010. The NSW Office of Water is also seeking involvement from collaborative partners to contribute to the completion of Stage Two.

For further information about the project contact:

Graham Carter, NSW Office of Water graham.carter@water.gov.au ph (02) 6701 9641

Poster: Phoslock®: an Australian developed product that is used globally to significantly reduce phosphorus and improve water quality

Phoslock Water Solutions Limited

Increasing concentrations of nutrients and the proliferation of algal growth (particularly toxin producing blue-green algae) is a common problem for many water body managers around the world. Blue-green algae utilise atmospheric nitrogen and therefore have a near unlimited supply; this is not the case with phosphate. Blue-green algae (BGA) are only able to acquire phosphate for metabolism from dissolved phosphorus in the water column. By significantly reducing the concentration of phosphate in the water body, there is a reduction in the concentration of algae, and the dominance of BGA.

Phoslock® is a modified bentonite clay that was developed in Australia by the Commonwealth Scientific Industrial and Research Organisation (CSIRO). Phoslock® permanently locks up bioavailable phosphorus (known as orthophosphate, FRP or SRP) from a water body into its matrix that then resides as a highly insoluble mineral in the sediment.

The benefits of phosphate reduction are:

- management of toxin producing blue-green algae
- dominance of natural, more stable microalgae
- eradication of “off-flavour” issues in drinking water or aquaculture species
- reduction of stress/disease to aquatic organisms due to improved water quality
- reduction in BGA leading to an increase in water clarity and re-establishment of macrophytes (restoring natural balance and ecosystem)

Chemical algicides are not suited to all water bodies as they may detrimentally affect aquatic species. In addition, when algal cells decompose, the phosphorus stored in the cells is released into the water. The released phosphorus is available to fuel new algal generations; enabling the algal cycle to continue. As the name suggests, Phoslock® adsorbs phosphate and locks it in its structure without release. Currently, other than Phoslock®, there are no non-toxic, sustainable tools to control blue-green algae in water bodies.

PWS is an Australian public company listed on the Australian Stock Exchange (ASX). We distribute Phoslock® globally through licensees and distributors to control phosphate and manage algal blooms in a variety of water bodies. Phoslock® has been applied to water bodies in over 20 countries ranging from: aquaculture ponds; community and recreational lakes; large drinking water reservoirs; and slow moving rivers. For more information about Phoslock®, please visit our website: www.phoslock.com.au .

Poster: Toxigenicity of a 1100 km long cyanobacterial bloom in the Murray River, Australia

Jamal Al-Tebrineh[1], Chester Merrick[2], Brett Neilan[1, 3], Andrew Humpage[4] and Lee Bowling[3,5]
1. School of Biotechnology and Biomolecular Sciences, University of New South Wales, Sydney, New South Wales, 2052, Australia
2. Office of Water, NSW Department of Environment, Climate Change and Water, PO Box 829, Albury, New South Wales, 2640, Australia
3. Australian Wetlands and Rivers Centre, University of New South Wales, Sydney, New South Wales, 2052, Australia
4. Australian Water Quality Centre, GPO Box 1751, Adelaide, South Australia, 5001
5. Office of Water, NSW Department of Environment, Climate Change and Water, PO Box 3720, Parramatta, New South Wales, 2124, Australia.

Cyanobacterial blooms in freshwater bodies are potential health hazards due to their production of several potent toxins. The major freshwater cyanotoxins include the hepatotoxic microcystins and nodularin, the neurotoxic saxitoxins and the cytotoxic cylindrospermopsin. There is an urgent need for a sensitive, reliable and specific method for the detection of toxin-producing cyanobacterial species.

A multiplex quantitative-PCR was developed based on the design of novel oligonucleotide primers and fluorescent TaqMan probes. The primers and TaqMan probes target conserved regions within specific toxin genes in strains that were selected as representatives of the global population of toxic cyanobacteria. The method is able to determine the major cyanotoxins present in environmental and cultured samples, based on the copy number of saxitoxin, microcystin, nodularin and cylindrospermopsin genes, all in a single reaction.

This is the first time these cyanotoxin genes have been amplified in one multiplex quantitative-PCR from globally isolated cyanobacterial strains, blooms, and sediments. Additionally, this method was also able to infer potential toxigenicity of samples, based on maximum toxin production rates. Following optimisation using isolated cyanobacterial strains the multiplex qPCR method was applied to water samples collected from different locations along a 1100 km bloom on the Murray River, Australia (March-May, 2009). This bloom comprised a mixed community of potentially toxic taxa, including *Anabaena circinalis*, *Microcystis aeruginosa* and *Cylindrospermopsis raciborskii*. The concentration of cyanotoxins measured via ELISA correlated positively with the individual cyanobacterial toxin gene copy number detected by qPCR, indicating that the latter can be used as a measure of potential toxigenicity in cyanobacterial blooms.

This is the first time, to our knowledge, that a mixed cyanobacterial community capable of producing all three toxins together has been reported.

Poster: Cyanobacterial blooms in New South Wales during the 2009-2010 spring, summer and autumn bloom period

Lee Bowling[1] and Chester Merrick[2]

1. NSW Office of Water, Department of Environment, Climate Change and Water, PO Box 3720, Parramatta, 2124, NSW
2. NSW Office of Water, Department of Environment, Climate Change and Water, 512 Dean Street, Albury, 2640, NSW

Cyanobacterial blooms were once again a feature of many inland freshwaters within NSW during late 2009 and the summer and autumn of 2010. The most notable problems blooms were:-

- A bloom composed mainly of *Anabaena circinalis* that impacted much of the Murray River from Lake Hume to Mildura in February and March 2010. The bloom also impacted associated water bodies in NSW, including the Mulwala Main Channel, Gulpa Creek, the Edward River and parts of the Wakool River. Although analysis by PCR indicated that the bloom had a capacity to produce toxins, toxicity testing results were all below the level of detection.
- A bloom that impacted the Olympic rowing lake and warm-up lake at the International Regatta Centre in Penrith in February and March 2010. The lakes had to be closed for a number of recreational activities during this period.
- Prolonged blooms occurred in several of the larger headwaters storages providing water for several catchment areas within the Murray Darling Basin – notably Pindari, Copeton and Windamere reservoirs. Blooms of shorter duration also occurred in Chaffey, Burrendong and Wyangala Reservoirs.
- Prolonged blooms in small water bodies impacted by urban development within the lower Hunter and in the Hawkesbury-Nepean catchments.
- A prolonged bloom in Wiangaree Lagoon in the Richmond River catchment near Kyogle

Summer and autumn rainfall in southern Queensland led to good river flows throughout the Darling River, greatly reducing the likelihood of blooms in that river.

2nd National Cyanobacteria Workshop Attendees

Mr Dave Addis
Hazelwood Power
PO Box 195, Morwell, Vic 3840
dave.addis@hazelwoodpower.com

Mrs Pradeepa Adihetty
Dept of Sustainability & Environment, Victoria
8 Nicholson St, East Melbourne, Vic 3002
Pradeepa.Adihetty@dse.vic.gov.au

Dr Michele Akeroyd
Water Quality Research Australia
L3/250 Victoria Square, Adelaide, SA, 5000
michele.akeroyd@wqra.com.au

Dr Peter Baker
Australian Water Quality Centre
250 Victoria Square, Adelaide, SA, 5000
peter.baker@sawater.com.au

Mr Chris Barry
Dept of Sustainability & Environment, Victoria
574 Main Street, Bairnsdale Vic 3875
Chris.Barry@dse.vic.gov.au

Ms Nina Bate
Centre for Environmental Science EPA Vic
Ernest Jones Drive, McLeod Vic 3085
Nina.Bate@epa.vic.gov.au

Mr Brett Beaumont
Westernport Water
2 Boys Home Rd, Newhaven Vic 3925
bbeaumont@westernportwater.com.au

Ms Karen Beirne
Department of Health and Families, NT
PO Box 40596, Casuarina NT 0811
Karen.Beirne@nt.gov.au

Ms Heather Bishop
National Health and Medical Research Council
16 Marcus Clarke Street, Civic, ACT, 2601
heather.bishop@nhmrc.gov.au

Dr Sophie Bourgues
Melbourne Water
100 Wellington Pde, East Melbourne, Vic, 3002
sophie.bourgues@melbournewater.com.au

Dr Lee Bowling
NSW Office of Water
PO Box 3720, Parramatta, NSW, 2124
lee.bowling@dnr.nsw.gov.au

Mr Nick Bray
Goulburn Valley Water
104-110 Fryers Street, Shepparton Vic 3632
nickb@gvwater.vic.gov.au

Mr Aden Broocker
Mansfield Shire Council
Private Bag 1000, Mansfield Vic 3724
Aden.Broocker@mansfield.vic.gov.au

Dr William Buchanan
Barwon Water
44 Lonsdale St, South Geelong Vic 3220
William.Buchanan@barwonwater.vic.gov.au

Dr Mike Burch
Australian Water Quality Centre
250 Victoria Square, Adelaide, SA, 5000
Mike.Burch@sawater.com.au

Dr Michelle Burford
Griffith University
Kessels Road, Nathan Qld 4111
m.burford@griffith.edu.au

Mr Dean Chambers
Westernport Water
2 Boys Home Rd, Newhaven Vic 3925
dchambers@westernportwater.com.au

Mr Brian Chatelier
South Gippsland water
14-18 Pioneer Street, Foster Vic 3960
bchatelier@sgwater.com.au

Dr Nagur Cherukuru
CSIRO Land and Water,
GPO Box 1666, Canberra, ACT 2601
nagur.cherukuru@csiro.au

Ms Brigid Creasey
Barwon Water
44 Lonsdale St, South Geelong Vic 3220
brigid.creasey@barwonwater.vic.gov.au

Dr Nicholas Crosbie
Melbourne Water
PO Box 4342, East Melbourne, Vic, 3001
nick.crosbie@melbournewater.com.au

Dr David Cunliffe
Department of Health, SA
PO Box 6, Rundle Mall, Adelaide, SA, 5000
david.cunliffe@health.sa.gov.au

Ms Vesna Cvjeticanin
National Health and Medical Research Council
16 Marcus Clarke Street, Civic ACT 2601
Vesna.Cvjeticanin@nhmrc.gov.au

Ms Olivia Daniels
Bldg 6/2.19 Central Queensland University
Rockhampton Qld 4701
o.daniels@cqu.edu.au

Dr Warren Davies
Deakin University, Geelong Campus
Pigdons Road, Waurn Ponds Vic 3215
Warren.davies@deakin.edu.au

Ms Louisa Davis
Dept of Sustainability & Environment, Victoria
8 Nicholson St, East Melbourne, Vic 3002
louisa.davis@dse.vic.gov.au

Dr Timothy Davis
Australian Rivers Institute, Griffith University
170 Kessels Road, Nathan Qld 4111
t.davis@griffith.edu.au

Ms Jennifer Dreyfus
Australian Water Quality Centre
250 Victoria Square, Adelaide SA 5000
Jennifer.Dreyfus@sawater.com.au

Mrs Suzanne Egan
Just Algae
306 Flagstaff Road, Lake Heights, NSW, 2502
suzanne.l.m@optusnet.com.au

Dr Kumar Eliezer
ALS Environmental (Water Resources Group)
22 Dalmore Drive, Scoresby Vic 3179
KEliezer@ecowise.com.au

Dr Raquel Esteban
Tasmanian Dept of Health and Human Services
L3/25 Argyle Street, Hobart Tas 7001
Raquel.Esteban@dhhs.tas.gov.au

Mrs Sally Everson
Tweed shire Council
PO Box 816, Murwillumbah NSW 2484
sallye@tweedlab.com.au

Assoc/Prof Larelle Fabbro
Central Queensland University
BLG 6, CQU, Rockhampton, Qld, 4702
l.fabbro@cqu.edu.au

Prof. Ian Falconer
University of Adelaide
44 Mirning Crescent, Aranda, ACT, 2614
ifalconer@netspeed.com.au

Dr Linhua Fan
RMIT University,
124 La Trobe St, Melbourne 3000
linhua.fan@rmit.edu.au

Mr Mark Ferguson
Grampians Wimmera Mallee Water
PO Box 481, Horsham Vic 3400
mark.ferguson@gwmwater.org.au

Mr Stephen Fisher
Westernport Water
2 Boys Home Road, Newhaven Vic 3925
sfisher@westernportwater.com.au

Dr David Fotheringham
Bestech Australia Pty Ltd
7/35 Taunton Drive, Cheltenham, Vic, 3192
dfotheringham@bestech.com.au

Dr Suzanne Froscio
Australian Water Quality Centre
250 Victoria Square, Adelaide SA 5000
Suzanne.Froscio@sawater.com.au

Ms Angela Gackle
Water Quality Research Australia
L3, 250 Victoria Square, Adelaide SA 5000
angela.gackle@wqra.com.au

Dr Anas Ghadouani
University of Western Australia
MO 15, 35 Stirling Highway, Crawley WA 6009
Anas.Ghadouani@uwa.edu.au

Mr Steve Giglio
Australian Water Quality Centre, SA Water
250 Victoria Square, Adelaide, SA, 5000
steven.giglio@sawater.com.au

Mr Yong Tee Goh
RMIT University
APT 907A/8 Franklin St, Melbourne Vic 3000
yongtee.goh@rmit.edu.au

Mr Bruce Gray
Dept of Environment, Water, Heritage and the Arts
GPO Box 787, Canberra ACT 2904
Bruce.Gray@environment.gov.au

Dr Sarah Groves
Phoslock Water Solutions Ltd
PO Box 105, Frenchs Forest, NSW, 1640
sgroves@phoslock.com.au

Dr David Halliwell
Water Quality Research Australia
PO Box 13172
Law Courts Office, Melbourne Vic 8010
david.halliwell@wqra.com.au

Dr Rita Henderson
UNSW Water Research Centre, University of New South Wales, H22, Kensington Campus, Kensington, NSW, 2052
r.henderson@unsw.edu.au

Dr Lionel Ho
Australian Water Quality Centre, SA Water
250 Victoria Square, Adelaide, SA, 5000
lionel.ho@sawater.com.au

Dr Daryl Holland
Monash University
Wellington Rd, Clayton Vic 3800
daryl.holland@monash.edu.au

Bianca Huider
Goulburn Murray Water
PO Box 165, Tatura Vic 3616
biancah@g-mwater.com.au

Dr Andrew Humpage
Australian Water Quality Centre
250 Victoria Square, Adelaide, SA, 5000
andrew.humpage@sawater.com.au

Prof Syed Hussainy
Victoria University
PO Box 14428, Melbourne Vic, 8001
syed.hussainy@vu.edu.au

Mr Victor James
Aquafilt Engineering Pty Ltd
20 Jefferson Crescent, Bonnet Bay NSW 2226
aquafilt@ozemail.com.au

Mr Stephen Jewell
Grampians Wimmera Mallee water
PO Box 481, Horsham Vic 3400
stephen.jewell@gwmwater.org.au

Mr Brian Jones
ACT Health – Health Protection Service
25 Mulley Street, Canberra ACT 2611
Brian.Jones@act.gov.au

Ms Sam Kelly
Department of Health, Victoria
64 Church Street, Traralgon Vic 3844
sam.kelly@health.vic.gov.au

Mr Kris Kleeman
Murray Darling Basin Authority
4/51 Allara Street, Canberra ACT 2601
Kris.Kleeman@mdba.gov.au

Dr Yoshi Kobayashi
NSW Dept of Environment, Climate Change and Water
PO Box A290, Sydney South, NSW, 1232
Yoshi.Kobayashi@environment.nsw.gov.au

Mr Jared Koutsoukos
Dept of Health WA, Grace Vaughan House
227 Stubbs Tce, Shenton Park WA 6008
Jared.Koutsoukos@health.wa.gov.au

Mr Brian Lawrence
Murray Darling Basin Authority
GPO Box 1801, Canberra ACT 2601
brian.lawrence@mdba.gov.au

Dr Margaret Leonard
ESR, PO Box 29-181, Christchurch NZ 8041
Margaret.Leonard@esr.cri.nz

Mr Lance Lloyd
Lloyd Environmental Pty Ltd
PO Box 3014, Syndal Vic 3149
lance@lloydenviro.com.au

Dr Daniel Mainville
Dept of Sustainability & Environment, Victoria
71 Hotham Street, Traralgon, Vic, 3844
daniel.mainville@dse.vic.gov.au

Dr Timothy Malthus
CSIRO Land and Water
GPO Box 1666 Canberra, ACT 2601
tim.malthus@csiro.au

Dr Glenn McGregor
Qld Dept of Env & Resource Management
120 Meiers Road, Indooroopilly, Qld, 4068
glenn.mcgregor@derm.qld.gov.au

Mrs Toni Menjivar
Queensland Health Forensic Scientific Services
39 Kessels road, Coopers Plains Qld 4108
Toni_Menjivar@health.qld.gov.au

Dr Chester Merrick
NSW Office of Water
PO Box 829, Albury, NSW, 2640
chester.merrick@dnr.nsw.gov.au

Mr Noel Miles
Melbourne Water
PO Box 512 Altona North, Vic, 3025
noel.miles@melbournewater.com.au

Dr Thorsten Mosisch
South Australian Water Corporation,
GPO Box 1751, Adelaide, SA, 5001
thorsten.mosisch@sawater.com.au

Ms Vanora Mulvenna
Department of Health, Victoria
GPO Box 4541, Melbourne Vic 3001
vanora.mulvenna@health.vic.gov.au

Mr Danny Murphy
Melbourne Water
PO Box 4342, Melbourne Vic 3001
Danny.Murphy@melbournewater.com.au

Mr Max Murphy
Department of Health, Victoria
74-78 Queen Street, Bendigo Vic 3550
max.murphy@health.vic.gov.au

Jennifer Muscat
Department of Health Victoria
GPO Box 4541, Melbourne Vic 3001
rodney.dedman@health.vic.gov.au

Dr Jackie Myers
University of Melbourne
3A Bellarine Hwy, Queenscliff Vic 3225
jhmyers@unimelb.edu.au

Prof Brett Neilan
University of New South Wales
L3/Bioscience Bldg, Sydney, NSW, 2052
b.neilan@unsw.edu.au

Mr Bruce Nelan
NSW Food Authority
PO Box 6682, Silverwater, NSW, 1811
bruce.nelan@foodauthority.nsw.gov.au

Dr Gayle Newcombe
Australian Water Quality Centre, SA Water
GPO Box 1751, Adelaide, SA, 5001
Gayle.Newcombe@sawater.com.au

Ms Duyen Nguyen
Australian Laboratory Services Pty Ltd
32 Shand Street, Brisbane Qld 4053
duyen.nguyen@als.com.au

Dr Thang Nguyen
RMIT University
LaTrobe St, Melbourne Vic 3001
thang.nguyen@rmit.edu.au

Dr Dayanthi Nugegoda
RMIT University
PO Box 71, Bundoora, Victoria 3083
dayanthi.nugegoda@rmit.edu.au

Ms Suzanne Nuroo
Veolia
PO Box 1089 (Phillis St) Kangaroo Flat Vic 3555
suzanne.nuroo@veoliawater.com.au

Mr Glen O'Brien
ALS Environmental (Water Resources Group)
22 Dalmore Drive, Scoresby Vic 3179
Glen.O'Brien@alsglobal.com

Mr Anthony Ohlsen
Central Highlands Water
PO Box 152, Ballarat Vic 3353
Aohlsen@chw.net.au

Dr Phillip Orr
South East Queensland Water
PO Box 16146, City East Qld 4002
porr@seqwater.com.au

Dr Andrea Paparini
Murdoch University
90 South Street, Murdoch WA 6150
A.Paparini@murdoch.edu.au

Ms Wendy Paul
University of Waikato
Private bag 3105, Hamilton NZ 3240
wpaul@waikato.ac.nz

Mr Siraj Perera
Dept of Sustainability & Environment, Victoria
8 Nicholson St, East Melbourne Vic 3002
siraj.perera@dse.vic.gov.au

Mrs Lian Potter
Ministry for the Environment, New Zealand
PO Box 10362, Wellington NZ 6143
Lian.Potter@mfe.govt.nz

Ms Pauline Porter
Southern Grampians Shire
1 Marke Pl (Locked Bag 685) Hamilton Vic 3300
pporter@sthgrampians.vic.gov.au

Ms Feng Qian
Dept Chem & Biomol Engineering (Bldg 167)
University of Melbourne, Melbourne Vic 3010
fqian@unimelb.edu.au

Mr Charan Ramen
Sydney Catchment Authority
L5/2-6 Station Rd, Penrith NSW 2750
ramen.charan@sca.nsw.gov.au

Mr Ravi Raveendran
South Gippsland Water
14-18 Pioneer St, Foster Vic 3960
ravi@sgwater.com.au

Dr Elke Reichwaldt
University of WA
MO 15, 35 Stirling Highway, Crawley WA 6009
Elke.Reichwaldt@uwa.edu.au

Dr Tarren Reitsema
Department of Water WA
L4/256 Adelaide Tce, Perth WA 6000
Tarren.Reitsema@water.wa.gov.au

Mr Luc Richard
Department of Health, Victoria
GPO Box 4541, Melbourne, Vic, 3001
luc.richard@health.vic.gov.au

Ms Kirsty Robertson
Sydney Water Corporation
51 Hermitage Road, West Ryde, NSW, 2114
kirsty.robertson@sydneywater.com.au

Prof Felicity Roddick
RMIT University
GPO Box 2476, Melbourne, Vic, 3001
felicity.roddick@rmit.edu.au

Mr Gareth Roeszler
Water Quality Research Australia
L3/250 Victoria Square, Adelaide 5000
gareth.roeszler@wqra.com.au

Ms Amy Russell
Goulburn Murray Water
PO Box 165, Tatura, Vic, 3616
amyr@g-mwater.com.au

Mrs Natasha Ryan
NSW Office of Water,
PO Box 2213, Dangar, NSW, 2302
natasha.ryan@dnr.nsw.gov.au

Ms Sarah Salmons
South Gippsland Water
Begg Street, Leongatha Vic 3953
ssalmons@sgwater.com.au

Mr Jared Scott
Barwon Water
40-44 Lonsdale Street, South Geelong Vic 3220
Jared.Scott@barwonwater.vic.gov.au

Dr Barbara Sendall
Queensland Health
39 Kessels Road, Coopers Plains, Qld, 4108
Barbara_Sendall@health.qld.gov.au

Mr David Sheehan
Department of Health, Victoria
GPO Box 4541, Melbourne Vic 3001
david.sheehan@health.vic.gov.au

Dr Brad Sherman
CSIRO Land and Water
GPO Box 1666, Canberra, ACT, 2601
brad.sherman@csiro.au

Ms Karen Simonsen
ALS Environmental (Water Resources Group)
22 Dalmore Drive, Scoresby Vic 3179
Karen.Simonsen@alsglobal.com

Ms Erin Simpson
Goulburn Murray Water
PO Box 165, Tatura Vic 3616
erins@g-mwater.com.au

Mr Phillip Slessar
North Central Catchment Management Authority
628-634 Midland Hwy, Huntly Vic 3551
phillip.slessar@nccma.vic.gov.au

Mr Craig Smith
Southern Rural Water
1/307 Maroondah Hwy, Ringwood Vic 3134
craigs@srw.com.au

Mr Greg Smith
Goulburn-Murray Water
PO Box 165, Tatura, Vic, 3616
gregs@g-mwater.com.au

Ms Karen Stacey
North East Regional Water Authority
106 Hovell St, Wodonga, Vic, 3690
kstacey@nerwa.vic.gov.au

Ms Lisa Stephenson
ALS Environmental (Water Resources Group)
22 Dalmore Drive, Scoresby Vic 3179
Lisa.Stephenson@alsglobal.com

Dr Ian Stewart
Queensland Health
39 Kessels Road, Coopers Plains, Qld, 4108
ian.stewart@griffith.edu.au

Mr Peter Symes
Royal Botanic Gardens, Melbourne
Private Bag 2000, South Yarra Vic 3141
Peter.Symes@rbg.vic.gov.au

Mr Scott Tucker
Clearwater Lakes and Ponds
PO Box 219, Bundoora Vic 3083
scott@clearwaterlakesandponds.com.au

Mr Dick Van Den Bosch
Grampians Wimmera Mallee Water
PO Box 481, Horsham Vic 3400
Dick.VanDenBosch@gwmwater.org.au

Mr Mark Vanner
Murray Darling Basin Authority
4/51 Allara Street, Canberra ACT, 2601
mark.vanner@mdba.gov.au

Dr Bala Vigneswaran
Sydney Catchment Authority
2 - 6 Station Street, Penrith, NSW, 2750
bala.vigneswaran@sca.nsw.gov.au

Prof David Waite
University of New South Wales
School of Civil and Environmental Engineering, Sydney, NSW, 2052
d.waite@unsw.edu.au

Dr Kristina Wall
NSW Health, Water Unit,
PO Box 798, Gladesville, NSW, 1675
kristina.wall@doh.health.nsw.gov.au
Dr Andrew Watkinson
South East Queensland Water
240 Margaret St, Brisbane 4001
awatkinson@seqwater.com.au

Mr Jake Weir
Southern Rural Water
Suite1/307 Maroondah, Ringwood Vic 3134
JakeW@SRW.com.au

Ms Leanne Wells
Department of Health Victoria
GPO Box 4541, Melbourne Vic 3001
leanne.wells@health.vic.gov.au

Dr Wasa Wickramasinghe
University of Queensland, EnTox
39 Kessels Road, Coopers Plains Qld 4108
w.wickramasinghe@uq.edu.au

Mr Steve Wickson
Glenelg Hopkins Catchment Management
79 French Street, Hamilton Vic 3300
s.wickson@ghcma.vic.gov.au

Mr Greg Whorlow
Grampians Wimmera Mallee Water
PO Box 481, Horsham Vic 3400
Greg.Whorlow@gwmwater.org.au

Dr Susie Wood
Cawthron Institute
Private Bag 2, Nelson NZ 7042
Susie.Wood@cawthron.org.nz

Dr Paul Wright
Tweed Shire Council
PO Box 816, Murwillumbah, NSW 2484
paulw@tweedlab.com.au

Mr Russell Yap
University of New South Wales
11 Botany Road, Kensington NSW 2033
ryap@unsw.edu.au