Meeting the recycled water challenge for Sydney

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Sydney Water is seeking to maximise the delivery of recycled water meeting suitable standards for the intended use. The approach of health risk management through the 12 components of the national guidelines for water recycling is used in close consultation with the NSW Department of Health. Considerable effort is being put into demonstrating compliance with the guidelines when they are applied to specific recycling projects.

The recycling challenge

Sydney has very high quality surface water sources of drinking water. However, with a growing population, unpredictable rainfall, the impact of a prolonged drought and the potential impacts of climate change, these sources needed supplementing. The 2006 NSW Metropolitan Water Plan [1] sought to diversify the sources of water available in Sydney and at the same time to provide flows to maintain river health. The plan set an ambitious target for water recycling from sewage to save 70 billion litres ($70x10^9$ litres) of potable water by 2015 to be achieved through a diverse range of schemes covering domestic, industrial, irrigation and river replacement flows (Figure 1).

Implementing the Australian guidelines for recycled water

The *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* [2] (AGWR phase 1) were released in November 2006. Order of magnitude estimates of the efficacy of wastewater treatment processes required to meet health targets for a range of applications of recycled water were given, expressed as log-removal rates. Among others applications, the AGWR phase 1 covered large-scale treated sewage use for residential garden watering, car washing, toilet flushing, fire fighting and in industry. The *AGWR: Augmentation of Drinking Water Supplies* [3] (AGRW – ADWS) followed in May 2008. The latter expand on the principles and information provided in the phase 1 guidelines, including measured levels of pathogens in sewage and expected removal rates provided by a range of sewage treatment processes. The health-based targets for recycled water treatment guidelines have used quantitative microbial risk assessment (QMRA) to set targets for pathogen removal over the whole treatment train appropriate for the intended uses of the recycled water.

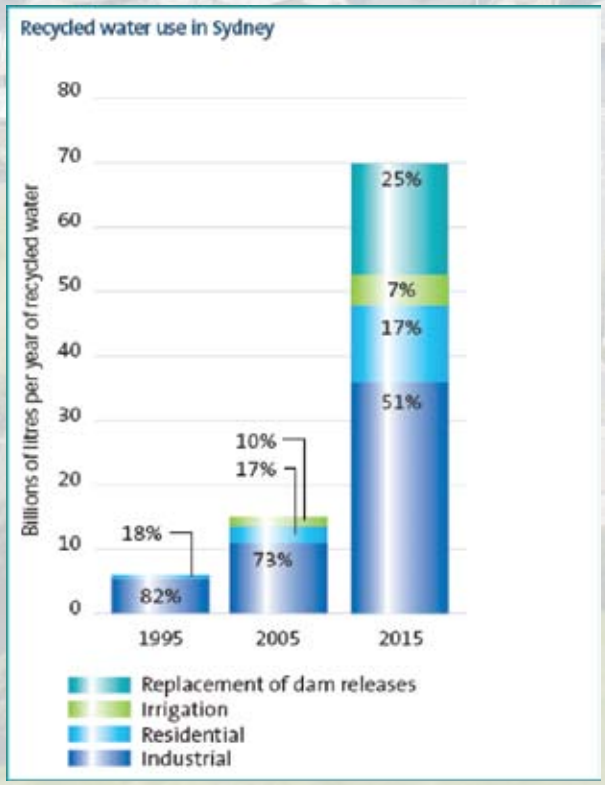

Figure 1. Sydney's recycled water targets for 2015 [1].

These Guidelines use the same 12 elements for managing water quality that are used in the *Australian Drinking Water Guidelines* (ADWG, 2004) and are based on international standard management systems. Some of the elements are:

- Management commitment to responsible use and management of recycled water.
- Supporting requirements that include research, validation of treatment barrier performance, documentation and reporting.
- Review, including verification monitoring and auditing.

Sydney Water is developing recycled water quality management plans to demonstrate that each recycling scheme is managed according to the guidelines. These are built on pre-existing ISO 9000 and ISO 14000 systems. Risk assessments are carried out for each scheme. Substantial contributors to risk are investigated. For example, pathogen presence and removal by treatment processes in place or proposed are validated, as is the extent of human exposure at the point of use. Sydney Water is also researching better understanding of the microbiological risks from recycled water.

Wollongong Stage 2 recycling implementation

Stage 2 of the recycled water scheme for the Wollongong sewage treatment plant (STP) will be the provision of recycled water to the Port Kembla coal terminal for dust suppression on the coal stockpiles. The coal terminal lies immediately south of the STP (Figure 2) and has historically used considerable amounts of potable water for this purpose (Figure 3). Secondary treated wastewater is supplied to the recycled water facility on the STP site (Figure 4).

Working with consultants from Water Futures, Sydney Water's Science and Technology staff undertook a QMRA using three model index pathogens – Campylobacter (bacterial index), rotavirus (viral index) and Cryptosporidium (protozoan index). Exposure was assessed through aerosol or ingestion for site workers and fire fighters.

A validation monitoring program using microbial surrogates *E. coli* (for bacteria such as *Campylobacter* spp.), MS-2 bacteriophage (for viruses including rotavirus) and *Clostridium perfringens* (for parasitic protozoa including *Cryptosporidium parvum*) was undertaken on primary, secondary and tertiary treatment processes at the Wollongong recycled water plant between December 2007 and April 2008 (n=17) (Table 1).

The QMRA undertaken for the (non-potable) use of recycled water at Wollongong Stage 2 did not identify any human health risks that exceeded the acceptable annual risk benchmark of 10^{-4} (1 infection per 10,000 persons *per annum).* A validation monitoring program demonstrated log reduction of pathogens

Figure 2. An aerial view of the Wollongong STP and the Port Kembla coal loading facility.

at the Wollongong Stage 2 recycled water plant exceeding those required in the 2006 *Australian Guidelines for Water Recycling* for industrial, municipal and fire fighting use, in most cases by many orders of magnitude. Values of 14.3 log reduction were achieved for bacteria (target 5.3), 9.3 log for viruses (target 6.5) and greater than 6.6 log reduction for protozoa (target 5.1), ensuring that recycled water was treated fit for its intended application in industry and irrigation as well as fire fighting.

The recycled water quality management plan for this scheme was endorsed by the NSW Health Department and approved prior to allow the data collection pre-commissioning for the scheme to commence on time in June 2008.

Figure 3. Water used for dust suppression.

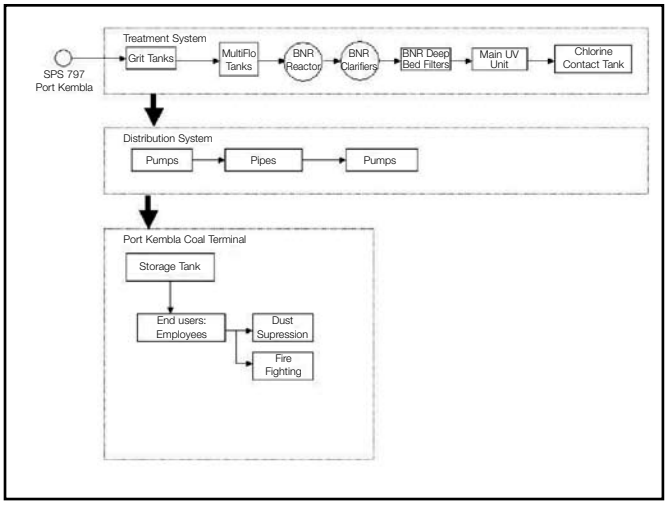

Figure 4. Schematic of treatment train and delivery of recycled water delivered to Port Kembla coal loading facility for dust suppression and fire fighting used to inform the quantitative microbial risk assessment. BNR – biological nutrient reduction.

Opportunistic pathogens in recycled water distribution system biofilms

Through the wastewater program of the Cooperative Research Centre for Water Quality and Treatment, a national survey of opportunistic pathogens in water delivery systems was undertaken [4] to better understand the risks they may pose and inform the operational management of recycling systems. Eight water utilities participated in the study, including Sydney Water, using seven drinking water and six recycled water systems as

Table 1. Log reduction rates obtained in the validation monitoring program and used in the risk assessment for the major pathogen groups (bacteria, virus and protozoa) in primary, secondary and tertiary treatment at Wollongong STP.

	Log (decimal) reduction		
	Bacteria	**Virus**	**Protozoa**
Primary/secondary			
Primary	0.25 (0-0.5)	0.05 (0-0.1)	0.25 (0-0.5)
Secondary	2.0 (1.0-3.0)	1.25 (0.5-2.0)	0.75 (0.5-1.0)
Tertiary			
Dual-media filtration	0.5 (0-1.0)	1.75 (0.5-3.0)	2.0 (1.5-2.5)
Chlorination	4.0 (2.0-6.0)	2.0 (1.0-3.0)	0.25 (0-0.5)
UV	3.0 (2.0-4.0)	> 3.0	> 3.0
Total (predicted)	**9.75**	**8.05**	**6.25**
Total (validated)	**14.3**	**9.3**	**>6.6**
Target [2]			
Municipal	4.0	5.2	3.7
Industrial	5.1	6.4	5.0
Fire fighting	5.3	6.5	5.1

study sites (Figure 5). With the exception of the Rouse Hill dual reticulation system, where water is designated for indirect human contact through toilet flushing, car washing and garden use, the recycling schemes used recycled water for industrial use as well as the irrigation of municipal landscape and recreational grounds. The University of New South Wales, CSIRO, the Australian Water Quality Centre and Sydney Water laboratories provided specialised research and analysis.

The study had three aims, namely to:

- Determine the incidence of opportunistic pathogens and faecal indicators and pathogens in potable and recycled water distribution systems.
- Undertake a preliminary (screening-level) qualitative risk assessment to estimate their significance within a water distribution system.
- Assess the efficacy of factors leading to their control and risk management.

Traditional faecal indicators *E. coli,* total coliforms and enterococci were quantified by standard methods for water testing in the recycled systems. Opportunistic pathogens tested for included *Acanthamoeba* spp., Aeromonads, Legionella, Mycobacteria and Pseudomonads. In addition to these organisms, the presence of Campylobacter (by culture) and Helicobacter (by PCR) were also assessed. Both water and pipe biofilms (Figure 6) were tested. To assess seasonal variability, samples were taken during a winter (June-August 2005) and a summer (January-March 2006) (Table 2). For each recycled water system investigated, an adjacent potable water distribution system was used to provide an estimate of relative risk between both systems.

In addition to the microbiological parameters, physical and chemical water quality parameters were also collected to assess their impact on the regrowth of bacteria in the water distribution systems. This information included the level of water treatment, age and condition of the distribution system, piping material, quantity and size distribution of particles, disinfectant type and concentration, nutrient concentration, pH, conductivity, temperature and hydraulic demand.

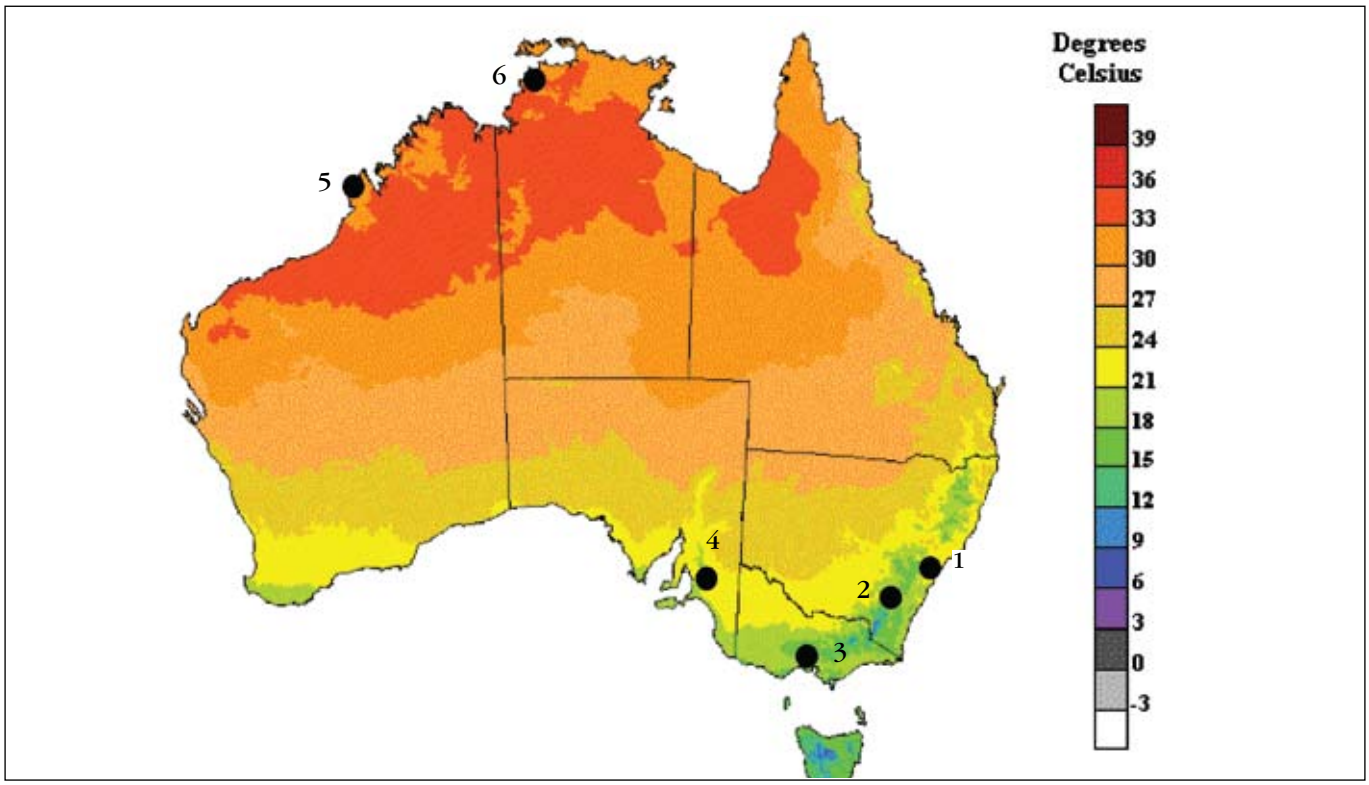

Figure 5. Project study recycled water scheme locations covered major climatic zones in Australia.
1. Rouse Hill Development Area, NSW (Sydney Water); 2. North Canberra Effluent Reuse Scheme, Fyshwick (ACTEW-AGL and Ecowise Environmental), ACT; 3. Eastern Treatment Plant, Carrum Downs (Melbourne Water), VIC; 4. Bolivar Recycled Water Plant (SA and United Water), SA; 5. Broome Recycled Water Scheme (Water Corporation), WA; 6. Darwin Recycled Water Scheme (Power and Water Corporation), NT. (Map courtesy of Australian Bureau of Meteorology).

Table 2. Incidence of opportunistic pathogens in recycled water distribution systems biofilms during summer (S: January – March 2006) and winter (W: June – August 2005) months.
1. North Canberra Water Reuse Scheme, ACT; 2. Rouse Hill Development Area, NSW; 3. Eastern Treatment Plant, VIC; 4. Bolivar STP, SA; 5. Broome Recycled Water Scheme, WA; 6. Darwin Recycled Water Scheme, NT. Results are expressed as colony forming units (cfu) in biofilms per square centimetre of pipe surface.

	1		2		3		4		5		6	
	S	W	S	W	S	W	S	W	S	W	S	W
Coliforms								NT				
E. coli								NT				
Enterococci								NT				
Somatic phage								NT				
F-RNA phage								NT				
Aeromonads								NT				
Pseudomonas								NT				
Legionellae								NT				
Burkholderia	NT	NT	NT	NT	NT	NT	NT	NT				
Campylobacter								NT				
Clostridia								NT				

NT – Not tested
<1000 cfu/cm²
Not detected
>1000 cf
<100 cfu/cm²

In this study, the water temperature, hydraulic demand and level of disinfectant residual were most correlated with the presence of opportunistic pathogens in recycled water systems. The detection of opportunistic pathogens in the environment is rarely associated with disease. The data obtained were used to perform a screening level (qualitative) microbial risk assessment for each scheme. Every scheme examined was shown to provide recycled water fit for purpose.

Acknowledgements

In addition to those groups mentioned in the article, the work described was carried out in close liaison with many groups in Sydney Water covering operations, planning and laboratory analysis.

Figure 6. Recycled water biofilm.

References

1. Metropolitan Water Directorate (2006) Metropolitan Water Plan, NSW Government.
2. The *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)* (2006) Environment Protection and Heritage Council, the Natural Resource Management Ministerial Council and the Australian Health Ministers' Conference.
3. *Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies* (2008) Environment Protection and Heritage Council, the National Health and Medical Research Council and the Natural Resource Management Ministerial Council.
4. Storey, M *et al.* (2008) Opportunistic pathogens in drinking and recycled water distribution systems *Water* 35, 38-45.

Peter Cox is currently Program Manager for Water Quality and Public Health in the Science and Technology group of Sydney Water's Sustainability Division. He has worked in water microbiology for 18 years for Sydney Water and the Sydney Catchment Authoring including periods in molecular microbiology methods development and project management.

Mark Angles and Michael Storey are microbiologists who are Project Managers in the Water Quality and Public Health team at Sydney Water. Both have extensive experience in microbial water quality and risk assessment. Mark managed a project in the Cooperative Research Centre for Water Quality and Treatment (CRC WQT) to assess nutrient impacts on biofilm development in drinking water distribution systems and has recently validated pathogen and water quality indicator removal in wastewater treatment process used to supply recycled water. Michael has previously worked with the Swedish Institute for Infectious Disease Control and CSIRO in the field of quantitative microbial risk assessment and microbial regrowth, and in particular with the legionellae. He currently advises Sydney Water on related matters, with particular emphasis on its recycled water schemes.