The safe use of recycled water

David Cunliffe

Department of Health
PO Box 6, Rundle Mall
Adelaide SA 5000
Tel (08) 8226 7153
Email david.cunliffe@health.sa.gov.au

Continued population growth, droughts and limited water storage capacity are placing ever increasing pressure on Australian water supplies. One of the responses to this pressure has been increased use of recycled water (Figure 1). However, increased use has to be balanced against protection of public health; the greatest risk is from enteric microorganisms. The separation of human drinking water supplies from wastewater has been the largest single contributor to improved population health in the developed world through reducing infectious disease and extending life expectancy [1, 2]. The new *Australian Guidelines for Water Recycling* (AGWR) [3] describe how recycled water schemes can be designed, operated and managed to ensure that they are safe. Reactive management based on end-point monitoring and using *E. coli* as a focus for assessing microbiological safety has been superseded by a preventive risk management approach.

Australian guidelines for water recycling

Limitations in guidance on safe and sustainable use were seen to be a significant barrier to the expanded use of recycled water [4, 5]. As a result, the development of new AGWR was commenced in late 2003. The first phase was published in 2006 and a second phase module on *Augmentation of Drinking Water Supplies* [6] was published in 2008. The second phase will be completed in early 2009. From a public health point of view, the major differences between the AGWR and previous guidelines include a focus on applying a risk management strategy to assure safety prior to use of recycled water. This is underpinned by a quantitative definition of microbial safety. The strategy includes methods for setting and meeting health-based targets for enteric bacteria, viruses and protozoa.

Figure 1. Signs indicating use of recycled water at Mawson Lakes.

Definition of safety

An essential first step is providing a quantifiable definition of safety. The guidelines do this using the metric of disability-adjusted life years (DALYs) to assess potential health impacts. An advantage of DALYs is that they recognise that not all pathogens are created equal, some only cause mild diarrhoea while others such as *E. coli* 0157 can cause more severe symptoms including haemolytic uraemic syndrome and death. DALYs reflect this variability by multiplying the frequency and severity of symptoms by duration to determine a burden of illness for individual pathogens. In the AGWR, safety is defined as being below a burden of 10^{-6} DALYs per person per year. This is equivalent to about one case of diarrhoea per 1000 people per year, which is well below the reported annual rate 0.8-0.92 cases of diarrhoea per person in Australia [7, 8].

Risk management

The definition of safety provides the goalposts that need to be achieved. The mechanism for meeting the goal is a risk management system. The guideline describes a purpose-designed system derived from the model included in the *Australian Drinking Water Guidelines* [9]. It incorporates hazard analysis and critical control point principles as well as features from other existing risk management systems.

At the heart of the system is risk assessment, identification of appropriate control measures and monitoring of those measures. For pathogens, quantitative microbial risk assessment (QMRA) is used to determine the likelihood of illness occurring from specific pathogens in sources of recycled water. This is then converted to health impacts using the DALY approach. It is not practical to do this for all pathogens, so Campylobacter, rotavirus and Cryptosporidium have been used as representatives of enteric bacteria, viruses and protozoa.

The guidelines provide default values for concentrations of pathogens in sewage and for exposures associated with typical end uses. Using QMRA, this enables calculation of reductions required to meet the goalpost of 10^{-6} DALYs per person per year (Table 1). These can be achieved by either reducing pathogen concentrations using treatment or by reducing exposure through mechanisms such as application controls (e.g. drip versus spray irrigation), applying buffer zones between points of use, and public access or crop restrictions (e.g. irrigation of fruit trees rather than lettuce).

Table 1. Log reductions for the safe use of treated sewage.

End-use	Exposure (L p.a.)	Required log reductions Viruses	Cryptosporidium & Campylobacter
Dual reticulation (toilet flushing, gardens)	0.67	6.5	5
Food crops	0.49	6	5
Irrigation of parks	0.05	5	4
Drinking water augmentation	700	9.5	8

Table 2. Achieving required virus reduction for irrigation of parks with treated sewage.

Log reduction required	Exposure reduction	Log reduction	Treatment	Log reduction
5			Secondary treatment Filtration Disinfection	5-6
5	No access Buffer zones Spray drift control	2 1 1	Secondary treatment Filtration Disinfection	2-3

The guidelines describe typical reductions achieved by various types of treatment and exposure controls. Table 2 demonstrates how both types of control can be applied to achieve virus log reductions required for safe irrigation of parks. This dual approach means that even sewage with relatively low levels of treatment can be used safely, provided appropriate end-use or on-site restrictions are applied. However, high exposure uses such as dual reticulation will always rely on high levels of treatment.

In a risk management approach, the focus of monitoring is to ensure that control measures work effectively. This is based on testing for surrogates and indicators of treatment performance and does not involve testing for *E. coli* or any other microorganism. For example, contact time with chlorine correlates with inactivation of enteric bacteria and viruses, while removal of turbidity by filtration correlates with removal of particles such as Cryptosporidium. Providing the relationship between the indicators and pathogens has been established, then monitoring the indicators can be used to demonstrate that pathogen reduction has been achieved. The advantage of the indicators is that many can be measured continuously using automatic monitoring devices connected to alarm systems. Schemes such as the dual reticulation supply at Rouse Hill (NSW) and the salad crop irrigation pipeline at Virginia (SA) use online monitoring devices to measure effective treatment and removal of pathogens. Traditional end-point monitoring and testing for *E. coli* is retained but it is not used as a short-term management tool and it is only one component of measuring microbial safety.

Conclusion

Australia has come a long way since the use of sewage farms in the late 19th and early 20th centuries. The AGWR describes how to apply a risk management approach to ensure that recycled water can be used safely. The guidelines provide a quantifiable definition of safety and mechanisms for reducing concentrations of enteric bacteria, viruses and protozoa to safe levels.

References

1. Pruss, A. *et al.* (2002) Estimating the burden of disease from water, sanitation and hygiene at a global level. *Environ. Hlth. Perspect.* 110, 537-542.
2. Cutler, D. and Miller G. (2005) The role of public health improvements in health advances: the twentieth century United States. *Demography* 42, 1-22.
3. Natural Resource Management Ministerial Council, Environment Protection and Heritage Council, Australian Health Minister's Conference (2006). *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1).* Commonwealth of Australia.
4. Rathjen, D. *et al.* (2003) *Recycling Water for Our Cities. Report to the Prime Minister's Science Engineering and Innovation Council.*
5. Radcliffe, J. (2004) *Water Recycling in Australia.* Australian Academy of Technological Sciences and Engineering.
6. Natural Resource Management Ministerial Council, Environment Protection and Heritage Council, National Health and Medical Research Council (2008). *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2). Augmentation of Drinking Water Supplies. Commonwealth of Australia.*
7. OzFoodNet Working Group (2003). Foodborne disease in Australia: incidence, notifications and outbreaks. Annual report of the OzFood Network 2002. *Comm. Dis. Intell.* 27, 209-243.
8. Hellard, M.E. *et al.* (2001) A randomised, blinded, controlled trial investigating the gastrointestinal health effects of drinking water quality. *Environ. Hlth. Perspect.* 109, 773-778.
9. National Health and Medical Research Council, Natural Resource Management (2004) *Australian Drinking Water Guidelines.* Commonwealth of Australia.

David Cunliffe is the principal water quality adviser with the South Australian Department of Health. He has over 25 years' experience dealing with health aspects of water and wastewater quality and has contributed to the development of a range of Australian and international water quality guidelines.