Matching treatment to risk

This paper highlights how different treatment levels reflect distinctly different responses to perceptions of risk associated with recycled water. Drawing on analysis of the eight case studies, it was found that the level of treatment for recycled water for the various end-uses generally exceeded the recommendations set by the Australian Guidelines for Water Recycling (AGWR).

While there are various reasons for this, the overarching driver appears to be the mitigation of the perceived risk associated with the use of recycled water, and in certain cases, the lack of an inbuilt capacity to adapt responses to shifts in circumstances. That is, there are other business and organisational risks and risk perceptions that are inextricably intertwined with health and environmental risks, and that drive different outcomes.

This study is funded by the Australian Water Recycling Centre of Excellence under the Commonwealth's Water for the Future Initiative

ABOUT THE PROJECT

This national collaborative research project entitled "Building industry capability to make recycled water investment decisions" sought to fill significant gaps in the Australian water sector's knowledge by investigating and reporting on actual costs, benefits and risks of water recycling **as they are experienced in practice.**

This project was undertaken with the support of the Australian Water Recycling Centre of Excellence by the Institute for Sustainable Futures (ISF) at the University of Technology Sydney (UTS), in collaboration with 12 partner organisations representing diverse interests, roles and responsibilities in water recycling. ISF is grateful for the generous cash and in-kind support from these partners: UTS, Sydney Water Corporation, Yarra Valley Water, Ku-ring-gai Council, NSW Office of Water, Lend Lease, Independent Pricing and Regulatory Tribunal (IPART), QLD Department Environment & Resource Management, Siemens, WJP Solutions, Sydney Coastal Councils Group, and Water Services Association of Australia (WSAA).

ISF also wishes to acknowledge the generous contributions of the project's research participants – approximately 80 key informants from our 12 project partners and 30 other participating organisations.

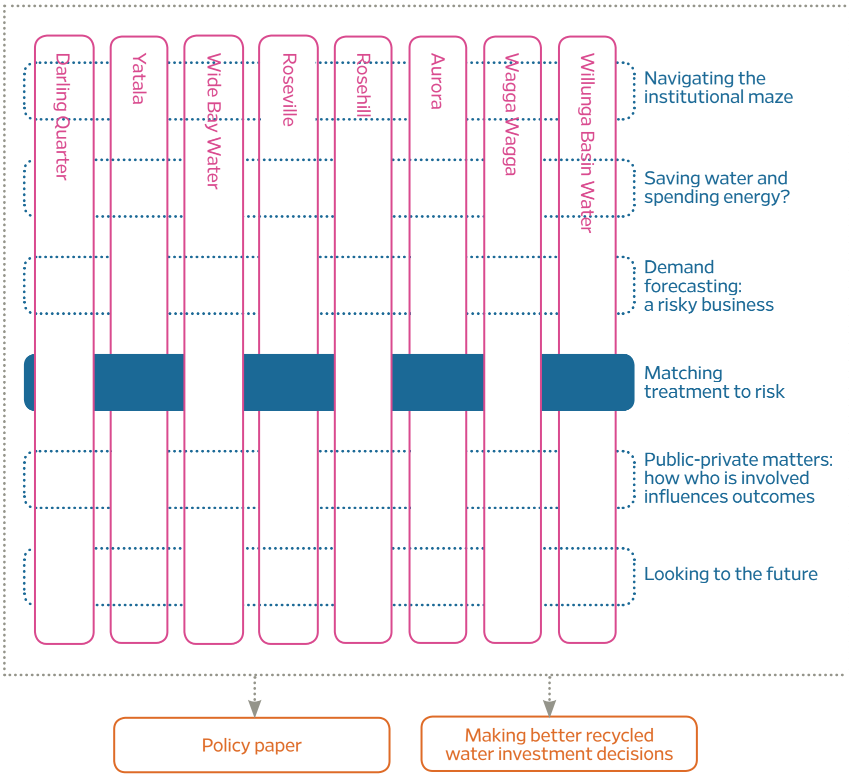
Eight diverse water recycling schemes from across Australia were selected for detailed investigation via a participatory process with project partners. The depth of the case studies is complemented by six papers exploring cross-cutting themes that emerged from the detailed case studies, complemented by insights from outside the water sector.

For each case study and theme, data collection included semi-structured interviews with representatives of all key parties (e.g., regulators, owners/investors, operators, customers, etc) and document review. These inputs were analysed and documented in a case study narrative. In accordance with UTS ethics processes, research participants agreed to participate, and provided feedback on drafts and permission to release outputs. The specific details of the case studies and themes were then integrated into two synthesis documents targeting two distinct groups: policy makers and investors/planners.

The outcomes of the project include this paper and are documented in a suite of practical, accessible resources:

- **8 Case Studies**
- **6 Cross-cutting Themes**
- **Policy Paper, and**
- **Investment Guide.**

For more information about the project, and to access the other resources visit www.waterrecyclinginvestment.com



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The Institute for Sustainable Futures (ISF) is a flagship research institute at the University of Technology, Sydney. ISF's mission is to create change toward sustainable futures through independent, project-based research with government, industry and community. For further information visit www.isf.uts.edu.au

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DISCLAIMER

Introduction

In recent years, recycled water has been perceived as a reliable source of water for irrigation, non-potable use and commercial processes. However, concerns about the health and operational risks associated with the quality and distribution of recycled water have in some cases led to higher than necessary treatment regimes, despite further risk reduction being available through end-use controls.

The practice of over-treating water i.e. using higher quality water for lower grade purposes, is questioned in this paper. Such questioning is not new, as the accompanying 1958 quote from the United Nations Economic and Social Council shows (UN ECOSOC 1958). There are three main consequence of "over-treatment": an inefficient initial capital investment, ongoing operational and maintenance costs, and ongoing environmental costs (e.g. increased GHG emissions), all of which could be avoided or reduced if the water was treated in a manner that was fit-for-purpose.

"No higher quality of water, unless there is surplus of it, should be used for a purpose that can tolerate a lower grade" (UN ECOSOC 1958)

The introduction of the Australian Guidelines for Water Recycling (AGWR) in 2006 shifted the focus for recycled water from a prescriptive end product management approach to one that focuses on systems-based risk management (EPHC, NRMMC, & AHMC 2006). The guidelines require proponents to undertake scheme-specific risk analysis, rather than comply with prescriptive standards (as was required in the past). The challenge therefore is **to steer a sensible course between the extremes of failing to act when action is required and taking action when none is necessary** (NHMRC 2011). A lack of action can compromise public health (NHMRC & NRMMC 2011), whereas excessive caution can have significant social, environmental and economic consequences.

For the schemes investigated in this project, it would appear that there is a mismatch between the AGWR and practice. These studies reveal that the perception is often that "best quality" and not "fit-for-purpose" water is required to mitigate risk, which adds unnecessary additional costs and impacts in some cases.

In addition, for small schemes and councils there is a concern that the risk management approach and processes advocated by the AGWR are costly and may be impeding investment. The requirement to demonstrate compliance with the AGWR, and the approvals and validation process in general, have proved difficult for councils facing time and resource constraints.

The risk management approach requires an assessment of the risk, i.e. an assessment of the likelihood and consequences of something going wrong, and designing mitigating actions appropriately. Much of the work on the risks of recycled water has adopted this quantitative, objective approach. What this approach fails to take account of is that in any population, there is a wide range of perceptions about how dangerous a risk is, about how we balance a risk with its associated rewards, and about what actions we believe are worth taking to mitigate the risk. What it also misses is that any organisation involved at any point in the provision, financing or regulation of recycled water has other risks to contend with. The development of a more nuanced understanding of these risks is in its infancy, and will be essential to the longer term goal of a more equitable distribution of costs, benefits and risks across the stakeholders in recycled water service provision.

Analysis of the case studies

This section provides a brief analysis of the treatment regimes used in the eight case studies and the scheme described in the cross-cutting theme paper – '*Navigating the Institutional Maze*'. It covers the source and end-uses of the recycled water, the treatment levels and the levels of treatment recommended by the AGWR. The levels of treatment (not accounting for end-use controls) for each scheme as compared with the recommended log removals in the AGWR are illustrated in the table that follows (see next page).

SCHEMES

SCHEME	DESCRIPTION	DEVELOPERS, OWNERS, OPERATORS AND RETAILERS	CASE STUDY TREATMENT LEVELS COMPARED WITH AGRW RECOMMENDATIONS
1. Aurora VIC	Residential greenfield third-pipe	Public utility (Yarra Valley Water)	Higher than AGWR
2. Darling Quarter NSW	Residential and commercial precinct	Private developer (Lend Lease) Private operator and retailer (Veolia)	Higher than AGWR
3. Wide Bay Water QLD	Irrigation reuse – crops and plantations; some industrial estate gardens	Public utility (Wide Bay Water Corp)	Higher than AGWR Meets AGWR
4. Rosehill NSW	Industrial reuse; some irrigation reuse	Private developer, owner and operator (AquaNet consortium) Public utility retailer (Sydney Water)	Higher than AGWR
5. Roseville NSW	Irrigation reuse – public open space and golf course; toilet flushing	Local government (Ku-ring-gai Council) Private company (Roseville golf club)	Lower than AGWR
6. Wagga Wagga NSW	Irrigation reuse – public open space; crops	Local government (Wagga Wagga City Council)	Lower than AGWR
7. Willunga SA	Irrigation reuse – crops	Private utility (Willunga Basin Water Corporation)	Higher than AGWR Meets AGWR
8. Yatala QLD	Brewery reuse	Private company (Carlton United Breweries)	Meets AGWR
9. Gordon NSW (see *'Navigating the Institutional Maze'*)	Irrigation reuse – golf course	Local government (Kuring-Gai Council)	Higher than AGWR

1. AURORA

SOURCE

Domestic sewage

USES

The scheme was designed to serve 8,500 homes and currently provides 2,500 homes with recycled water for toilet flushing and garden watering as well as public open space municipal sporting fields irrigation.

TREATMENT

Class A, including chlorination of the final product. The Victorian Guidelines for Class A require Virus=7 log removal, Protozoa=6 log removal (EPA Victoria 2005).

By the time the treatment development was ready to proceed however, the uptake of lots was significantly slower than anticipated, which meant that the recycling plant was mothballed for 2–3 years after construction because of inadequate flows.

RECOMMENDED BY AGWR

Virus=6.5 log removal, Protozoa=5 log removal. Rolling six-monthly cross-connection audits with all houses inspected every five years.

2. DARLING QUARTER

SOURCE

Draw off from a nearby Sydney Water sewer main.

USES

Wastewater recycled through this scheme is used for toilet flushing, irrigation and cooling towers.

TREATMENT

In addition to the treatment train (Moving Bed Biofilm Reactor, Membrane Bioreactor and Reverse Osmosis), chlorine dosing and monitoring equipment was added to ensure a greater than 6.5 log removal for viruses, including adenovirus, is achieved in its daily operations. The plant actually achieves approximately 10 log removal of viruses.

RECOMMENDED BY AGWR

AGWR recommends virus=6.5 log removal for toilet flushing and irrigation. No treatment levels are recommended for cooling towers.

3. WIDE BAY WATER

SOURCE
Sewage

USES
The reuse scheme initially focused on providing irrigation water for sugarcane farms. However, reuse was limited by the seasonal nature of cane irrigation and lower than expected uptake. Wide Bay Water Corporation subsequently purchased a native hardwood plantation to extend its reuse operations and balance demand throughout the year through its irrigation of the plantation. However, this application is limited by naturally high salt levels in local soils and in wet seasons by reduced demand. Reuse water is also used for the irrigation of a golf course and sporting fields, and seasonal drip irrigation at the Airport Industrial Estate.

TREATMENT
Eli Creek, Pulgul and Nikenbah are the three main sewage treatment plants, treating sewage to B, B and A class respectively. Water from Nikenbah is mixed with Eli Creek water, so all reuse water produced from the scheme is classified as B. Nikenbah was deliberately designed with the potential to be upgraded to supply A+ class potable water during droughts as this enabled it to attract a substantial reuse subsidy.

RECOMMENDED BY AGWR
It is difficult to align the Queensland Guidelines with the AGWR, except for Class A+ (V=6.5, P=5, B=5), which is equivalent to the level of treatment recommended by the AGWR for toilet flushing.

The Queensland Guidelines suggest Class C for sugar cane irrigation, Class D for irrigating trees and Class A+ for toilet flushing (EPA Queensland 2005).

4. ROSEHILL

SOURCE
Secondary effluent from Sydney Water's Liverpool to Ashfield Pipeline.

USES
Five major industrial users and one irrigation user.

TREATMENT
Class A; the treatment involves ultrafiltration and reverse osmosis (RO), and is monitored to meet water quality targets of < 50 mg/L TDS, pH of 6.5–8.5, Chlorine residual of 1 mg/L and turbidity of < 0.5 NTU.1

RECOMMENDED BY AGWR
The AGWR does not recommend a treatment standard for industrial use, since the standard required is determined by the needs of each industrial application. Given the potential for cross-connections, the standard would be Class A equivalent, but does not require RO.

5. ROSEVILLE

SOURCE
The stormwater capture was preferred to sewer mining since it offered a cheaper source of water – the cost of sewer mining would have been equivalent to what the golf club was paying for water from Sydney Water. In addition, the site is downstream of the Moore's Creek catchment, and it also provides the opportunity to collect debris in a gross pollutant trap (GPT), preventing it from entering Middle Harbour.

USES
Irrigation of the golf course and adjacent oval, and the flushing of public toilets.

TREATMENT
Due to the good quality source water, treatment is limited and involves a GPT, settlement in the constructed dam and a number of filters. No disinfection is currently used, as it was deemed unnecessary by the Ku-ring-gai Council.

RECOMMENDED BY AGWR
UV treatment

6. WAGGA WAGGA

SOURCE
Treated sewage

USES
Irrigation of local parks and ovals.

TREATMENT
Environmental discharge quality set by the EPA.

RECOMMENDED BY AGWR
A higher standard than environmental discharge quality standards.

7. WILLUNGA

SOURCE
Disinfected class B/C effluent from Christies Beach sewage treatment plant, which is disinfected using chlorine or UV prior to ocean discharge.

USES
Irrigation of vineyards, a golf course, two reserves and playing fields at a local school.

TREATMENT
Willunga Basin Water provides no additional treatment, but each wine grower filters the water onsite (using sand or disc filters) prior to irrigating vines. The recycled water compares favourably to groundwater (which irrigators were previously using) in terms of salinity.

RECOMMENDED BY AGWR
Chlorination is not required for crop applications, but UV or chlorination is required for the irrigation of public open spaces.

8. YATALA

SOURCE
Liquid trade waste. Human effluent from the site is not used and is directed to the standard sewer line.

USES
Cooling towers, boiler feed, CIP systems, pasteurisation, pre-cleaning of vessels and pipes (not final rinses), floor washing, toilet flushing, and onsite irrigation.

TREATMENT
Anaerobic, aerobic, and advanced water treatment processes including reverse osmosis, producing typically 80 ppm TDS and zero organics.

RECOMMENDED BY AGWR
The AGWR does not recommend a treatment standard for industrial use, since the standard required is determined by the needs of each application. Given the potential for cross-connections between potable and recycled water, Class A+ (QLD) equivalent would satisfy the AGWR treatment recommendations, but RO would be considered a higher level of treatment.

9. GORDON (SEE *'NAVIGATING THE INSTITUTIONAL MAZE'*)

SOURCE
Sewage

USES
Golf course irrigation

TREATMENT
three-stage treatment process (membrane bioreactor, ultraviolet disinfection and chlorination). Pathogen log reduction values of 6.0, 4.0 and 8.0 were validated for viruses, protozoa and bacteria, respectively, for the sum of the ultrafiltration and free chlorine disinfection process. Insufficient information was provided to assign a pathogen log reduction value for the UV disinfection system but it is noted that the UV disinfection system will probably be capable of achieving some virus reduction (of the order 0.5 log) and significant protozoan and bacterial pathogen reduction (of the order 4.0 log) (iConneXX & Water Futures 2011), bringing the reduction values for viruses, protozoa and bacteria to 6.5, 8 and 12 respectively.

RECOMMENDED BY AGWR
Ku-ring-gai Council's scheme for the golf club at Gordon is not a private scheme and therefore the guidelines do not apply. However, the guidelines underpin the risk-based approach to the management of recycled water systems. The AGWR recommends reduction values of 5.2, 3.7 and 4 for viruses, protozoa and bacteria, respectively for unrestricted irrigation. The AGWR does not suggest chlorination in addition to membrane filtration and UV treatment.

Most of the schemes analysed provided recycled water of a quality that exceeded, by varying degrees, the recommended treatment levels and associated log removals in the AGWR for the various end-uses. The level of treatment required for recycled water depends on a combination of the scientifically assessable risks, and the perceptions held by key individuals of the risks associated with its source and use. From our case studies we identified four categories of drivers for over-treatment:

1. Regulations to safeguard public health set by government (Aurora, Willunga)
2. Reputation concerns on the part of the owner or operator (Darling Quarter)
3. Variable quality requirements by the customers (Rosehill)
4. Treatment quality chosen to respond to anticipated or projected demand (Wide Bay Water).

In some case studies there was more than one level of treatment quality due to the varying applications of the recycled water. The Willunga Basin Water example is interesting in that it meets the AGWR standards for some applications and exceeds them for others. It receives water from the waste water treatment plant that was designed to disinfect to produce a better quality product prior to ocean discharge. The AGWR does recommend disinfected water (through chlorination or UV) for the irrigation of public spaces, yet the vast majority of the water is used for vineyard irrigation. Under the guidelines this application does not require chlorinated water, so a large volume of the recycled water is of a higher quality than required. Wide Bay Water also meets AGWR requirements in some categories and exceeds them in others, since one of the three plants produces higher quality water than is required, and this water is blended with other outputs that are of lower quality but are still within the AGWR recommendations.

Two of the case studies (Roseville and Wagga Wagga) have systems that do not meet the AGWR recommendations for different reasons. Recycling of water by metropolitan councils in NSW is not yet governed by any formal state government approvals, and hence they can make their own judgements with regard to risk levels. Using AGWR guidelines, Ku-ring-gai Council analysed the risk of exposure for their component of the Roseville stormwater recycling scheme and concluded that it was low. They judged that there is a low probability of anyone being on the field during irrigation because it is done at night and there are signs advising the public not to enter during times of irrigation. The risk of ingesting the toilet water, cross contamination and consequences of drinking the water were all considered low. The Council have not ruled out disinfection however, and will revisit their decision whilst developing the scheme's future management plan.

Wagga Wagga Council, as a regional council, falls under the jurisdiction of the NSW Local Government

Act 1993, and is therefore required to produce recycled water in line with the recommendations of the AGWR. Council undertook major upgrades to their sewerage treatment plants in the late 2000s to comply with the EPA Pollution Reduction Program. At that time they considered the requirements for the recycling component of the scheme according to the then newly introduced AGWR, and sought regulator advice. However, due to a lack of clarity on what was required it was decided to seek approval for the recycling scheme after completion of the sewage treatment plant upgrades. To get approval under the Local Government Act 1993 (NSW), they are now likely to have to implement increased treatment (such as UV treatment) in order to achieve the required log removals for water used
in their recycling schemes.

The following sections provide some insights into the four categories of drivers for overtreatment.

1. Regulations to safeguard public health

Regulations for water quality in Australia are based on anticipating potential public health and environmental risks and preventing them from arising through the risk management approach provided under the National Water Quality Management Strategy in the form of the Australian Guidelines for Water Recycling (AGWR) (EPHC et al 2006). Health and environmental risk-based targets are used by the AGWR to calculate "performance targets" for water recycling schemes. These targets are the minimum performance levels that must be achieved. They are based on a combination of the quality of the water that people may be exposed to (determined by the **treatment process**) and preventive measures taken to prevent people from being exposed to it **(exposure pathways)**. Concerns about exposure of the public to risk are typically focused on food irrigated with recycled water, parks and fields irrigated with recycled water, facilities supplied with recycled water through dual reticulation systems, and occupational exposure to recycled water (e.g. use of recycled water by fire-fighters). When such concerns exist, the treatment includes disinfection through chlorine dosing or UV treatment, as recommended by the AGWR (EPHC, NRMMC, & AHMC 2006, p. 103).

It is difficult to make direct correlations between the varying state regulations and classification systems with the process-based risk management approach underpinning the AGWR. While the AGWR guidelines provide the flexibility needed to deal with a wide range of scheme types, it also necessitates greater engagement by proponents and regulators in undertaking risk analysis, identifying the required log reduction values, designing the scheme (including the treatment train and onsite controls), and setting appropriate parameters for validation and verification. Some states still use a more prescriptive approach, in which recycled water is classified into four classes (Classes A to D) based on end use. Class A is usually the best quality recycled water. It must meet stringent microbiological health standards so that it is fit for irrigating all crops, including fresh vegetables (Class A+ is used in Queensland and refers to the same very high quality recycled water described as Class A in other states). Class A water is generally produced using tertiary and/or advanced treatment processes and includes a disinfection process. The lower classes of recycled water (B, C and D) have restrictions placed on them for health reasons. The restrictions relate to the crops that can be irrigated and the extent of direct human contact with the water (Horticulture Australia Limited 2006).

A key issue is determining the **level of residual risk** that is deemed to be acceptable, because this sets the performance benchmark. The level of treatment recommended by the AGWR is based on an acceptable residual risk of less than one person in 1000 getting diarrhoea per year. This is the same as the Canadian Guidelines, but less than the US EPA target of an infection rate of 1:10 000 (Health Canada 2010). However, Hellard, Sinclair, Forbes and Fairley (2001) demonstrated in a randomly selected Melbourne sample, where micro-organisms had been removed from the supplied potable water, that the rate of diarrhoea was still 0.8 cases per person per year. The residual risk recommended by AGWR is more than 800 times more than this.

The risk of diarrhoea is strongly linked to **exposure pathways** such as consuming recycled water through cross-connections or ingesting irrigation sprays. The incidence of cross-connections in Australia is spatially and temporally rare within distribution systems, with the incidence reported as being on average in the order of 1 event in 10 000 dwellings per year (Storey, Deere, Davison, Tam, & Lovell 2007). Further, the likelihood of ingesting a significant volume of recycled water indirectly through irrigation sprays is very low.

Variations in regulating health risks

The AGWR have been interpreted in varying ways, depending on who the regulatory authority is, the scale of the scheme in question, and who the proponent is (see also the thematic paper on *Navigating the Institutional Maze*).

- **Regulations differ between states**
  The legislation surrounding water recycling can require proponents to obtain approval from one of several different state agencies, in both formal and informal capacities. Some states have produced new legislation to regulate the

use of recycled water, whereas others have continued to manage it within existing wastewater management regimes and associated reuse legislation (Power 2010). This creates the potential for states to have differing interpretations of the level of risk associated with various recycling sources and end uses. For example, the Victorian guidelines on the use of recycled water for indoor use suggest higher treatment levels than those suggested by the AGWR.

There exists an interesting mismatch between roles and responsibilities when it comes to regulating public health risk for recycling schemes. In most states the approval for reuse schemes is done by the state's environmental protection agency, whose primary concern is for discharges to the environment, and not for public health. Health departments do not have specific powers to regulate recycled water, but in most cases they have an advisory role. In the ACT for example, there are no specific powers in the Public Health Act 1997 to regulate recycled water schemes. Similarly, NSW Health only has an advisory role for recycling schemes in relation to potential public health risks, guidelines and conditions. In Victoria, the role of the Department of Health is slightly stronger, and applications for reuse of Class A water require the Department's endorsement (Power 2010).

- **Legislation for private recycling based on size**
  The current state-based regulatory systems for wastewater and recycling in Australia are based on a two-tier system which recognises the following two categories:
  - on-site wastewater management for single and multiple dwellings
  - large centralised wastewater treatment and recycling plants.

The two tiers are dealt with under different acts and their associated regulations, resulting in varying degrees of public health risks being considered, since there are variations in the size of plant and associated exposure limits. In NSW for example, on-site schemes are approved by the relevant local council, whereas for larger schemes NSW Health provides guidelines and conditions for consideration by the NSW Office of Water when it issues approvals. Power (2010) recommends replacing the current two-tier regulatory system based on size with a system based on the level of exposure to health risk, regardless of the size of the plant.

- **Different requirements/regulations for public and private schemes**
  In NSW, recycling initiatives managed by local councils (such as Wagga Wagga) are not subjected to the same regulatory requirements as those for utilities or private sector schemes (such as Rosehill). Local councils in NSW need approval from the NSW Office of Water to develop recycling schemes, whereas private schemes require a licence under the Water Industry Competition Act (WICA).[1] The WICA requires that a private corporation (other than a public water utility) must obtain a licence to construct, maintain or operate any water industry infrastructure which supplies water (potable or non-potable), consistent with the AGWR. The approval of schemes by different bodies within the same state, or under different rules in different states, creates the opportunity for inconsistency in the interpretation of risk and the necessary treatment regimes.

  A further inconsistency is that councils in metropolitan NSW (such as Ku-ring-gai Council) are not covered by either the Local Government Act or the WICA and so they require no formal state government approvals (see also the thematic paper on *Navigating the Institutional Maze*). The only driver for public health risk management for these councils is to protect themselves against liability. In some instances this has enabled some metropolitan councils the freedom to pursue innovative schemes.

For example, Ku-ring-gai, which is metropolitan council, has responded to risk differently in two different instances. They chose not to disinfect the recycled stormwater used for irrigation and toilet flushing in Roseville (as discussed earlier). The risks were discussed with the NSW Office of Water, which suggested installing a UV system in line with the AGWR but recognised a lower risk exposure compared to, for example, schemes where recycled sewage is piped throughout a residential subdivision. The council proceeded with the use of recycled stormwater without UV treatment due to the low risk to public health.

On the other hand, in protecting their liability, Ku-ring-gai implemented multiple disinfection for the reuse of recycled sewage on the Gordon golf course (see *'Navigating the Institutional Maze'*). The application of both UV and chlorine treatment provides an additional margin of safety to meet the "multiple barrier principle" of the AGWR, but results in a level of treatment that far exceeds the recommendations of the AGWR.

Validation of treatment processes

The AGWR require treatment processes to be validated prior to the operation of water recycling schemes. This is a positive approach which shifts the focus from end point monitoring to process barriers and the operational monitoring of those barriers. In the case of pathogens, end point monitoring is expensive and may not identify water quality risks until well after the public have been exposed to them.

However, the AGWR does not provide a prescriptive approach to validating or verifying the treatment train. The length of the validation period, the frequency of monitoring, and the range of operating conditions that need to be considered are not specified as they are dependent on the particular technology being used (MWD 2012). In addition, different states and territories across Australia impose varying requirements regarding validation and verification, making regulatory compliance harder for market participants who operate schemes in numerous jurisdictions. There has been no process for national recognition of validation studies undertaken either overseas or as part of approval processes within Australia. There is also limited agreement between jurisdictions on the validation requirements for treatment processes or schemes. The AGWR describes the concept of validation and the need for it, but does not include specific requirements. This has led to high validation costs and time delays.

In addition, validating the treatment process for low risk schemes has been cited by potential developers as excessive in its requirements and has proven to be costly (Power 2010). The costs for initial validation are between \$5000 and \$100 000 depending on the plant size, and are similar for the ongoing annual performance verification of the plant (ISF & P3iC, 2012). It has been suggested that low risk schemes (such as the Roseville stormwater recycling scheme) should be exempt from individual validation of treatment process, since they require lower log removals according to AGWR. A database of log removal values for treatment systems and their corresponding operational parameters (such as turbidity and UV transmissivity) would be sufficient for low-risk schemes (Power, 2010).

In response, the Australian Water Recycling Centre of Excellence (AWRCoE) has worked with regulators and industry to develop a draft National Validation Framework (NatVal), with the aims of: setting rules or guidelines to validate specific technologies; sharing knowledge on existing schemes and validation undertaken; making available data to assess the feasibility of approaches; and setting up quality assurance programs for measurement requirements within validation programs (Muston & Halliwell, 2011). The introduction of such a framework would ensure consistency, avoid the validation of processes on a case-by-case basis by the various states, and reduce the costs and time associated with the validation procedure. Stage 1 of NatVal identified a number of knowledge gaps, most of which fall into the following general areas (Halliwell, Roeszler, & Muston 2012):

- the absence of current rules or guidelines to validate specific technologies
- lack of shared knowledge on existing schemes and validation undertaken
- insufficient available data to assess the feasibility of an approach
- a lack of quality assurance programs for measurement requirements within validation programs.

Stage 2 of the NatVal program will commence before the end of 2013 and will move towards full implementation of a Validation Framework by addressing the identified knowledge gaps.

Ongoing audits for cross-connections

Cross-connection events in Australia are spatially and temporally rare, with the incidence so far being on average 1 event in 10 000 dwellings per year (Storey et al 2007). The AGWR recommend supplying dual reticulation water for which the pathogen concentration is tolerable, with an annual cross-connection frequency of around 1 event in 1 000 dwellings per year. That would seem to suggest that the industry is in general over-cautious, investing in systems that involve one-tenth of the risk that the guidelines suggest is acceptable.

There have been a few instances of cross-connections between recycled water and drinking water pipework in Australia (MWD 2012, p. 115). Most of these were in the early days of the sector. For example, the Rouse Hill recycled water scheme in Sydney was the first and largest scheme of its type, and 50 cross-connections were found prior to the scheme's commissioning in 2001 due to plumber error inside residences (Hambly, Henderson, Baker, Stuetz, & Khan, 2012). Sydney Water has since introduced a robust audit program in cooperation with NSW Health, industry and customers. Other utilities have adopted similar audit programs and consequently the incidence of cross-connections has reduced (Power 2010; Storey et al 2007).

Victoria's response has been more stringent. The Victorian EPA's concern about the ongoing risk of cross-connections has resulted in all households connected to recycled water having to undergo an inspection audit every five years (consistent with Table 2.8 of the AGWR). Under current arrangements, the additional cost at Aurora (around \$50/household/year – see the Aurora case study) is borne by Yarra Valley Water and it is spread across the whole customer base. Given that experience suggests the current likelihood of a cross-connection is 1:10 000 dual reticulated houses per year (Storey et al 2007), this level of auditing would appear excessive. Rather than a blanket audit of all houses, a system that audits only those houses which have had plumbing alterations would reduce this cost burden. In addition, educating home owners and plumbers of the dangers of cross-connections would further reduce their incidence.

2. Reputation concerns

The mitigation of risks associated with recycled water treatment is also driven by the need for owners, proponents and operators to protect their reputations, and to ensure their "products" are not damaged, and if possible, even enhanced. The risk of bad odours or adverse public perceptions of their products resulting from the treatment of the recycled water or its use in production processes is viewed as important.

The developers of the high quality office space at Darling Quarter, for example, were concerned that odour from the plant might affect tenant amenity, and thereby their reputation for having buildings and amenities of a high standard. This led to additional treatment processes being installed that effectively increased the planned capital and operating costs.

A concern from the owners of a sanitary paper manufacturing plant using recycled water from the Rosehill scheme was the potential negative public perceptions associated with the use of recycled water in the manufacture of personal use paper. Therefore the recycled water was only used for industrial processes such as cooling and boilers. Potable water was used as an ingredient in the manufacture of the actual products.

3. Variable quality requirements of customers

The risk involved in producing recycled water for a range of customers is that they have varying water quality needs. Some manufacturing processes require well filtered water to avoid blockages in spray nozzles (e.g. in the Willunga scheme customers use onsite filters), whereas others need to have water with low total dissolved solids (TDS) for use in cooling towers, boilers and pre-cleaning of equipment (such as at the Yatala Brewery) and therefore require reverse osmosis. The treatment processes in these cases may well exceed the relevant requirements of the AGWR in their quest to meet the operational demands of the end-uses. Higher levels of treatment are not always better, however – costs aside, higher treatment levels can introduce other unforseen operational and cost risks. For example, at Darling Quarter an intention to go well beyond the AGWR led to including reverse osmosis, which led to a need to resalt the water to avoid fixtures being corroded, but the resalting of the recycled water with calcium resulted in struvite precipitation in highly water-efficient urinals.

The example of Rosehill shows that the treatment processes may not match the varying quality demands of the customers. The Rosehill industrial scheme was developed during a time of heightened drought in NSW. At least one prospective customer agreed to be involved only if low TDS water was supplied, and thus reverse osmosis was considered essential by the developers to secure sufficient demand volumes from foundation customers. In retrospect, not all customers required energy-intensive reverse osmosis treated water, and it could have been more cost-effective overall for customers requiring low TDS water to undertake additional treatment on their own sites. However, the higher quality water used for cooling towers and boilers has unexpectedly brought some customers substantially greater maintenance cost savings than they had originally anticipated.

4. Treatment quality chosen to respond to anticipated demand

Changes in the anticipated demand for high quality water can introduce the risk of over treating the recycled water, i.e. there is a risk that the amount of demand for high quality water is insufficient to meet the design requirements, and this will in turn incur inefficient capital and operational costs, as in the example of Wide Bay Water. An incremental approach to water quality treatment may be more prudent when the demand is uncertain. In such cases treatment could be upscaled to meet water quality demand when needed.

The Wide Bay Water scheme was developed over many years by taking advantage of various government subsidies and grants to produce Class B recycled water – a cheaper and more acceptable option for dealing with wastewater from the growing population in contrast to the alternative of ocean outfall. More recently, the facility at Nikenbah was constructed using government drought proofing subsidies to produce Class A recycled water, and this facility and was deliberately designed with the potential to be upgraded to supply Class A+ potable water during drought. Alignment with the then state government policy agenda driving potable reuse was influential in securing the subsidy. However, there is currently no demand for Class A water, so it is blended with the other Class B water before application. Since the plant was not designed to be flexible and produce Class B water, it continues to provide water which is of a higher quality than necessary, resulting in higher operational costs.

A more nuanced assessment of risk

What these analyses show is that in each case study, there were contextual reasons for the decisions that were taken around how to manage the health and other risks associated with each scheme. Whilst the AGWR provides a world-leading framework for thinking through the health and environmental risks, it appropriately stops short of making prescriptions about the decision-making processes associated with business or organisational approaches for determining what risks are acceptable, and what risks need to be mitigated, and what level of investment is acceptable in that mitigation process.

There are other frames that can help to tease apart this much more subjective side of risk and how it is managed. Chief among these is cultural theory, first proposed by Douglas and Wildavsky (1982) in their ground-breaking book, *Risk and Culture*. They argue that there are discernible patterns in the responses that individuals have to the same situation. This view has stood the test of time, and has been applied to widely differing realms, including transport planning (Hendriks 1994) and urban water governance (Beck et al 2011). The basic idea is that perceptions of risk drive behaviours, and risk perception is a social and cultural phenomenon. Different perceptions of risk are based on perceptions of nature and its capacity to respond to impacts (e.g. resilient vs. fragile), about people and their propensities (e.g. for selflessness or selfishness), and inherent responsibilities (e.g. of people to share, of governments to regulate or let the market rule, and of entrepreneurs to make money). All of these perceptions are present in water recycling, as elsewhere in life, so the water recycling sector would likely benefit from a deeper investigation of this frame.

The spirit of the AGWR is about the assessment and management of potential health and environmental risks through treatment and/or preventative measures. However in practice the management of health-related risk is inextricably intertwined with the management of other business and organisational risks, such as reputational or financial risks. Hence, this analysis demonstrates the need to engage with these broader and more nuanced representations of risk, and it demonstrates that cultural theory may provide a valuable entry point (see the related guidance materials from this project, *Making better recycled water investment decisions,* for more details).

Notes

1. The Water Industry Competition Act is currently under review with the aim of addressing concerns raised in this paper and elsewhere.

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