COMPLIANCE OF WATER RECYCLING SCHEMES IN WESTERN AUSTRALIA

An analysis of water recycling from 2003 to 2009

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ABSTRACT

Water recycling schemes have been in operation in Western Australia since 1960. Periodic microbial water quality monitoring has been in place to demonstrate fit-for-purpose recycled water as part of the regulatory framework for wastewater reuse. This study analysed the compliance of water recycling schemes in the Department of Health database over a seven-year period (2003–2009). The original intention was to analyse the compliance of all 92 schemes in the database; however it was necessary to exclude 21 schemes because they either lacked sufficient data or their recording standards were too inconsistent for the analysis.

Compliance was analysed by comparing: i) the observed microbial results against the quality criteria; and ii) the number of samples analysed against the expected number of samples based on regulatory frequency requirements. The results indicate that 12% of the 71 schemes analysed did not comply with water quality criteria over the seven-year period and most of the original 92 recycling schemes did not comply with the expected number of samples. Challenges faced by existing schemes in conforming to the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (Phase 1) (2006) and the *Guidelines for the Non-Potable Uses of Recycled Water in Western Australia* (2011) are discussed.

Keywords: health risk; water management; water quality; water recycling.

INTRODUCTION

Wastewater recycling is a sustainable option for reducing the pressure on existing drinking water resources through the substitution of lower quality water for applications that do not require drinking water quality. In Western Australia, recycling schemes have been in operation for over 50 years.

The first wastewater reuse scheme used in WA was approved by the Department of Health (DOHWA) in 1958 and became operational in 1960. Since then the DOHWA has approved over 150 schemes, most outside the metropolitan area, and the majority of those to country local governments for open space irrigation. Recycled water from these schemes is mainly used for the irrigation of public ovals and sports facilities, tree plantations and industrial uses such as dust suppression and construction activities. The DOHWA conditions of approval for recycling schemes during the study period (2003–2009), were set based on the *National Water Quality Management Strategy Guidelines for Sewerage Systems – Use of Reclaimed Water* (ARMCANZ ANZECC and NHMRC, 2000).

In WA, responsibility for the different aspects of recycled water quality is shared across the DOHWA, the Department of Environment and Conservation (DEC), the Department of Water (DOW), the Environmental Protection Authority WA (EPAWA) and the particular local government where the scheme is located. The regulation of wastewater and recycled water in WA is provided by a range of legislative and regulatory instruments under the provision of the *Health Act 1911*.

The requirements for on-site wastewater system approval are specified in the *Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974* (Government of WA). Similarly, the use of greywater is regulated under the *Code of Practice for the Reuse of Greywater in Western Australia* (DOHWA, 2010). Applications for recycling schemes come directly to the DOHWA and require approval from the Executive Director of Public Health (EDPH).

Since 2000, there has been a significant increase in both the number of recycling schemes and potential end-uses (National Water Commission, 2011). This is in response to increased pressure on fresh water sources and advances in treatment technologies that are able to achieve better wastewater quality.

In 2006, the *Australian Guidelines for Water Recycling – Managing Health and Environmental Risks (Phase 1)* were released (NRMMC and NHMRC, 2006). A simplified version, the *Guidelines for the Non-Potable Uses of Recycled Water in Western Australia*, is intended to bring WA recycled water practices and schemes up to the National Guidelines standards (DOHWA, 2011).

Both National and State Guidelines are designed to provide planning, risk management and implementation frameworks for water recycling schemes through the assessment of human and environmental risks, and through the implementation of the '12-element' risk assessment framework, which was initially developed for the *Australian Drinking Water Guidelines* (NRMMC and NHMRC, 2004).

This study analysed the water quality data from existing recycling schemes in WA. The primary objectives of this study were to:

- Determine the water quality compliance of water recycling schemes in WA based on the intended end-uses; and
- Determine the compliance of water recycling schemes with the number of samples analysed based on the expected number of samples and the number of months the schemes are in operation.

METHODOLOGY

SAMPLING PROTOCOL

Sampling is mainly the responsibility of local government Environmental Health Officers (EHO) who are required to take monthly water samples of all recycling schemes within their area. Samples were collected, preserved and transported to

PathWest (a NATA-accredited laboratory) as per the Recycled Water Sampling Technique Factsheet (Environmental Health Directorate, 2010).

The microbiological quality of the recycled water was analysed in accordance with AS/NZS 4276.7-1995: *Water Microbiology – Thermotolerant Coliforms and Escherichia coli – Membrane Filtration Method* (Standards Australia, 1995a) and AS/NZS 4276.14-1995: *Water Microbiology – Salmonellae* (Standards Australia, 1995b). Results of analysis were sent to the local government and electronic copies sent to the DOHWA.

For this study, data were accessed from the DOHWA Global Data Management System (GDMS), which is a centralised data access point that has been customised to meet the DOHWA requirements.

DATA ANALYSIS

Manual data cleaning and validation were conducted to detect and correct (or remove) incomplete or inaccurate data from the DOHWA's database that could affect the validity of the analysis. Incorrectly entered site codes, years of approval, sample results, names of the schemes and other errors of the data were carefully examined and, where possible, were corrected using semi-structured interviews. As a result of this process, 21 schemes were found to have a lack of data or inconsistent information. They were marked as 'non-compliant' and excluded from the analysis, leaving 71 out of 92 recycling schemes for analysis.

Both *E. coli* and Thermotolerant Coliforms have been reported as useful indicators of possible faecal contamination. *E. coli* is a more reliable indicator of faecal contamination (Leclerc *et al.*, 2001); however, it was excluded from the analysis, as it was not consistently analysed over the study period. Although some Thermotolerant Coliforms can be found naturally in the environment (Tallon *et al.*, 2005), they have been commonly used as 'Faecal Indicators' for monitoring wastewater samples.

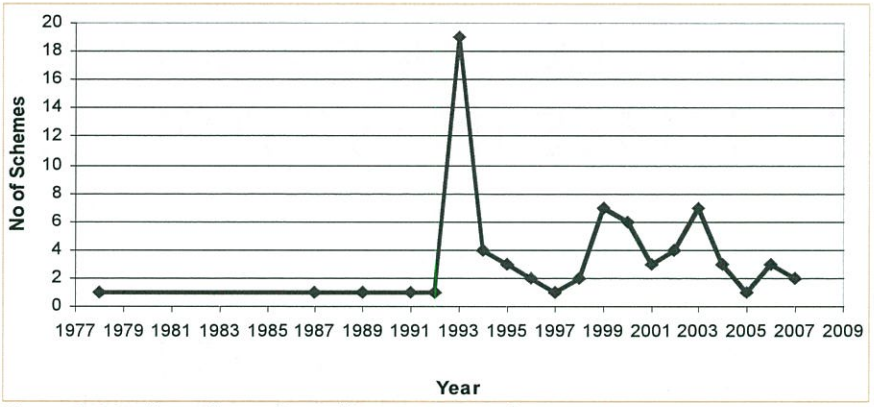

Figure 1. Number of recycling schemes approved per year.

A series of trend analyses were conducted to identify and investigate tendencies and periodicity that may have occurred within the collected data at the specific sampling sites. Microbial test data were extracted based on test definition, whereby confirmed Thermotolerant Coliform data were collectively analysed as Faecal Indicators.

Incidences of compliance were measured according to minimum microbial values in cfu/100mL. Microbial compliance values were determined depending on the product quality required for end use (Table 1). Schemes using recycled water for the irrigation of public open spaces with restricted access and application are classified as a "low" exposure risk level. Given that 85% of the schemes (Figure 2) were this "low" level, they were required to demonstrate compliance with the microbial compliance value of Thermotolerant Coliform/*E. coli* < 1000 cfu/100mL (ARMCANZ, ANZECC and NHMRC, 2000).

Thermotolerant Coliforms were measured using count data. Each scheme submitted five samples from the same sampling point for analysis and the results of these were averaged to determine water quality performance.

Compliance requirements in relation to the number of samples analysed were compared with the annual number of expected samples. A minimum of six months' sampling results was considered to determine the expected number of samples. The majority of water recycling schemes operate only in the dry season from October to May, consequently a minimum of six batches of five samples were expected. As most of the conditions of approval require that samples are taken monthly when a scheme is in use, it is expected that 12 batches of five samples will be submitted annually by each water-recycling scheme. Conditions of approval require schemes to notify the months of proposed operation. However, there was very limited information available for the majority of the schemes.

RESULTS

RECYCLING SCHEMES IN WA

The majority of schemes were approved in 1993 when 19 local governments

Table 1: Minimum microbial compliance values.

Exposure Risk Levels	End Uses	Microbial Compliance Value
High	Urban residential garden watering	Thermotolerant coliform/*E. coli* < 10 cfu/100mL
Medium	Drinking water for stock (except pigs)	Thermotolerant coliform/*E. coli* < 100 cfu/100mL
Low	Irrigation of open spaces with controlled public access	Thermotolerant coliform/*E. coli* < 1000 cfu/100mL
Non-human food chain		Thermotolerant coliform/*E. coli* <10,000 cfu/100mL

Source: National Water Quality Management Strategy Guidelines for Sewerage Systems Use of Reclaimed Water (2000).

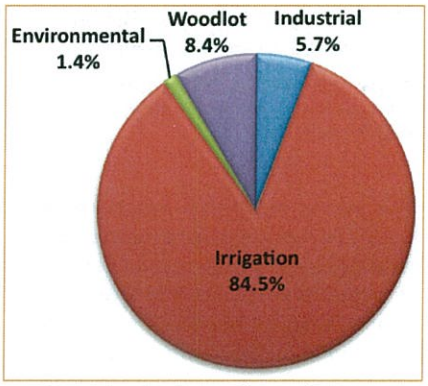

Figure 2. Proportion of recycling schemes by end-uses.

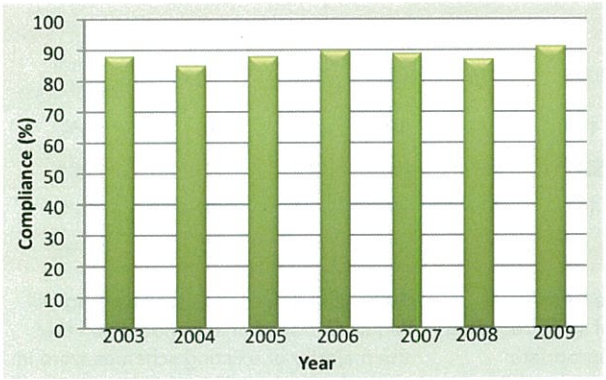

Figure 3. Annual microbial compliance of recycling schemes in WA, 2003–2009.

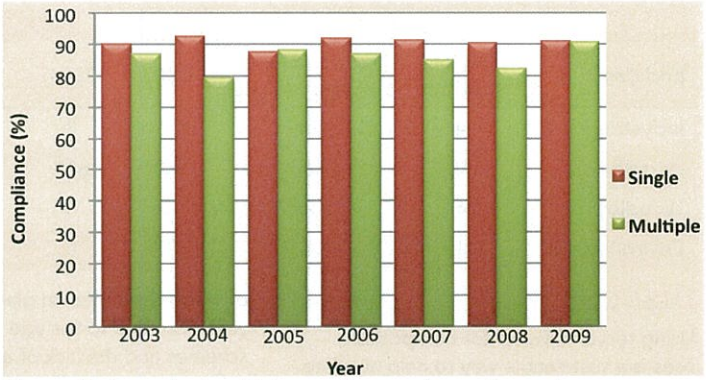

Figure 4. Annual microbial compliance of recycling schemes by type of scheme.

Table 2. Number of samples taken by type of scheme per year.

Operator Type	No of schemes	No of expected samples per year	2003	2004	2005	2006	2007	2008	2009	Total Compliance
Single	26	156	164	215	253	312	286	282	244	100%
Multiple	45	270	271	312	300	163	183	244	245	43%

in country areas initiated the use of municipal wastewater for irrigation of ovals and sport facilities (Figure 1). Between 1978 and 1993, the DOHWA approved only one per year and, after 1993, the DOHWA approved between one and seven recycling schemes every year (Figure 1).

Most of the analysed recycling schemes (84.5%) used treated wastewater to irrigate municipal green spaces such as ovals, golf courses, parks, gardens and race courses with a few schemes irrigating pasture crops. A further 8.4% used recycled water for non-edible crop irrigation (woodlots, turf, flowers) and 5.7% used the water for dust suppression of roads on mine sites (Figure 2). One of the schemes (1.4%) used treated wastewater to enhance the environmental flows of a river.

Microbial compliance ranged from a minimum of 85% in 2004 to a maximum of 91% in 2009 (Figure 3). On average, the percentage of microbial non-compliance with expected water quality for the analysed period was 12%. The overall quality of recycled water slightly improved towards the end of the period 2003–2009. Each recycling scheme was individually analysed for microbial compliance and the total number of samples taken (data not shown).

OPERATION OF RECYCLING SCHEMES BY SINGLE AND MULTIPLE ENTITIES

There were 26 single entity schemes (in which only one organisation is responsible for all stages of the process from wastewater collection to end-use) and 45 multiple entity schemes (in which at least two organisations are involved, one as the wastewater provider and the other as the scheme manager) operating in WA over the study period. Single entity schemes demonstrated better microbial compliance than the multiple entity schemes, except for the years 2005 and 2009 when both types of schemes showed approximately 90% microbial compliance (Figure 4).

Single entity schemes also tended to perform better in relation to the number of expected samples (Table 2). For instance, if we assume that the operation period of all analysed recycling schemes is only six months a year, then the estimated minimum number of samples that is required to be taken by single and multiple entity schemes combined can be calculated as follows (figures taken from Table 2):

For single entities schemes: 26 schemes x 6 months = 156 samples/year

For multiple entity schemes: 45 schemes x 6 months = 270 samples/year.

By comparing the above calculated numbers with the actual numbers of samples that were taken by each category of entity, it can be noted that during the analysed period, single entity schemes consistently took more than the minimum 156 samples required each year and, therefore, showed 100% compliance. In comparison, multiple entity schemes took fewer than the minimum 270 samples required in all but three of the years examined.

PERFORMANCE OF RECYCLING SCHEMES BY END-USES

Microbial water quality compliance of the analysed recycling schemes by end-uses is presented in Figure 5. Most schemes performed well with between 80 to 100% microbial compliance for the period 2003–2009. All four recycling schemes that reuse treated wastewater for industrial use demonstrated 100% microbial compliance in each year of the analysis period.

Not all of the schemes, however, took the required number of samples per year to demonstrate microbial compliance (Table 3). For instance, the 'Environmental' recycling scheme, which uses treated wastewater to enhance a river stream, took an insufficient number of samples over the study period. This scheme, which has been in operation since 2002, did not submit samples for microbial analyses in 2003, 2004, 2007 and 2008. Even though in 2005 the scheme took only four samples, the result of all these samples exceeded the Thermotolerant Coliform/*E. coli* <1000cfu/100ml compliance value. In 2006 the scheme took samples only once (Table 3) and demonstrated 100% compliance (Figure 5). In 2009, the scheme collected only two samples (Table 3) with 50% compliance (Figure 5).

Considering that the majority of schemes for irrigation and industrial uses were approved before the analysed period, the problem of under-sampling is clearly identified.

Table 3. Number of samples collected by end uses per year.										
End Uses	No of schemes	No of expected samples per year	2003	2004	2005	2006	2007	2008	2009	Total Compliance
Industrial	4	24	7	8	12	17	10	19	18	0%
Irrigation	60	360	428	511	526	440	459	498	418	100%
Woodlot	6	36	0	8	11	17	0	9	51	14%
Environmental	1	6	0	0	4	1	0	0	2	0%

DISCUSSION

Using recycled water for non-potable uses is a sustainable way to help alleviate the pressure on scarce water resources, provided public health is adequately protected. Currently there are National and State Guidelines to ensure adequate management of health and environmental risk by implementing a risk management framework. Most of the 92 approved recycling schemes in WA analysed during the seven-year study period do not comply with water quality monitoring requirements stipulated in the conditions of approval, mainly due to the low number of samples taken rather than non-compliance with microbial water quality.

Notifying individual schemes of microbial water quality results that fall outside compliance values, or a lack of samples submitted for analysis, is done by the DOHWA. This is not done consistently, however, and the schemes do not always send the requested samples to the laboratory. The lack of human resources and high staff turnover at local governments may also have impacted on sampling frequency. An additional complication is that when non-compliance has occurred, the DOHWA has been unable to take prompt corrective actions due to the lack of resources. This gap can be better addressed through adequate resources, better data management systems, and a better communication and follow-up of approved recycling schemes by the DOHWA.

The DOHWA regulations and guidelines for recycled water deal largely with 'open space' irrigation recycling schemes, many of which have been in place for over 30 years. So, due to the age of some recycling schemes and the lack of appropriate risk management documentation and planning, none of the 92 analysed schemes in WA are in full compliance with *Australian Guidelines for Water Recycling* (Phase 1). The high levels of staff turnover reinforce the need to implement adequate documentation and reporting mechanisms such as written procedures on the operation and maintenance of recycling schemes to ensure continuity and consistency of operations.

This study found that multiple entity schemes performed more poorly than single entity ones, highlighting that it is necessary to ensure that the responsibilities of the entities are clearly stated and that both parties know their roles and responsibilities. Recycled water supply agreements between the supplier and the user are often in place, but not always. Moreover, agreements signed in accordance with the *National Water Quality Management Strategy Guidelines for Sewerage Systems Use of Reclaimed Water* (2000) did not specify the water quality targets of recycled water to be delivered by the wastewater service provider. As a result, the operation of a multiple-entity recycling scheme is less controlled and the quality of recycled water does not always comply with the requirements of the DOHWA.

The DOHWA requirements during the study period were set based on the *National Water Quality Management Strategy Guidelines for Sewerage Systems Use of Reclaimed Water* (2000). These Guidelines did not include the current risk management framework approach, which also includes the concept of tolerable or acceptable risks to end users of recycled water. Adoption of the National and State guidelines for water recycling will require a transitional period given that the majority of existing schemes were in operation before their implementation.

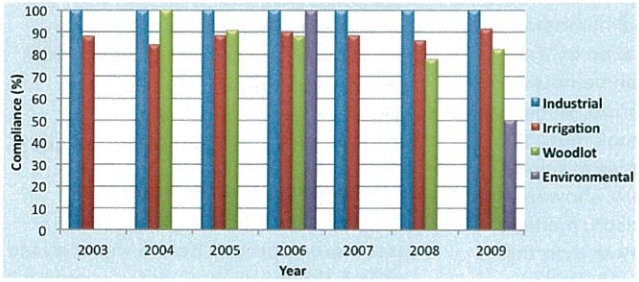

Figure 5. Annual microbial compliance of recycling schemes by end-uses.

Under-sampling was a significant issue for several schemes, with the sampling data unavailable for entire years in some cases, particularly from those schemes that were more isolated and from areas with smaller populations. The failure to take regular samples is also a concern, as regular sampling provides a much clearer picture of water quality trends.

At present, new schemes are required to provide sufficient detail relevant to the proposal for assessment including a Recycled Water Quality Management Plan (RWQMP). The level of detail required depends on the type of system and the associated risk to health, which is based on the proposed end use and potential for human exposure. It is expected that existing schemes in WA will amend their operational procedures and will develop and implement a RWQMP in order to comply with the new guidelines within a two- to five-year transitional period.

This study identified that poor performance of the water recycling schemes was related to inadequate planning and management of the schemes. This was also highlighted by Keremane and McKay (2007), who found that sustainability of recycled water can be achieved with adequate policies, good planning and management, adequate financial obligations, and public participation and support.

CONCLUSION

This study was undertaken using water quality data collected over a seven-year period between 2003 and 2009 to examine compliance of water recycling schemes in WA. The issue of non-compliance of recycling schemes with DOHWA requirements was mainly due to under-sampling rather than water quality. This was considered to be a significant problem and will need to be addressed by the DOHWA. Most of the non-compliance can be attributed to the lack of appropriate risk management and

documentation; therefore, it is expected that implementation of the National and State Guidelines will address this gap. This implementation would help identify and manage risk in a proactive way rather than reacting to problems when they arise. Adoption of these Guidelines will require a transitional period for the development and implementation of RWQMPs. It is, therefore, expected that all stakeholders, in particular the Water Corporation as the main wastewater service provider in WA, and local governments as the main end-user, will work in a coordinated and collaborative way to achieve compliance with the new Guidelines.

RECOMMENDATIONS

To improve the performance of the water recycling schemes in WA, it is recommended that:

DOHWA:

- Improve the maintenance, follow-up and response procedures of the recycled water quality database in order to provide prompt feedback when non-compliance results arise;
- Review all conditions of approval of schemes previously approved and develop a plan with each scheme to agree to the activities and timeframe for implementation of new regulatory requirements;
- Establish risk mitigation priorities and practices to ensure that the responsibilities of each party are clearly defined and the recycled water is 'fit for purpose';
- Enforce internal and external audits of all water recycling schemes to ensure that the schemes operate in accordance with the approvals;
- Request that managers of recycling schemes submit annual reports that include monitoring programs, monitoring results, incidents, compliance and maintenance programs, and provide an overview of how the scheme is operating;
- Address the knowledge gaps over the implementation of the National and State Guidelines as well as the lack of linkages between science policy makers, science practitioners and end users (i.e. adopters) through the educational training and workshops, particularly in regional areas.

Wastewater service providers:

- Conduct regular maintenance and upgrading of systems to ensure that equipment and systems are adequate;
- Ensure that all sections of the 'Recycled Water Supply Agreement' are addressed and the quality of the provided water is suitable for the intended end use;
- Implement process control programs following the HACCP approach to ensure the plant is operating as per operational target limits;
- Where feasible, invest in scientific research, particularly in relation to how contaminants and pathogens can be inactivated, improving treatment plant and pipe system cleaning operations, and improving wastewater treatment efficiencies;
- Develop a Memorandum of Understanding for Wastewater Services implementing a risk-based approach for wastewater management in line with National and State Guidelines.

Scheme managers:

- Be responsible for the implementation of the Recycled Water Quality Management Plan and for the notification of end-users of the conditions of recycled water use and their responsibilities;
- Define the roles and responsibilities of all stakeholders and organisations involved in the scheme;
- Commit to the recycling scheme with the allocation of resources for the long-term viability of the project;
- Perform regular internal audits of recycling schemes to ensure that the management and operational strategies are undertaken and any non-compliance is dealt with;
- Maintain written procedures on the operation and maintenance of recycling schemes for continuity of the operation.

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