Water Recycling in Western Australia. Analysis of 2003 – 2009 water quality monitoring program

Natalia Shishkina, Toni Hannelly, Clemencia Rodriguez

Natalia Shishkina (corresponding author)

Department of Health, Government of Western Australia, Grace Vaughan House, 227 Stubbs Terrace, Shenton Park, WA 6008, Australia

Tel: +61 8 9388 4940; Fax: +61 8 9388 4910

E-mail: Natalia.Shishkina@health.wa.gov.au

Toni Hannelly

School of Public Health, Curtin University, GPO Box U1987 Perth, WA 6845, Australia

Clemencia Rodriguez

School of Population Health, Faculty of Medicine, Dentistry and Health Sciences, The University of Western Australia, 35 Stirling Hwy, (M431) Crawley, WA 6009, Australia

Abstract

Water recycling schemes have been in operation in Western Australia since 1960. As a requirement of the regulatory framework for wastewater reuse, periodic water quality monitoring has been implemented to demonstrate microbial compliance for the intended end-use. For this study, we originally planned to analyse the compliance of the 92 water recycling schemes in the database over a seven-year period (2003-2009), 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 remaining 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

Over the last three decades, there has been a decreasing trend in rainfall in Perth, Western Australia (WA) and an increasing demand for drinking water as the city has one of the highest population growth rates in Australia (Blair 2004). Australia was reported as the second highest water usage country after the United States of America with approximately 320 litres per person per day, domestic water use (Stenekes 2006). However, during the last years, Australian water consumption by households declined to 225 litres per person per day for the period 2008/2009 (ABS 2010). Despite a National decrease in water consumption, in Perth per capita domestic water use for the

period 2008/2009 was still above the National water consumption and was reported as 290 litres per person per day (Water Corporation 2010). This imbalance between water availability and use is causing considerable stress on already overstretched water resources.

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 (White 2003). However, recycled water poses some challenges related to pharmaceuticals and industrial chemicals that may pose a risk to human and environmental health (Levine and Asano 2004). In addition to the cost, one of the main problems associated with wastewater reuse is negative community perceptions of the risks that may arise from the use of recycled water (Boland 2005). It is therefore essential that when using recycled water, the public is made aware that human and environmental health are protected at all times (Australian Water Recycling Centre of Excellence 2010). This can be achieved through good design, installation and appropriate management of recycled water schemes.

Recycled Water Regulation

The first wastewater reuse scheme used in WA was approved by the Department of Health of Western Australia (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 so they can use municipal wastewater for open space irrigation. Recycled water from these schemes is mainly used for the irrigation of ovals, golf courses, parks, gardens and race courses. A few schemes also provide water for the irrigation of tree plantations (Water Corporation 2006) or for industrial uses such as dust suppression and construction. Other entities such as the Water Corporation, Department of Education, private sporting clubs, mining companies and other industries have also implemented recycling schemes throughout the State.

The DOHWA requirements for recycling schemes approved 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). Recycling schemes can be operated by single or multiple entities. In 'single entity' schemes only one organisation is responsible for all stages of the process from wastewater collection to end-use, in 'multiple entity' schemes there are at least two organisations involved, one as the wastewater provider and the other as the scheme manager. A common example of "multiple entity" schemes are those in which the Water Corporation WA owns the wastewater treatment plant and the local government operates the water recycling scheme. For multiple entity schemes, a 'Recycled Water Supply Agreement' has been required since 2000 by the DOHWA in order to specify obligations and responsibilities of both entities.

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 approval are specified in the *Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974* (Government of Western Australia 1974*)*. Similarly, the use of grey water is regulated under the *Code of Practice for the Reuse of Greywater in Western Australia (2010*) (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 in Australia (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, which apply a risk management framework for water recycling to identify and manage all hazards and hazardous events from wastewater collection to end use(s) in order to ensure the final product is of a defined quality and will be "fit for purpose" to protect human and environmental health.

The *Guidelines for the Non-Potable Uses of Recycled Water in Western Australia* (2011) is a simplified version of the *Australian Guidelines (Phase 1)* (NRMMC and NHMRC 2006) and are 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 a planning, risk management and implementation framework 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 developed for the *Australian Drinking Water Guidelines* (2004) (NRMMC and NHMRC 2004). The emphasis is now placed on operational performance monitoring to confirm that measures to control identified hazards are working as expected rather than just monitoring the end product recycled water quality (verification monitoring) as before.

This study analysed the water quality data (verification monitoring data) from existing schemes in WA. Currently the challenge for both existing schemes and the DOHWA is how to best achieve the implementation of the new guidelines. Therefore, 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.

Methodology

Sampling Protocol

Sampling of recycled water schemes is mainly the responsibility of the local government Environmental Health Officer (EHO). The officer is 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). 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 1995) and AS/NZS 4276.14-1995: *Water microbiology—Salmonellae* (Standards Australia 1995). Results of analysis are sent to the local government EHO and an electronic copy is sent to the DOHWA data base.

For this study, data were collected 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 was conducted to detect and correcting (or removing) 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. These interviews were with industry practitioners such as recycling schemes operators, PathWest staff (the major microbial government laboratory), and the Water Cooperation (the major wastewater service provider in WA) operators.

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 This left 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 2001), however, it was excluded from the analysis, given that it was not consistently analysed over the study period. Although some Thermotolerant Coliforms can be found naturally in the environment (Tallon 2005), they have been commonly used as 'Faecal Indicators' for monitoring of wastewater samples.

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. Summary statistics were conducted using Microsoft Excel 2007. 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 uses (Table 1). Schemes using recycled water for the irrigation of public open spaces with restricted access and application are considered as a low exposure risk level. Given that 85% of the schemes (Figure 2) are low risk exposure level, they had 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, with an incidence of noncompliance coded as '1' and compliance as '0'. Each scheme submitted 5 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 6-month sampling results were considered 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 6 batches of 5 samples is considered acceptable. Non-compliance or undersampling was determined when fewer than 6 batches of 5 samples were submitted for analysis. 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 5 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.

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/100 mL
Medium	Drinking water for stock (except pigs)	Thermotolerant coliform /E.coli < 100 cfu/100 mL
Low	Irrigation of open spaces with controlled public access	Thermotolerant coliform /E.coli < 1000 cfu/100 mL
Non-human food chain		Thermotolerant coliform /E.coli <10,000 cfu/100 mL

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

Results

Recycling schemes in WA

Ot the total 92 wastewater recycling schemes operating over the study period (2003 – 2009), 21 schemes were excluded due to insufficient data. Of the 71 analysed schemes, 67 (95% of the total) were located outside of the Perth metropolitan area.

The majority of schemes were approved in 1993 when 19 Local Government in country areas initiated the use of municipal wastewater for irrigation of ovals and sport facilities (Figure 1). Before 1993, the DOHWA approved only one per year and after the DOHWA approved between one and seven recycling schemes every year (Figure 1).

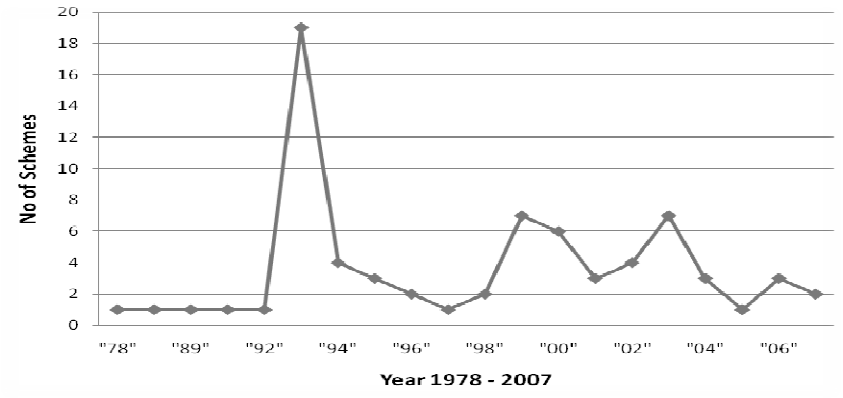

Figure 1: Number of recycling schemes approved per year.

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.

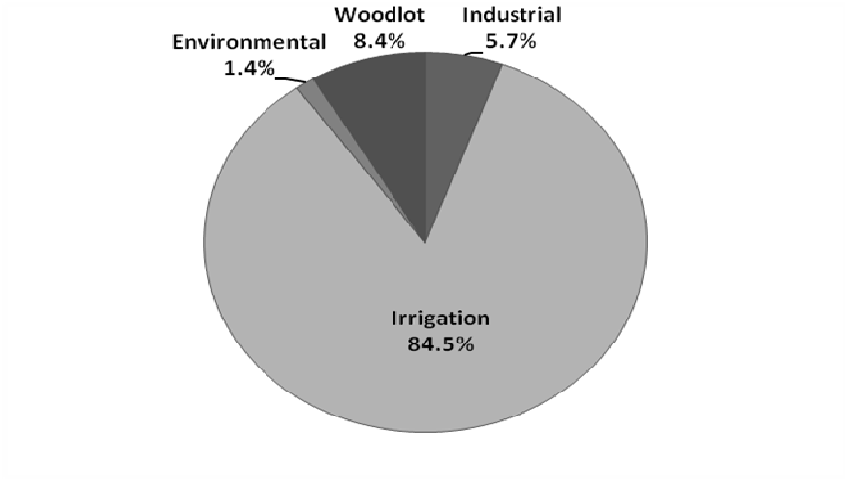

Figure 2: Proportion of recycling schemes by end uses.

Microbial compliance ranged from lowest 85% in 2004 to highest 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).

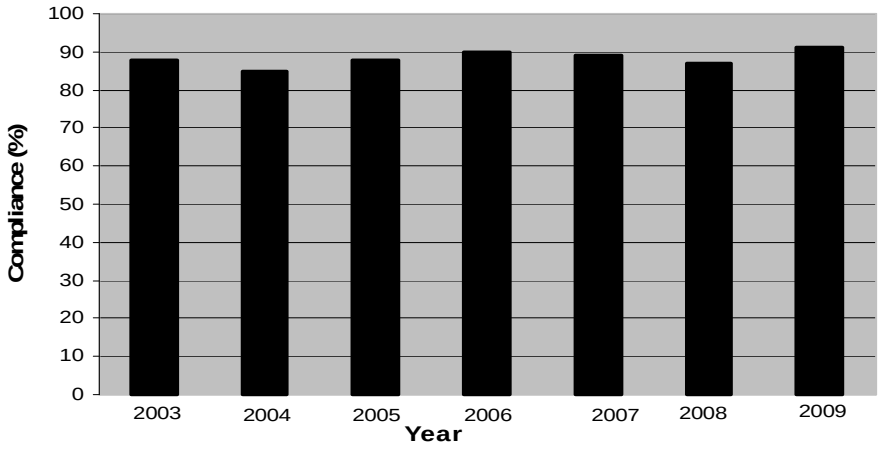

Figure 3: Annual microbial compliance of recycling schemes in WA 2003-2009.

Operation of recycling scheme by single and multiple entities

There were 26 single entity schemes and 45 multiple entity schemes operating in WA over the study period (Table 2). Single entity schemes demonstrate 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).

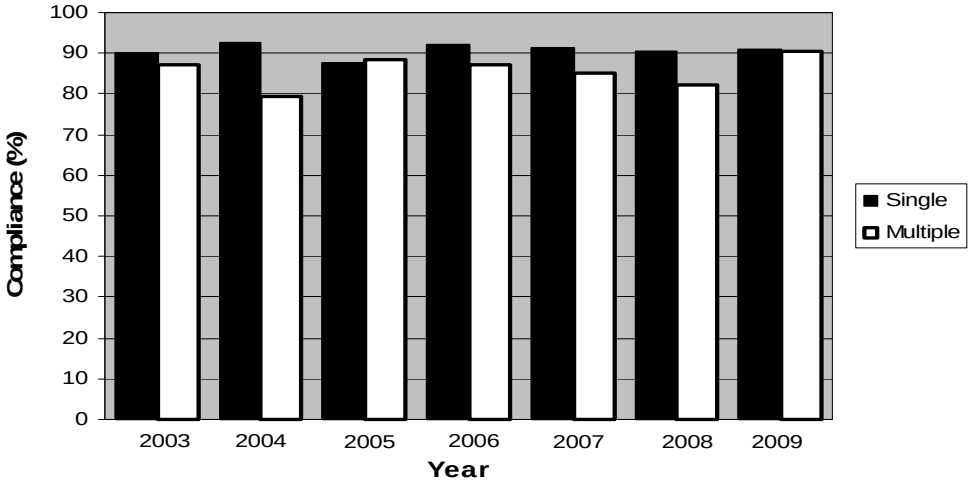

Figure 4: Annual microbial compliance of recycling schemes by type of scheme.

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 6 months a year, then the estimated minimum number of samples that is required to be taken by single and multiple entity schemes 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.

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

Operator type	N of schemes	N 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%

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. Whereas multiple entity schemes took fewer than the minimum 270 samples required in all but 3 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 each year of the analysis period. Not all of the schemes however take the required number of samples per year to demonstrate microbial compliance (Table 3). For instance, the recycling scheme shown as 'Environmental' in Figure 5, which uses treated wastewater to enhance a river stream took an insufficient number of samples over the study period. Table 3 indicates that this scheme, which has been in operation since 2002 did not report samples for microbial analyses in 2003, 2004, 2007 and 2008. Even though in 2005 the scheme took only 4 samples, the result of all these samples exceeded the Thermotolerant Coliform/E.coli <1000cfu/100ml compliance value (Figure 5 shows 0 % compliance). In 2006 the scheme took samples only once (Table 3) and demonstrated 100% of compliance (Figure 5). In 2009 the scheme collected only 2 samples (Table3) 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.

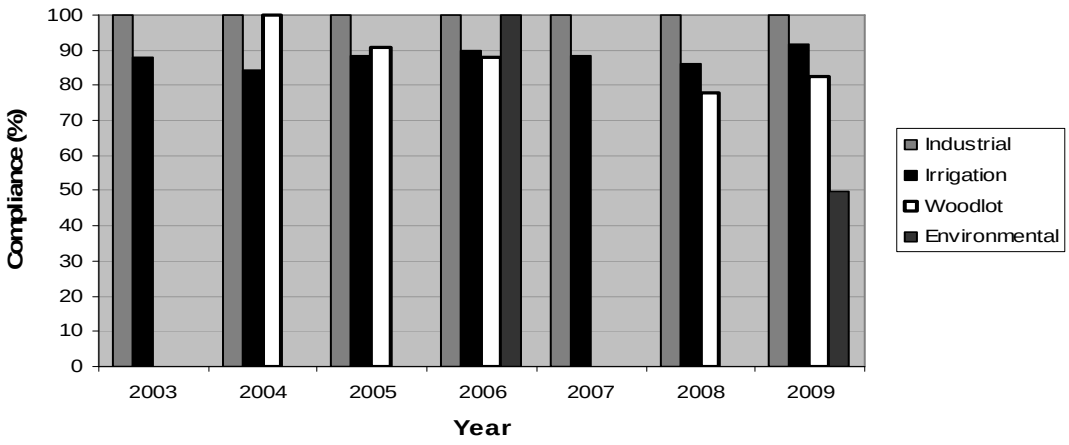

Figure 5: Annual microbial compliance of recycling schemes by end uses.

Table 3: Number of samples reported by end uses per year.

End uses	N of schemes	N 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 lack of samples submitted for analysis is done by the DOHWA via fax. However, this is not done on regular basis and when performed, the schemes not always send the corresponding samples to the laboratory. Lack of human resources at local governments may impact on sampling frequency requirements. An additional complication is that when non-compliance has occurred, the DOHWA has been unable to take prompt corrective actions due to lack of resources and staff turn over. This gap can be better addressed through, adequate resources, better data management system 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. It has come to the Department’s attention that due to the age of some recycling schemes, the turnover of staff at country local governments and, principally, the lack of appropriate risk management documentation and planning, none of the 92 analysed schemes 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 the continuity and consistency of operations.

This study found that multiple entity schemes performed more poorly than single entity ones. It is therefore 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 majority of entities using recycled water are large organisations, such as local governments and mining companies which are responsible for ensuring that public access is restricted during irrigation periods and allow access to the irrigated area only when the ground is dry. When restricted access and irrigation times are used as measures to minimise public exposure, these measures, any corrective action required and the ways to verify their implementation must be part of the process control program of the reuse schemes. For example, frequency of visual inspections to ensure adequate signage of the irrigated area, ponding control and times of irrigation including person responsible, need to be documented in the process control program. Additionally, the scheme manager is responsible for the safety of workers on the site including training and where necessary, vaccination.

Approval for a recycling scheme may include a number of conditions issued by the DOHWA, which need to be addressed in the final submission before "approval to use" or to operate the scheme is granted. Currently the approval to install an apparatus for the treatment of sewage includes a condition that treated effluent water quality need to be validated and verified according to the intended end-use before approval to use is granted.

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 include the concept of tolerable or acceptable risks to end users of recycled water expressed as Disability Adjusted Life Years (DALYs). Adoption of the National and State guidelines for water recycling will require a transitional period given that the majority of existing schemes have been in operation before their implementation. Given that the Western Australian Guidelines have been endorsed by the EDPH, it is expected that existing schemes will amend their operational procedures and will develop and implement a Recycled Water Quality Management Plan in order to comply with the new guidelines within a two to five year transitional period.

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 with small 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. 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. HACCP

principles are being applied to ensure that, as far as possible, any non-conformity with the system requirements is detected before the supply or application of recycled water, to minimise the risk to public health.

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

Based on the above, it has come to the authors' attention that to improve performance of the water recycling schemes in WA the DOHWA should:

- Improve the maintenance, follow-up and response procedures of the recycled water quality database in order to provide prompt feedback when non-compliant 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 to all water recycling schemes to ensure that the schemes operate in accordance with the approvals.
- Request managers of recycling schemes to submit annual reports which include monitoring programs, monitoring results, incidents, compliance and maintenance programs and provide an overview of how the scheme is operating on a regular basis.
- 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.

Although this study was carefully prepared, there were some unavoidable limitations. The following limitations were identified in considering results of the study. First, possibly due to the remote locations and lack of sample collection training provided to Environmental Health Officers, the manually entered data have gaps and errors that affect the analysis (for instance, the site code allocated to some schemes did not match the name or location of the scheme or was not entered in the way described in the Recycled Water Sampling Technique factsheet). Second, despite having schemes in operation for more than 20 years, a longer data analysis period was not possible given that some data before 2003 was manually entered and there were issues with its validity. Third, E. coli data were only available for some schemes but it was excluded from analysis where confirmed Thermotolerant Coliform data ware available for the same site and collection date to achieve consistency. Finally, as data on free residual chlorine

levels were not available, it was not possible to determine any correlation between these levels and microbiological quality.

Conclusion and Recommendations

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 the 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 to identify and manage risk in a proactive way rather than reacting to problems when they arise. Adoption of the National and State Guidelines will require a transitional period for the development and implementation of recycling water quality management plans. 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.

General Recommendations

Wastewater service providers should:

- 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 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 should:

- 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 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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