Research article

Evaluation of Chemical Contaminants in Recycled Water for Firefighting

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Abstract One particular application of recycled water is for firefighting purposes, in situations when water supply is limited. The objective of this study was to evaluate whether the guidance endorsed by the use of Queensland Class A+ or Queensland Class B recycled water for firefighting is appropriate to control potential risks to firefighters. As part of this assessment, a study of chemical contaminants was undertaken at an urban water treatment facility producing recycled water using dual reticulation to evaluate the water in terms of its use for firefighting purposes. The health risks to firefighters from recycled water mains were associated with the chemical and endotoxin composition of Class A+ recycled water produced by advanced water treatment plants relative to the potable water supply. While the coverage of microbial hazards was detailed, the specific reference to chemical hazards was limited to endotoxins and briefly mentioned the health effects from exposure to chemicals through chronic exposure to contaminated water rather than from short-term (acute) exposure. An additional objective was to identify if further study of chemical contaminants at the designated water treatment facility producing recycled water was examined to give a better understanding of less well-known contaminants (fluoride, molybdenum, and selenium). The comprehensive data set of microbiological data from another study was combined with the current chemical contaminant study in a more informed risk assessment. The overall finding from the risk assessment was that the Class A+ recycled water from the water treatment facility evaluated in this study would be safe for firefighting. The summary statement of applicability based on an extensive review and analysis of risk data through exposure to contaminated water concluded that health risks tend to manifest as a result of prolonged (chronic) exposure rather than from short-term sporadic (acute) exposure.

Keywords wastewater, recycling, firefighting, human health, risk assessment.

INTRODUCTION

Recycled water provides a practical means to meet water supply needs by reutilizing wastewater. Since the early 2000s many countries including North America, Australia, and the Middle East have investigated recycled water sources to meet supply gaps. The assessment of water recycling schemes is quite sophisticated and considers material flow analysis, life cycle assessment, environmental risk assessment, and their integration to give integrated assessment tools for recycled water schemes (Chen et al., 2012). A review of water recycling in Australia identifies that guideline development became a point of focus to align recycled water with water guidelines for drinking water, agricultural practices, and aquatic environments (Apostolidis et al., 2011). The Sydney Olympic Games, held in Australia in 2000 demonstrated how urban water cycle management principles at the Olympic Village could be adopted in an integrated manner and reduce the amount of water needed from the environment by incorporating recycling. Recycled water provides a viable means to supplement water supply and can alleviate environmental loads.

Key toxicological parameters in recycled water were reviewed by the Australian Department of Health and Aged Care (DHAC, 2001). Many indicators are well understood from the drinking water perspective and appropriate limits exist in the Australian Water Quality Guidelines (NHMRC and

NRMMC, 2011) or those for recreational use (NHMRC, 2008). Recycled water has been recognized as an additional input to water use in both urban and farming communities. A particular application of water from its regular supply points is for firefighting. An assessment of health effects from sewage by the WSAA identified that human health risks were only estimated as significant when extensive and prolonged exposure to consumers was demonstrated by using conservative assumptions that assumed a worst case. There was no evidence that brief exposure to chemicals in recycled water would lead to human health effects (WSAA, 2004). A review of water recycling in Australian urban environments included the new Springfield Water Recycling Centre (Fig. 1) as a role model for new urban developments in Greater Brisbane, southeast Queensland, which introduced dual reticulation and open space firefighting but had not yet been assessed for firefighting purposes (Noller and Wickramasinghe, 2006). Recycled water from the nearby advanced water treatment plant was proposed as an alternative to potable water supply by adopting reuse practices in the new urban development and Springfield and used secondary treated effluent from the Carole Park sewage treatment plant (STP) (Fig. 1) at Ipswich, Queensland and <10 km from the Springfield recycling plant (Gardner, 2003).

The role that aerosol forms play in exposure is clearly important where recycled water is used for fire fighting due to the proximity of the heat source, the utilization of water on a large scale as a mist, and the production of particles of contaminants from aerosol forms following evaporation of the water. It is the very fine (< 5 micron) particles that penetrate deep into the lung. Mode of accidental ingestion as a means of assessing exposure of firefighters was identified (WSAA, 2004). Absorption through the skin and contact with the eyes may be a significant pathway of exposure to recycled water. Queensland firefighters were estimated to spend 1-10 hr at a fire event (an average of 2 hr per event). Particles present from substances that remain after aerosol water is evaporated may have toxicological impacts and are grouped into eleven categories (Noller and Wickramasinghe, 2006).

The Queensland guideline values for recycled water (for low exposure uses) (QEPA, 2005a) are Class A+ Less than 1 E. coli cfu / 100mL or less than 1 E. coli Myeloproliferative neoplasms (MPNs) / 100 mL in at least 95% of samples taken in the previous 12 months; Class A Less than 10 E. coli cfu / 100 mL or less than 10 E. coli MPN / 100 mL in at least 95% of samples taken in the previous 12 months; and Class B Less than 100 E. coli cfu / 100 mL or less than 100 E. coli MPN / 100mL in at least 95% of samples taken in the previous 12 months. Additional microbiological criteria are required when dual reticulation is supplied to households as is the case at Greater Springfield (Fig. 1).

OBJECTIVE

The objective of this study was to evaluate whether the guidance endorsed by the Queensland Class A+ or Queensland Class B recycled water for firefighting is appropriate to control potential risks to firefighters and to identify if further study of chemical contaminants at water treatment facilities producing recycled water can demonstrate a better understanding of lesser contaminants.

METHODOLOGY

The study was conducted on the effluent of the Carole Park sewage treatment plant (STP) wastewater treatment plant. The wastewater at the plant is processed to remove organics and suspended solids and is then chlorinated and stored in an open 14 ML lagoon within the operational area of Ipswich Water, S.E. Queensland (Noller and Wickramasinghe, 2006). Treated effluent is released via a submerged outfall 500 m downstream of the Brisbane River confluence of Woogaroo Creek, which is 63.7 km Adopted Middle Thread Distance (AMTD) to the Pacific Ocean. The Carole Park catchment receives substantial trade waste load from industry and the treatment process. This can include runoff from historical coal mining waste and fly ash from the former Swanbank Power Station. Treated effluent is then given further processing at the Springfield Recycled Water Plant using microfiltration, UV treatment, and chlorination producing Queensland Class A+ recycled water (Noller and Wickramasinghe, 2006; QEPA, 2005b).

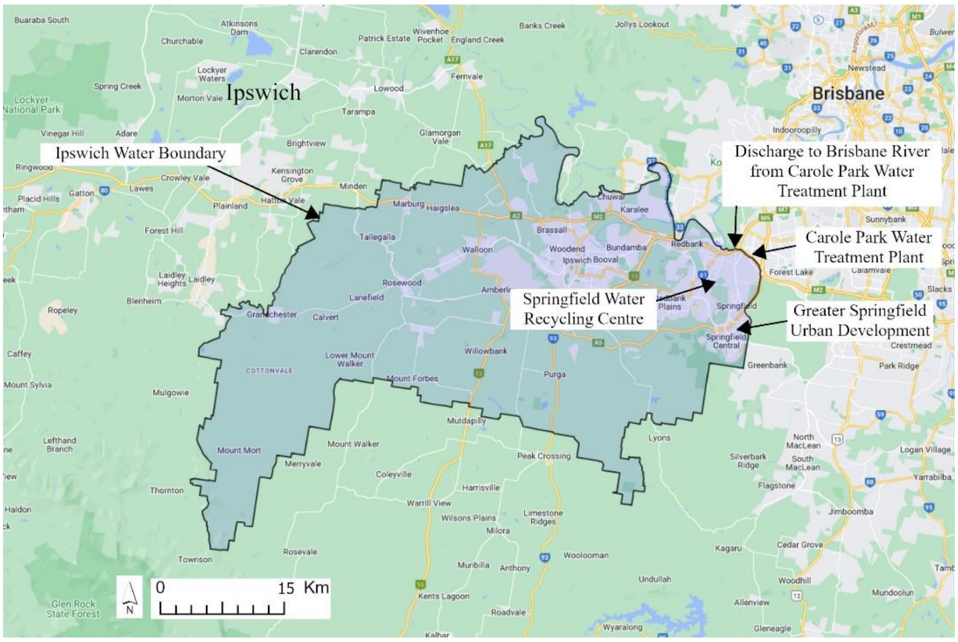

Fig. 1 Location of the Carole Park sewage treatment facility and the Springfield water recycling centre within the Ipswich water boundary

The urban Springfield Water Recycling Treatment Centre also receives about 3 ML per day of treated water from the Carole Park STP. The chemical loads in sewage that are treated to become recycled water at the Springfield recycling plant are typically 60% urban and 40% industrial sources of sewage collection from a catchment with inputs of wastes from historical coal mining and power station operation within the Ipswich Water operational area (Fig. 1).

Data provided for the review of chemical toxicity (Noller and Wickramasinghe, 2006) included access to recycled water quality for dual reticulation use at homes in Springfield (QEPA, 2005b). The summary of this data indicates the kinds of contaminants accumulated from within the Carole Park catchment. Analyses were carried out by Ipswich Water's Environmental Laboratory.

RESULTS AND DISCUSSION

Table 1 provides selected water quality data in the effluent of the Carole Park STP recycled water supplied to Springfield. An assessment was made of levels of contaminants that could be a health risk from recycled water at Springfield. Samples were collected weekly to three times to assess variation in time scale. More data is found in the original report (Noller and Wickramasinghe, 2006; QEPA, 2005b). Health risks of the chemical and endotoxin composition of Class A+ recycled water produced by the Springfield advanced water treatment plant compared to potable water supply (NHMRC and NRMMC, 2011). The median pH in the first treated water was 7.1 and all pH values were 6.8-7.7. This is within the drinking water target range of 6.5 to 8.5 (NHMRC and NRMMC, 2011). Total chlorine residual was a median of 1.7 mg/L and all measurements were 0.7 - 3.0 mg/L with 5 measurements <1.0 mg/L. The median free chlorine residual was 0.1 mg/L, indicating all disinfectant is in the form of chloramines. The median final stage turbidity was 0.228 NTU (range 0.1 - 0.26 NTU) and within the ADWG target of < 1 NTU where chlorination is practiced.

Sodium had a median value of 190 mg/L and this is marginally above the ADWG target for drinking water of 180 mg/L. Bromine in the water entering the Springfield WTP was a median of 540 μg/L. Subsequent measurement of bromate concentration in water leaving the Springfield WTP showed <20 μg/L bromate (NHMRC and NRMMC, 2011). After treatment, the median molybdenum level was <10 µg/L. As molybdenum is an oxyanion it usually remains in solution. Treated water showed an upper level of 24 µg/L compared to a (e.g. arsenic) ADWG of 7 µg/L but a median level of < 5µg/L was also found. Organics, PAHs, chlorinated hydrocarbons, pesticides, and radioactivity, not listed in Table 1, were all at their respective detection limits. Atrazine and related herbicides such as simazine and diuron may warrant attention as they are water-soluble and are not removed by absorption of solids. However, atrazine with a median level of 0.35 µg/L and a maximum of 0.88 µg/L was well below the ADWG 40 µg/L limit for drinking water. Nutrient measurements for nitrogen and phosphorus for secondary treated effluent at the Carole Park STP show average total nitrogen levels of around 6 mg/L and total phosphorus levels averaged around 3.4 mg/L above the minimum to trigger algae blooms in the 14 ML effluent storage dam at Carole Park.

Table 1 Effluent water quality of Carole Park STP recycled water supplied to Springfield

Measurement [a]	Units	Median	Range	Drinking water [b]
pH	nil	7.0	6.7-7.3	6-5-8.5
EC	µS/cm	1450	1200-1690	-
N-Nitrate	mg/L	2.9	<0.2-8.5	10
Total Nitrogen	mg/L	5.4	2.2-10.8	-
Total Phosphorus	mg/l	2.8	0.7-6.9	-
Aluminum	µg/L	18	<10-100	200
Arsenic	µg/L	<40	<40	7
Boron	µg/L	90	70-140	4000
Cadmium	µg/L	<10	<10	2
Chromium	µg/L	10	7-54	50
Copper	µg/L	<10	<10	1000
Fluoride	µg/L	720	430-970	1500
Iron	µg/L	100	<10-810	300
Lead	µg/L	<10	<10-100	10
Manganese	µg/L	34	24-74	100
Mercury	µg/L	<10	<10	1
Molybdenum	µg/L	36	14-158	50
Nickel	µg/L	10	<5-20	20
Selenium	µg /L	<70	<70	10
Zinc	µg/L	28	20-33	3000

Notes: a. Trace metals/metalloids are total concentrations, b. Drinking water guidelines (NHMRC and NRMMC, 2011)

The historical finding of coal mining waste being associated with fluoride, molybdenum, selenium, and other trace elements (Noller and Henderson, 2023) indicates that Permian Coal formations in NSW (similar geology to coal formations at Ipswich) are likely to have high levels of fluoride, molybdenum and selenium in similar natural formations. The historical sources from coal mining and power station activities via the leaching of alkaline water from waste dump seepage that enters the catchment need to have better environment control to minimize their dispersion to the Carole Park STP. Characteristics of Permian Coal formations found in the Ipswich Water operational zone (Fig.1) require further evaluation as this data enables new interpretations of the sources of fluoride, molybdenum, and selenium found in the Ipswich Water operational zone.

However, no measurements for Microcystins and Cylindrospermopsin nor their treatment byproducts were available at that time. It is also noted that Lipopolysaccharide endotoxins are difficult to measure and not easily sampled (NHMRC, 2008). A priority was given to chemicals including fluoride, molybdenum, selenium, and herbicides such as triazines group (e.g. atrazine) and also to ensure that significant levels of cyanobacterial toxins and endotoxins do not arise in the water sent to the Springfield Recycled Water Treatment Plant as the treatment processes at this plant would not remove these toxins except when remaining inside algae. The National Guidelines (NRMMC/ EHPC, 2008) and Queensland water recycling guidelines (QEPA, 2005a) are based on adherence to the overall principle that recycled water is a sustainable practice. The Springfield Recycled Water Treatment Plant demonstrates meeting the criteria for Class A+ recycled water.

The WSAA report has discussed lipopolysaccharide endotoxins in detail (WSAA, 2004). However, what was lacking was some discussion about specific cyanobacterial toxins. The blue-green algal toxins Cylindrospermopsin and Microcystins are the key toxins found in SE Queensland (CRC WQT, 2002). All these toxins are highly toxic through the oral route and the presence of these toxins in recycled water could be a threat to firefighters; Cylindrospermopsin is additionally a dermal toxin. This issue was also not addressed in the WSAA report. When used in firefighting, aerosols and dermal exposure are identified as the most likely exposure routes (NHMRC, 2008).

A risk assessment was completed for the Department of Emergency Services (DES, 2006) and Queensland Fire and Rescue Service (QFRS) to bring together all data and analyze the potential risks resulting from the use of Class A+ treated recycled water for firefighting purposes (DES, 2006), the treated recycled water from the Springfield Recycled Water Treatment Plant in Ipswich was used as a basis for this study. The overall finding from the risk assessment was that provided the additional controls highlighted in this report are implemented, the Class A+ recycled water from the Springfield plant would be considered safe for firefighting. The risk assessment process was completed using a Semi-Quantitative Risk Assessment (SQRATM). Most of the hazards are removed or reduced by the Springfield plant and exist at or near the limits of detection. Limited historical algae data for the Springfield system showed relatively low levels of blue-green algae. Consequently, based on evidence collected for this risk assessment, at that time, health risks for firefighters from such organics were considered insignificant. Further research and development and a 'watching brief' were considered the appropriate response by workshop participants. Acceptable risk levels for safe drinking water and comparison with the estimated risk associated with using Class A+ Recycled Water for firefighting national/international (WHO, 1998) drinking water guidelines and overviews presented by toxicological and microbiological specialists attending the workshop, including the author. Design and plant operational shortcomings were recommended for improvement from the risk assessment.

CONCLUSION

The summary statement of applicability is based on an extensive review and analysis of (i) Guidance on fire fighting with recycled water; (ii) Hazards found in recycled water (both microbial and chemical); (iii) Recycled sewage compared to other waters; (iv) Epidemiological risk assessment; and (v) Quantitative risk assessment modeling. Whilst the coverage of microbial hazards was detailed, the specific reference to chemical hazards is limited to endotoxins and brief mention that health effects from exposure to chemicals through exposure to contaminated water tend to manifest as a result of prolonged (chronic) exposure rather than from short-term sporadic (acute) exposure. Finally, a comprehensive data set of microbiological data from a parallel study and the current chemical contaminant study were combined in the risk assessment. The overall finding was that provided the additional controls were implemented, the Queensland Class A+ recycled water from the water treatment facility used in this study would be safe for firefighting. Health risks to firefighters from recycled water mains were associated with the chemical and endotoxin composition of Class A+ recycled water health risks to firefighters from recycled water mains and associated with the chemical and endotoxin composition of Queensland Class A+ recycled water. The historical finding of coal mining waste having an association with fluoride, molybdenum, selenium, and other trace elements indicates that historical sources from coal mining and power station activities need to have better environmental control to minimize their collection to the feed to the Carole Park STP.

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