Requirements for the supply of recycled greywater for cooling tower treatment plants

Guideline under the *Plumbing and Drainage Act 2018*

January 2023

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Purpose

The purpose of this Guideline is to support the safe treatment and supply of recycled greywater from greywater (cooling tower) treatment plants (GCTTP) for use as make-up water in cooling towers under section 79(5) of the *Plumbing and Drainage Act 2018* (the Act).

This Guideline should be used for the design, installation, commissioning, operation and maintenance of GCTTP's. This Guideline is intended to assist in meeting the requirements of the Act and the Plumbing and Drainage Regulation 2019 (PDR).

Authority

This Guideline is made under section 154 of the Act.

Under section 154(1), the chief executive may make guidelines for matters within the scope of the Act to help compliance with the Act.

Under section 154(2)(a) of the Act, the chief executive may make a guideline about carrying out plumbing or drainage work ('work'), including ways of complying with the code requirements for the work.

The Act[1] requires a licensee who is carrying out work to have regard to the guidelines that are relevant to carrying out the work.

The requirement to have regard to guidelines made under the Act extends to investigators appointed by the Queensland Building and Construction Commission (QBCC), local governments and inspectors employed by local governments. Investigators and inspectors are required to have regard to a guideline that is relevant to performing their functions[2], and a local government must have regard to guidelines that are relevant to its administration of the Act[3].

Scope

This Guideline implements a risk-based framework in accordance with the principles contained in the *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (phase 1).[4] The scope of treatment plant considered by this Guideline is limited to plants designed to treat more than 20kL of greywater per day for the single purpose of providing make-up water for air conditioning cooling towers in Queensland.

This Guideline does not apply to:

- domestic-scale greywater treatment plants which are required to comply with AS 1546.4:2016 and Queensland Plumbing and Wastewater Code (QPWC).
- treated greywater for uses not specified in the Act.

This Guideline considers greywater to be untreated, used water from domestic plumbing appliances which has not come into contact with toilet or kitchen waste. It may be collected from showers, wash basins, bathtubs, washing machines and laundry tubs. It does not include used

[1] Act, section 46(1).

[2] See the Act, section 133 and section 141.

[3] See the Act, section 138.

[4] Natural Resource Management Ministerial Council/Environment Protection and Heritage Council/Australian Health Ministers' Conference (2006).

water from urinals, toilets, kitchen sinks or dishwashers. Water discharged from kitchen sinks and dishwashers is excluded due to its unsuitability for reuse.

Typical installations of GCTTPs are expected to be limited to large apartment and hotel developments where significant volumes of treated greywater are available to be used for cooling tower make-up water. The scope of this document is limited to the greywater collection and treatment processes. It does not directly include consideration of how the recycled greywater is used by the cooling towers. This means that the potential exposure of humans to hazardous chemicals or microbes in the greywater will be limited to workers associated with the GCTTP and the cooling towers supplied by the GCTTP. It is expected that the health and safety of workers engaged in these plant operations will be protected by appropriate safeguards under the existing Queensland work health and safety regulatory framework. The actual use of the recycled greywater as make-up water for cooling towers should therefore be managed in accordance with the risk management system for cooling towers in Queensland (see *Guide to Legionella control in cooling water systems, including cooling towers* (Office of Industrial Relations, 2018)).

Regulatory approvals

Each installation of a GCTTP will require an approval from the relevant local government in accordance with the Act [5]

Recycled Greywater Management Plan

The PDR provides that an application for a GCTTP must be accompanied by a plan for managing the treatment plant – a Recycled Greywater Management Plan (RGMP)[6].

The purpose of the RGMP is to manage the risks associated with the provision of recycled greywater for cooling tower make-up water. The RGMP should define the water quality objectives for the system and describe how implementation of the RGMP will ensure those objectives are achieved and maintained.

The RGMP should be prepared in advance of the installation of the GCTTP. However, it should also be updated following commissioning of the plant to ensure anything learnt from the commissioning process is fed back into the operational procedures for the plant.

Under the PDR Schedule 6, section4A(3) the RGMP must including the following:

- the identity and contact details of all persons and their responsibilities in relation to the GCTTP including a list of relevant contractors, body corporate office holders, and emergency contacts, etc
- a description of the greywater collection system, the treatment processes and the location of the treated water transfer point to the cooling tower
- the identification of hazards, hazard sources and hazardous events associated with the greywater collection and treatment process
- an assessment of the risks associated with the identified hazards and hazardous events
- a description of the control measures and corrective actions to be implemented in response to the risks

[5] See the Act, section 66.

[6] PDR – Schedule 6, section 4A.

- the details of the commissioning validation monitoring to be undertaken to demonstrate the plant is able to produce water of the quality required
- a description of how the control measures and effectiveness of the RGMP will be monitored (via operational and verification monitoring)
- a description of the skills and awareness required by each employee and contractor working with recycled greywater, including staff that work on the cooling towers supplied by the GCTTP
- a description of the record keeping methods to be implemented under the RGMP
- a description of the frequency at which reviews and audits of the RGMP will occur.

An example template for a RGMP is shown in Appendix 1 of this document.

Responsible use and management of recycled greywater

The owner is responsible for ensuring compliance with the conditions of the permit including the requirements of the RGMP.

Description of the greywater collection and treatment system

The RGMP should describe in detail all aspects of the collection and treatment system that need to be understood by the GCTTP operators and maintenance staff, and also by any government agency staff or contractors involved in compliance or auditing of the system. This should include clear schematics (not technical drawings). The description of the system should include:

- the sources and volumes of the greywater intended for treatment and reuse (Table 1 shows some typical anticipated quality parameters)
- an outline of how the GCTTP will meet the standard prescribed by the PDR[7] for treated greywater standards (Table 2)
- each step in the treatment process for the greywater
- the location of online monitoring and water testing points
- any storage tanks, before or after treatment
- the provision of a backup water supply (potable or non-potable) including backflow prevention
- emergency overflow provision for disposal of out of specification water
- the location of the point of transfer between the GCTTP and the cooling tower intake for the make-up water.

[7] PDR – Schedule 7A.

Table 1. Typical physical and chemical parameters measured in untreated greywater (excluding kitchen wastewater)

Parameter	Units	Range
Suspended solids	mg/L	30-120[1]
Turbidity [2]	NTU	30-70[1]
BOD_5	mg/L	60-200[1]
Ammonia	mg/L	1-10[2]
Total phosphorous	mg/L	0.5-5[2]
Sulphate	mg/L	10-50[2]
pH	Nil	6-8.5[1]
Total hardness (as $CaCO_3$)	mg/L	130-150[2]
Conductivity	µS/cm	200-600[1]
Total Organic Carbon (TOC)	mg/L	50-100[2]
E. coli	cfu/100mL	100-10,000,000[1]

[1]AS/NZS 1546.4:2018.

[2]Technical Guide for Greywater Recycling System Singapore

Table 1 shows the range of some typical parameters within greywater during commissioning of the GCTTP. The actual values of the greywater influent to the plant should be characterised in case any aspects of the treatment process need to be adjusted.

Required standard for greywater from greywater (cooling tower) treatment plants

Table 2. Treated greywater standards for cooling tower use (Plumbing and Drainage Regulation 2022[8])

Parameter	Value	Unit
BOD_5	<5	mg/L
Turbidity	<2	NTU
pH	6-8.5	Nil
Free available chlorine	>0.5	mg/L
Heterotrophic colony count	<500	cfu/100mL
E. coli	Not detected	cfu/100mL
Total *Legionella*	Not detected	cfu/100mL

BOD_5 = five-day biochemical oxygen demand

mg/L = milligrams per litre

NTU = Nephelometric Turbidity Units

cfu = colony forming units

[8] PDR – Schedule 7A.

Hazard identification and risk assessment

Effective risk management of recycled greywater requires:

- the identification of all potential hazards and hazardous events associated with the collection, treatment and supply elements of the greywater system
- the identification the sources of those hazards
- an assessment of the level of risk presented by each hazard or hazardous event

While all hazard sources must be identified, it is not required to risk assess the hazard sources, only hazards and hazardous events.

Hazards

A **hazard** includes a biological chemical, physical or radiological agent that has the potential to cause harm. A **hazard source** includes the location or activity where the hazard arises. A **hazardous event** includes an incident or situation that can lead to the presence of a hazard (i.e., what can happen and how).

Physical and chemical hazards

There are few physical or chemical hazards in domestic greywater that represent a risk to human health when the treated water is supplied only as cooling tower make-up water. However, there are some parameters that may represent a hazard for the treatment process or the operation of the GCTTP or the cooling tower that uses recycled greywater. This could include:

- nutrients (especially nitrogen and phosphorus) that may support microbial growth within the cooling tower water system
- various chemicals (mostly salts like sodium, magnesium and calcium compounds) that contribute to the build-up of scale within the greywater treatment system, pipework and cooling towers. Scale also limits the number of cycles that can be used by each cooling tower, and therefore increases make-up water use.

Microbial hazards

Use of recycled greywater as make-up water for cooling towers limits the potential for direct human exposure to microbial hazards within the greywater. The only exposure pathway of concern for the public is indirect, via inhalation of cooling tower blower exhaust. As such, the microbial hazards of greatest concern are Legionella and the build-up of biofilm which may promote *Legionella* growth.

Legionella

Legionella bacteria are typically found in water and soil. There are over 50 species of *Legionella* bacteria, some of which can cause disease in humans. The most common disease-causing species are Legionella pneumophila, which occurs in water, and *Legionella longbeachae* which mainly occurs in soil and potting mix.

Most *Legionella* species, including *Legionella pneumophila*, thrive in warm water, and need the presence of other organisms (e.g. amoebae), as hosts, to multiply. They grow readily in man-made environments such as inside plumbing fixtures and pipes, where warm temperatures and the build-up of biofilm (also known as slime) provides an ideal environment.

Legionellosis is a collective term for diseases caused by *Legionella* bacteria including the most serious, Legionnaires' disease (which causes pneumonia), as well as the less serious condition of Pontiac fever. Humans might contract this disease by inhaling microscopic droplets (aerosols) of

water contaminated with Legionella bacteria from man-made systems such as cooling tower exhaust biofilm build up.

Biofilm is an accumulation of organic matter that coats the internal surfaces of all water pipes and other water treatment equipment, including water storages. It comprises a large and diverse community of algae, bacteria, protozoans and amoebae (as well as viruses) that thrive at temperatures typical of greywater (around 25-35°C).

Within water systems biofilms can help to protect opportunistic pathogens such as *Legionella* from stresses like temperature fluctuations and disinfecting chemicals, which makes them difficult to control.

Escherichia coli

Escherichia coli (E. coli) bacteria occur in the intestine of warm-blooded animals, including humans, and are shed in their millions in each gram of faeces. Small amounts of faeces are washed off people's bodies and their clothing and then make their way into greywater from showers, baths and laundries. While not necessarily associated with any particular human pathogens in water, their presence in treated greywater may indicate that the treatment process has not been operating effectively at all times.

Heterotrophic colony count

While only representing a small proportion of the overall total microbial population within water samples, heterotrophic colony count (HCC) provides an indication of the microbial load within the greywater. An effective treatment system should greatly reduce HCC levels in the treated water.

Hazard sources

Amongst the advantages of reuse of domestic greywater, in comparison with blackwater or sewage, is that the range of pollution sources is limited. As indicated above, the absence of toilet and kitchen waste, as well as trade waste (wastewater from industrial and commercial premises, which requires specific trade waste agreements with local government) means that many of the hazardous sources of contaminants normally found in municipal wastewater are absent.

Nevertheless, because greywater collection networks are in a sense 'open systems' it is still possible for people contributing to these networks to discharge hazardous chemicals to the system from time to time. Examples of this include paints, automotive oils and greases, pesticides and pharmaceuticals. While these will not all represent a risk to a GCTTP due to dilution, when present at a sufficiently high concentration, some of these chemicals could temporarily disrupt the effective operation of some types of greywater treatment, particularly where biological processes are relied upon as part of the treatment process.

The principal source of microbial hazards in greywater reuse systems is from the humans using the system. As people wash their bodies and their clothes, they inevitably shed microbes that exist on their skin as well as other parts of the body. It is not possible to prevent this, and so management of this hazard source will rely on the greywater treatment process itself.

Hazardous events

Hazardous events include both anticipated and unanticipated events that could disrupt either the greywater collection system or the treatment process. One example of a hazardous event that could cause significant disruption to a recycled greywater scheme would involve a cross-connection between the greywater collection pipework and the sewerage system that collects the blackwater and kitchen wastewater from the building. Such a scenario could arise in an apartment building where apartment owners are free to engage private plumbing contractors to undertake plumbing works. Given that the same pipe colour standards apply to greywater waste pipes from the kitchen

and from laundries and bathrooms, mitigation of, cross-connection risk must be considered. Mitigation of this risk is considered in the section on control measures and corrective actions.

The other principal source of hazardous events in a recycled greywater system is the treatment plant itself. The RGMP must consider all possible adverse events in the treatment process that could result in out of specification water being delivered to the cooling tower system and must provide appropriate controls to either prevent such events or reduce their impact to acceptable levels. Table 2.4 from *the Australian Guidelines for Water Recycling* provides a list of potential treatment plant failures:

- chemical dosing failures
- disinfection malfunctions
- equipment malfunctions
- failure of alarms and monitoring equipment
- inadequate backup for key processes
- inadequate equipment or unit processes
- inadequate filter operation and backwash recycling
- inadequate mixing of treatment chemicals/coagulants
- poor reliability of processes
- power failures
- significant flow variations through water treatment system
- use of unapproved or contaminated water treatment chemicals and materials.

Risk assessment

Once all relevant hazards and hazardous events have been identified, the RGMP must include an assessment of the risks posed by each of these. Risk is the likelihood of identified hazards causing harm either to the operation of the GCTTP, or to any exposed populations, in a specified timeframe, including the severity of the consequence (risk = likelihood × impact).

The *Australian Guidelines for Water Recycling* (section 2.2.4) recommend risk should be assessed at two levels:

- maximum (unmitigated) risk, which is risk in the absence of proposed measures; this is useful for identifying high-priority risks, determining where attention should be focused and preparing for emergencies and
- residual risk, which is risk after consideration of existing and proposed preventive measures; assessment of residual risk provides an indication of the safety and sustainability of the recycled greywater scheme or the need for additional preventive measures.

The person responsible for the GCTTP can select whatever risk assessment methodology they wish, noting that it must be relevant to the kind of risks being assessed. Suitable methodologies include those contained in the *Australian Drinking Water Guidelines*, the *Australian Guidelines for Water Recycling*, Hazard Analysis Critical Control Point (HACCP) or *ISO 31000:2018 – Risk management – Guidelines*. The risk assessment methodology from the *Australian Guidelines for Water Recycling* is illustrated in the template for RGMPs (see Appendix 1).

If the GCTTP is managed by the same entity that manages the cooling towers, it may be desirable for the entity to assess and manage risks associated with each facility as part of the same process. Where the GCTTP and cooling towers are managed separately, then each facility must assess and manage their risks separately, while still taking account of the interactions between both facilities. For example, the operator of the GCTTP has an obligation to ensure that an event or failure in the greywater treatment process that could compromise the operation of the cooling towers is communicated promptly to the cooling tower operator.

In general terms, the risk assessment process should:

- provide a prioritised list to help distinguish between high and low risks
- highlight any gaps in knowledge about hazards, hazard sources and risks that prevent accurate assessment of risks
- raise awareness amongst all persons with responsibilities for the GCTTPs of the significance of different risks
- help to guide investment in control measures towards the most significant risks, thereby potentially saving resources (both staff and money)
- help to prepare staff and contractors for what might go wrong, assisting with diagnosing incidents and emergencies.

Control measures and corrective actions

Control measures and corrective actions are the activities and processes used to prevent significant hazards from being present in recycled greywater or to reduce the hazards to acceptable levels. In the context of GCTTPs these controls may be applied at either the source of the greywater or during the treatment process.

Source water controls

A GCTTP should be designed to reliably treat greywater that conforms to the values described in Table 1. However, there is always the risk that members of the public or visiting contractors will not be sufficiently aware of the greywater recycling system within the building and thus they could dispose of certain contaminants that could impair the operation of the GCTTP. The risk of this happening in a multi-residence apartment building is less than for detached residences but is still possible. Therefore, operators of large GCTTPs are strongly encouraged to maintain the awareness of residents, visitors and contractors attending their building about what is not permitted to be put into any of the drains within a residence or room in the building.

To minimise the likelihood of occupiers disposing of unsuitable materials into the greywater collection system they should be made aware of the reuse of water from the facility and provided with any information they require to understand and comply with the requirements of the system.

This information should be available for the life of the project, not just at system start up. The information should include:

- which wastewater fittings in the premises feed the greywater system and which do not
- what waste is permitted to be discharged into these fittings
- what waste is not permitted to be discharged including paint, automotive oils and greases, pesticides and any other trade waste or industrial liquid waste
- a description of the treatment the water receives including where the treatment happens and what the treated water is used for

- on request, the RGMP should be available to all residents who own properties that contribute greywater to the GCTTP.

As discussed above under hazardous events, greywater recycling may involve a risk of accidental cross connections between the greywater pipes that carry kitchen wastewater from each dwelling and those that transfer greywater from the bathroom and laundry to the GCTTP. The Plumbing Code of Australia (PCA) requires that sanitary waste pipes connected to a GCTTP, or greywater diversion device, must be identified with labelling and placed at specific intervals as outlined by AS/NZS 3500.2. The label must state ‘greywater’ and comply with AS 1345 Australian Pipe Marking Standards.

If the supply of recycled greywater for a cooling tower is augmented by another water source, such as roof-harvested rainwater, the process of documenting hazards and hazard sources should include those that may arise from the additional water source.

Distribution system controls

All pipe work intended to distribute recycled greywater from the GCTTP as make-up water to cooling towers is required to be installed in compliance with the requirements of the PCA as a non-drinking water service. Recycled greywater must be supplied through plumbing installations in a way that avoids the likelihood of inadvertent contamination of any drinking water service, minimise any adverse impact on building occupants, the water service provider’s infrastructure, property and the environment. Pipes, pipe outlets, fittings, storage and holding tanks that are part of a non-drinking water service must be clearly identified as outlined in AS/NZS 3500.1.

Treatment plant controls

The most important control measures for a recycled greywater system are found in the GCTTP. This is because there are only limited opportunities for residents, visitors and contractors to significantly impair the quality of the source water (see above) and there should be no expectation for the operator of a cooling water system to remedy the quality of the treated greywater that is being received, beyond what is specified in agreed supply arrangements.

The *Australian Guidelines for Water Recycling* emphasise that treatment of any recycled water, including greywater, to a high standard, must include multiple treatment barriers. This will generally involve physical treatment, biological treatment and chemical treatment barriers. Physical treatment involves some form of screening or filtration to remove particles from the water. Biological treatment involves use of microbial biomass to break down pollutants into less harmful components. Chemical treatment may involve use of coagulation and flocculation chemicals to clump particles together to assist their removal through flotation or settlement as well as chemical disinfection, usually with chlorine compounds.

This multiple barrier approach is intended to ensure that reduced performance of one treatment barrier does not result in total loss of control over the entire treatment process. Equally, it may enable the GCTTP operator to temporarily increase the performance of other barriers while the defective barrier is being investigated or repaired (e.g. by increasing chlorine concentration during a temporary increase in turbidity). In the context of the supply of recycled greywater for use in cooling towers, it is recommended that GCTTPs use more than one type of treatment barrier (physical, biological or chemical) to achieve the required water quality standards at all times.

Critical control points and critical limits

Within a GCTTP critical control points (CCPs) are activities, procedures or processes where control can be applied, and that are essential for either preventing or reducing to acceptable levels those hazards that represent high risks. Risks that are very high will generally be the focus of CCPs.

Identification of CCPs is specific to each GCTTP, being based on knowledge of potential hazards and associated risks, and available control measures. Where possible, each identified hazard should have a CCP. More than one CCP may be associated with a single hazard, and a single CCP may prevent or reduce more than one hazard. CCPs should be selected appropriately because they will be the focus of operational control. Too many CCPs can make the system unwieldy, whereas too few can fail to provide adequate assurance of recycled water quality. For more information see *Australian Guidelines for Water Recycling*, section 2.3.2.

Once a control measure has been identified as a CCP, a critical limit must be set and validated. A critical limit is a prescribed value or level that distinguishes acceptable from unacceptable performance. When a process that represents a critical control point is operating within critical limits, performance in terms of hazard removal is regarded as being acceptable.

Corrective actions

Once all relevant CCPs and critical limits have been identified, and monitoring procedures put in place, it is essential for the RGMP to specify what the appropriate corrective actions should be in the event of any non-compliance with a critical limit. This is because deviation from a critical limit indicates loss of control of a process such that there may be an unacceptable water quality risk. In this case, appropriate corrective actions should be put in place immediately to re-establish control of the treatment process and the operator of the cooling towers should be notified.

Where the existing control measures identified do not sufficiently mitigate significant hazards, alternative and/or additional control measures should be identified that ensure risks are reduced to acceptable levels. A deviation outside an acceptable operating range for key parameters should result in the treated water either being recirculated or discharged to sewer until the parameter returns to the required range.

The *Australian Guidelines for Water Recycling* also recommend the setting of operational performance goals to provide early warning for when a critical limit is at risk of being non-compliant. These operational goals should be more stringent than critical limits so that corrective actions can take place before an unacceptable water quality risk occurs.

Greywater (cooling tower) treatment plant monitoring

There are three key forms of monitoring that should take place for a RGMP developed for new GCTTPs. These are:

- validation monitoring – will it work?
- operational monitoring – is it working now?
- verification monitoring – did it work?

These monitoring programs are usually understood to involve actual measurement and testing of treatment plant performance indicators but should also include ancillary aspects of the operation of the overall RGMP (e.g. testing of alarms).

Validation monitoring

Validation monitoring generally takes place during the commissioning phase for a new GCTTP. The system should be commissioned in accordance with the system specifications and manufacturer's instructions. Once a GCTTP is fully operational it is essential to have a specifically designed validation period that can demonstrate that the greywater collection and treatment process is able to continuously operate in accordance with the RGMP for the plant.

There is no pre-determined period over which validation testing should take place, but ideally it should encompass, as much as possible, the full range of operational conditions that the plant is designed to deal with. As there are only likely to be small variations in the quality of greywater being supplied to a typical GCTTP, the validation period does not need to be as extensive as for a recycled water plant treating municipal wastewater, and so four weeks at full flow could be a reasonable approach.

Any failures to meet water quality criteria during validation should prompt a thorough review of the system and a re-set of the validation timetable. As far as practicable, validation monitoring should be completed before recycled greywater is supplied to cooling towers, although it may continue into a pilot-testing period.

Operational monitoring

Before moving from system validation to full operations an operational monitoring program must be developed to ensure regular or, preferably, continuous oversight of the performance of each element of the treatment process. This means that for every potential CCP there needs to be a method for measuring those aspects of the incoming water that are critical to effective treatment, as well as those that indicate how effective each stage in the treatment process has been.

Where possible, monitoring of key treatment processes (e.g. filtration and disinfection) should be online and continuous, with alarm systems to indicate when operational target criteria become non-compliant. Failures of monitoring instruments should not compromise the system and, in some cases, particularly at CCP, backup equipment should be installed.

The response to a non-compliance with operational or critical limits will depend on the parameter or process being monitored, and its significance for the safety and regulatory compliance for the treatment plant but could even include shutting down supply of treated water if safe to do so.

Verification monitoring

Verification monitoring is not just about whether the final water quality standards have been complied with but also whether other key aspects of the RGMP have been properly implemented.

For example, a verification monitoring program for a GCTTP will need to not just demonstrate compliance with water quality standards shown in Table 2 but also should be able to show that:

- critical limits are in compliance with the plan
- alarms and other safeguards are functional
- all relevant signs and associated behavioural elements are in place (e.g. discouraging disposal, by residents or contractors, of unsuitable products into the greywater collection system)
- manuals and documentation are available to all relevant staff and contractors
- the operator of the cooling tower receiving the treated water is satisfied with the quality and quantity of water being supplied.

As with validation monitoring, verification monitoring should continue for a pre-determined period that is sufficient to demonstrate robust performance. Once there is sufficient evidence of compliance with all plan requirements, the system can transition to an ongoing program. Sampling points (preferably at the transfer point to the cooling towers) should be installed so that sampling can be carried out at the frequency specified in the RGMP. The testing of water samples should be performed by laboratories accredited by NATA for each specific test.

Quality control and quality assurance

Section 5.5 of the *Australian Guidelines for Water Recycling* state that quality assurance (QA) and quality control (QC) procedures are essential components of all phases of the monitoring program. They anticipate and help to avoid likely errors and problems and ensure that data collected are accurate and reliable. A quality assurance/quality control program should be developed and used for each component of the monitoring program. A key example would be the development of a schedule for periodic calibration of all instrumentation and equipment used in the GCTTP.

Employee awareness and training

Staff and contractors need to be aware of the potential consequences of system failure, and of how their decisions can affect the final water quality. Amongst the most important factors that need to be communicated and maintained are:

- an understanding of untreated and treated greywater quality
- the principles of risk management
- characteristics of the recycled greywater supply system and preventive strategies in place throughout the system
- regulatory and compliance requirements
- roles and responsibilities of employees and departments
- how their actions, or lack of action (e.g. in response to alarms), can affect water quality.

Record keeping

Efficient record keeping can indicate and forewarn of potential problems and provide evidence that the system is operating effectively. However, documentation and records systems should be kept as simple and focused as possible. There should be sufficient detail to provide assurance of operational control, when coupled with a suitably qualified and competent GCTTP operator. Activities that generate records include:

- assessment of the water supply system (flow diagrams, potential hazards, etc)
- employee and contractor training
- operational and recycled greywater quality monitoring
- corrective actions
- incident and emergency responses
- validation and verification monitoring results
- stakeholder consultation, including regulatory reporting.
- performance evaluations, reviews and audits.

Review and audit of the Recycled Greywater Management Plan

The performance of the GCTTP and the efficacy of the RGMP should be reviewed and audited on a systematic schedule. Management reviews of the RGMP are intended to allow relevant managers, operators and other key personnel to examine key aspects of the performance of the plant and to discover any adverse trends in water quality data or operational parameters that might give early warning of system failures. The scope of a management review could include some or all of the items shown above under Record keeping, plus any conditions attached to the plant as part of a regulatory approval.

External, independent audits are also essential to demonstrate to regulators and other stakeholders that the GCTTP is delivering compliant treated water to cooling towers and the RGMP is being properly and consistently applied. Frequency of external audits will be set down in the conditions of approval for each permit. External audits must be prepared by a suitably qualified person.

A suitably qualified person for the purposes of this Guideline means a person that:

- has the experience or qualifications appropriate to conduct the audit to which the report relates
- is familiar with the risks involved with the scheme
- is familiar with the requirements of the approved RGMP and the conditions of the plan
- has appropriate operational knowledge of both the scheme and its water quality criteria.

Where possible, the auditor should have audit accreditation or previous audit experience such as:

- International Organisation for Standards (ISO) such as ISO 9000, ISO 14000 and ISO 22000
- Hazard and Operability (HAZOP)
- Hazard Analysis and Critical Control Point (HACCP)
- Registrar Accreditation Board Quality Society of Australasia (RABQSA) – note RABQSA is now known as Exemplar Global
- regulatory auditing.

The auditor should also be familiar with the treatment technologies, operational procedures and public health risks associated with the scheme they are auditing.

Appendix 1 – Example template for a Recycled Greywater Management Plan

The text below can be used as headings for drafting of a recycled greywater management plan. Text in italics is advisory.

Introduction and purpose

This recycled greywater management plan (RGMP) is designed to ensure the protection of public health from hazards and hazardous events associated with the use of treated greywater from GCTTP as make-up water for cooling towers.

Scheme description

The scheme description should show the:

- *management commitment to safe recycling*
- *location of the GCTTP and scope of RGMP*
- *regulatory environment and compliance requirements (including conditions of approval, when granted)*
- *system process design (including source of feed water, treatment processes, storage and distribution, shown as a schematic that illustrates the flows of untreated and treated greywater)*
- *roles and responsibilities of managers, staff and contractors and key contact information for external stakeholders, including regulators.*
- *the expected source water quality and the treated water quality objectives*

Hazard identification

All potential hazards and hazardous events associated with the GCTTP should be documented.

Risk Assessment

For each identified water quality hazard or hazardous event, the significance of risk must be assessed, taking into account the probability of an adverse event occurring, the severity of the consequences of the event and the availability of control and/or mitigation measures.

Tables A1 to A3 provide an example of a qualitative risk assessment process using risk matrices adapted from the Australian Guidelines for Water Recycling. Hazards and associated risk levels will vary from scheme to scheme depending on the source greywater, treatment systems and how the cooling towers are managed. Identified hazards and risk levels will also vary according to the intent of the risk assessment. The outcome of the risk assessment process should be a prioritised list of hazards and hazardous events that must be controlled to ensure safe management of the supply of treated greywater to the cooling towers.

The examples shown in the tables below are for illustration only; each risk assessment must provide its own descriptors of likelihood and consequence for the risks being assessed.

Table A1. Qualitative measures of likelihood

Level	Descriptor	Example description
A	Rare	May occur only in exceptional circumstances, e.g. once in 100 years
B	Unlikely	Could occur within 20 years or in unusual circumstances
C	Possible	Might occur or should be expected to occur within a 5 to 10-year period
D	Likely	Will probably occur within a 1 to 5 year period
E	Almost certain	Is expected to occur with a probability of multiple occurrences within a year

Table A2. Qualitative measures of consequence or impact

Level	Descriptor	Example description
1	Insignificant	Insignificant impact or not detectable (e.g. a critical limit is out of compliance for short period, but no impact on supply)
2	Minor	Operational – Minor impact on water quality for limited time period (e.g., hours but not days) Health – Minor impact for small population (e.g. small risk of *Legionella* growth in water supply at transfer point but not in cooling towers)
3	Moderate	Operational – Minor impact for longer time period (e.g. failure of one treatment barrier impacting supply for days but not weeks) Health — Minor impact for large population (e.g. low *Legionella* count from cooling towers over several days)
4	Major	Operational – Major impact for limited time period (e.g. total loss of supply for hours but not days) Health — Major impact for small population (e.g. high *Legionella* count from cooling towers over several days)
5	Catastrophic	Operational – Major impact for extended time period (e.g., total loss of supply for more than a few days) Health — Major impact for large population (e.g. high *Legionella* count over several weeks)

Note: Operational impacts assumes impacts for GCTTP are assessed separately from cooling towers. Health impacts only need to be considered if risks from cooling towers are assessed and managed together with the GCTTP.

Table A3. Qualitative risk estimation

Likelihood	Consequence				
	1 Significant	**2 Minor**	**3 Moderate**	**4 Major**	**5 Catastrophic**
A Rare	Low	Low	Low	High	High
B Unlikely	Low	Low	Moderate	High	Very High
C Possible	Low	Moderate	High	Very High	Very High
D Likely	Low	Moderate	High	Very High	Very High
E Almost certain	Low	Moderate	High	Very High	Very High

Control measures

Describe here all locations, processes and activities (operational and critical control points) where a hazard or hazardous event can be managed and document control measures (including setting of critical limits) at these points, where possible. Include development of procedures for management of incidents and emergencies

GCTTP monitoring

Describe here all procedures for monitoring the effectiveness of the RGMP, including validation, operational and verification monitoring and QA/QC.

Employee and contractor awareness and training

Describe the skills required for each employee and contractor involved in the operation and maintenance of the GCTTP, and ensure that appropriate training and, over time, refresher training is provided to maintain the required awareness and skills for the life of the GCTTP. Also ensure that employees and contractors working on the cooling towers receiving the treated greywater are aware of any risks associated with its use.

Record keeping

Establish which records need to be maintained, the purpose for the record and how long it needs to be maintained. This should include maintenance of an accurate record of all observations and measurements at CCPs for long enough to ensure effective review by management and external auditors.

Review and audit

Describe how implementation of regular reviews and audits of the RGMP will occur.

Attachment 1: References

Queensland Government documents

Office of Industrial Relations (2018) *Guide to Legionella control in cooling water systems, including cooling towers*.

Other documents

Natural Resource Management Ministerial Council/Environment Protection and Heritage Council/Australian Health Ministers' Conference (2006) *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks* (phase1).

Australian Drinking Water Guidelines

Australian Guidelines for Water Recycling

Hazard Analysis Critical Control Point (HACCP)

ISO 31000:2018 – Risk management – Guidelines

Technical Guide for Greywater Recycling Systems – Singapore

National Construction Code, Volume 3 – Plumbing Code of Australia

AS 1546.4:2016 – On-site domestic wastewater treatment units – Part 4: Domestic greywater treatment systems

AS/NZS 3500.1:2021 – Plumbing and Drainage – Part 1: Water services

AS/NZS 3500.2:2021 – Plumbing and Drainage – Part 2: Sanitary plumbing and drainage

AS1345:1995 – Identification of the contents of pipes, conduits and ducts.

Attachment 2: Definitions

The following are definitions of terms used in this Guideline.

Term	Description
Hazard	A hazard includes a biological chemical, physical or radiological agent that has the potential to cause harm.
Hazard source	A hazard source includes the location or activity where the hazard arises.
Hazardous event	A hazardous event includes an incident or situation that can lead to the presence of a hazard (i.e. what can happen and how).