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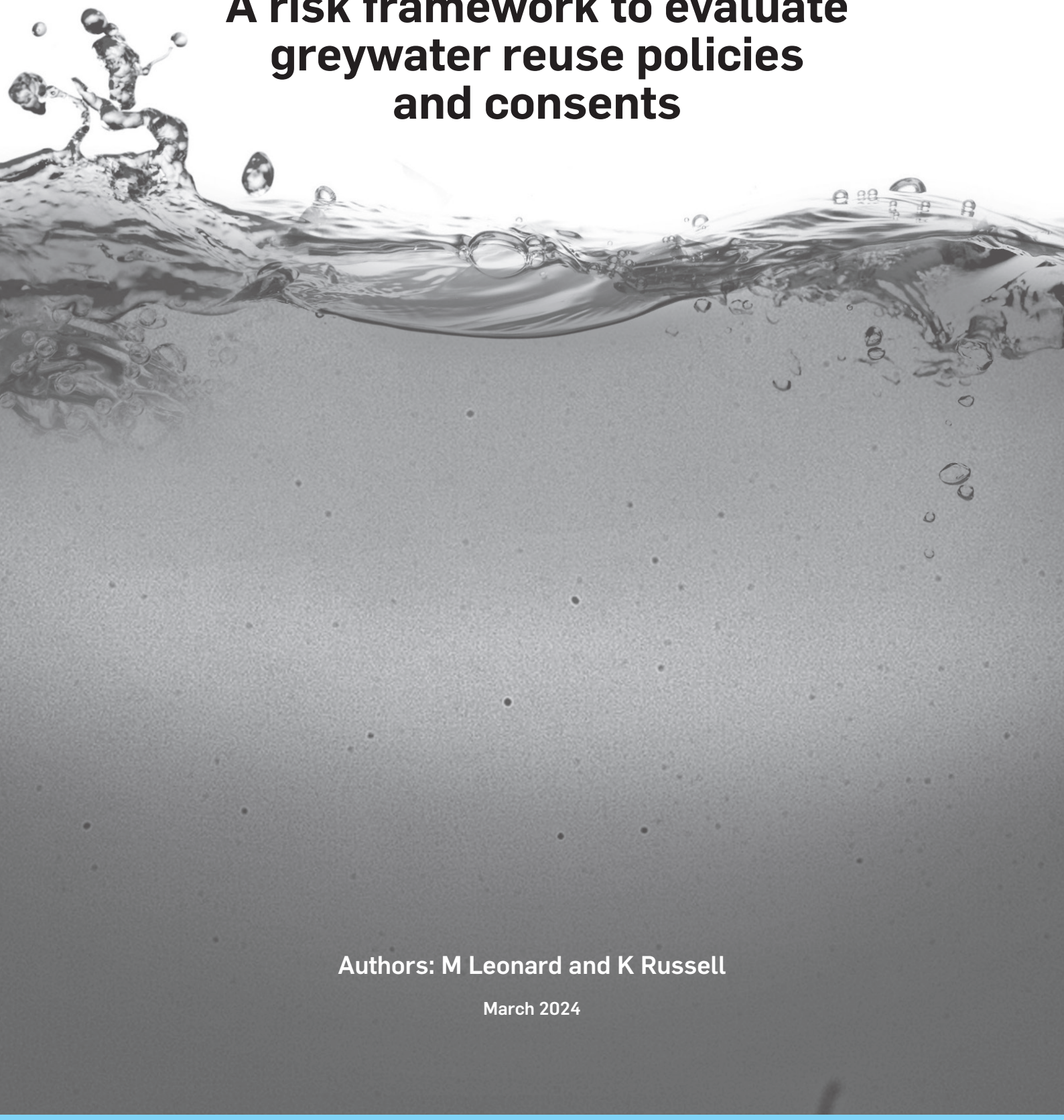
A risk framework to evaluate greywater reuse policies and consents



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INTRODUCTION

Greywater systems are becoming more widespread in New Zealand as the drivers for water reuse have expanded from management of hydraulic loading for poorly performing on-site wastewater treatment systems and managing high water use, to addressing water scarcity, water charges, climate change and sustainable design. Water conservation should be the first step to manage water scarcity and many council websites have good information on household water conservation tips. During drought conditions reuse of greywater during water restrictions is a pragmatic approach to managing an acute water shortage. Longer term, permanent systems may also be installed by householders as an adaptation to climate change, to manage increasing water charges, as part of sustainable design or because of issues with disposal of on-site wastewater either because the land area is too small or drainage is poor. Again, water conservation and/or rainwater use would be the preferable approach.

There are a broad range of greywater reuse practices in New Zealand which are regulated by regional councils. See Legislation, Regulations, Standards and Guidelines (page 8).

Contaminants in greywater may present a health or environmental risk (NRMMC et al 2006). Information resources are important to support safe practice, however, websites, manuals and guidelines tend to be specific to a particular reuse, with most information on permanent installations. There is a lack of appropriate information about safe practices. e.g. when, for instance, bucketing greywater onto the garden. Due to the informal nature of this activity, householders rely on council information such as websites, which varies across councils. Council rules, guidelines and consent conditions for other greywater reuse differ across New Zealand with different levels of risk management. In the absence of New Zealand guidelines a more consistent approach across New Zealand will support best practice.

This document presents elements of a risk framework that can be used as a tool to evaluate if the risks associated with greywater reuse are adequately addressed and that the risk mitigation measures will work within councils' policies, permitted activity rules, guidelines and resource consent applications. The framework uses parts of a risk framework relating to system analysis and management. It includes identification of hazards, appropriate preventive control measures for risk treatment and processes for assurance that the risk treatment(s) will be effective. It does not cover a full risk assessment which would be undertaken as part of the design process for greywater reuse schemes. *The Australian Guidelines for water*

recycling: Managing health and environmental risks (Phase 1) (AGWR), (NRMMC et al 2006) provide a full risk assessment methodology. The framework can be applied to assessing polices and rules for greywater reuse in a single dwelling, where there will be a number of exposure pathways to pathogens circulating within a household which presents a lower health risk, or larger facilities which will have increased potential exposure, and therefore risk, as there is the potential for pathogens to transfer to a larger number of people not already exposed, and facilities which cater to vulnerable groups such as children, elderly or people who are immuno-suppressed. Environmental risks are also likely to increase for larger facilities. For these larger reuse activities additional risk assessment, risk treatment, monitoring, assurance and a risk management plant would be required.

Information about common types of greywater reuse is presented within the framework to assist those involved in managing greywater reuse. Both health and environmental aspects are covered to provide a single resource that supports safe and sustainable practice.

The activities covered are those commonly used in New Zealand:

1. manually bucketing greywater over the garden
2. greywater diversion device to the garden
3. greywater treatment and disposal to land
4. greywater treatment and reuse for toilet flushing.

A brief summary of greywater and reuse systems is provided as an introduction. Examples are provided of greywater reuse, in a table which identify the hazards, appropriate preventative control measures and assurance processes which can give confidence that the risk treatment(s) will be effective. This framework provides a guide to analysing the issues that would need to be addressed in policy, guidelines and resource consent applications. It is not intended as an exhaustive list as there will be site specific issues and the size of the activity which need consideration. As water volumes and the potential for exposure increase, the risk will increase and will need to be assessed on a case-by-case basis.

GREYWATER REUSE

What is greywater?

Greywater is *"The domestic wastes from a bath, shower, basin, laundry and kitchen but excluding toilet and urinal wastes. It may contain pathogens"* (AS/NZS 2012). Where urine separation occurs, e.g. from a waterless toilet, the urine must be directed to a sewage treatment system. A survey of greywater systems in New Zealand showed that did not occur, with 23% of greywater systems surveyed containing greywater and urine (Leonard et al 2016). Inclusion of urine is a health concern as poor urine-faeces separation may be a source of faecal pathogens.

Contaminants in greywater reflect the source of the water. All sources potentially contain microbial pathogens and other micro-organisms. Greywater from the laundry may also contain laundry detergents, softeners and stain removers as well as contaminants on the clothes, such as grease, oils, fats and skin. The laundry tub may be used for disposal of chemicals such as oil, paint, cleaning products, stain removers and disinfectants. Greywater from showers and the bath may contain products used for personal care (soap, shampoo), dyes, skin, hair, cleaners, and disinfectants. Bathing babies or washing pets in baths, showers or laundry tubs may increase faecal contaminants. The bathroom sink is used to wash hands after the toilet which is a potential source of pathogens and the greywater may also contain personal care products and hair dyes. Kitchen greywater is normally excluded from domestic greywater reuse systems as it may contain may contain food with high concentrations of detergents, organic and solid contaminants and pathogens from food. The kitchen sink may also be used to dispose of household cleaners. Dishwasher greywater will have a very highly alkaline pH, due to detergents used.

The concentrations of contaminants are likely to be specific to a household, depending on the number and age of occupants, the amount of water used, and any relevant cultural practices (Roshan and Kumar, 2020; Shaikh and Ahammed 2020). Because greywater can contain a highly variable profile of contaminants, the concept of safer "light" greywater (low concentrations of contaminants) and higher health risk, "dark" greywater (higher concentrations of contaminants) is problematic and not supported by a New Zealand study of greywater characteristics (Leonard et al 2016). Variation in the concentration of contaminants can present design challenges for treatment systems, as there are no standard "greywater" characteristics (Leonard 2021). Specific designs are required where kitchen sink greywater is included and Australian guidelines refer the householder to the greywater treatment system manufacturers' instructions to ascertain if laundry tubs can be included.

Greywater reuse systems

On-site domestic greywater can be reused in a variety of ways, with and without treatment.

Untreated greywater

Householders may manually bucket untreated greywater onto the garden or attach a hose to the washing machine for garden irrigation. Using this method only low volumes of greywater are likely to be reused. The householder selects appropriate greywater sources, excluding greywater likely to be contaminated. The householder can also select which areas of the garden to water taking into account moisture levels, soil and plant health and they can vary the locations which are watered. The householder is present during the watering process to ensure there is no runoff or ponding. Suitable sources of greywater are identified in Box 1.

The other method of untreated greywater reuse is a greywater diversion device (GDD). This is a permanent installation which diverts untreated greywater from sewage treatment to the garden for subsurface irrigation. A filter removes solids and lint to avoid clogging the irrigation lines. Subsurface irrigation provides a physical barrier between the greywater and household occupants. It should only be used when the garden needs watering, reducing the risk of over-watering and runoff. There are no applicable standards for the greywater quality, but the householder can ensure that the greywater has low levels of contamination and only use appropriate sources (Box 1).

Treated greywater

Treating greywater increases the range of reuse options but may also increase the potential for human contact, increasing the associated human health risk, so the assurance process needs to be more substantive. The quality of the treated greywater determines the type of reuse. Suitable sources of greywater are given in Box 1 with a summary of treatments.

The most basic level of treatment is removal of solids (measured as total suspended solids – TSS) and organic matter (measured as BOD_5). Kitchen sink greywater is not normally included, but if it is, the greywater treatment system (GTS) must be specifically designed to treat the high concentrations of solids, fat, oil, grease and organic contaminants from food. Dishwashers have very high pH and should not be connected. Food waste disposal units create high concentrations of solids and organic material and increase water volumes. Their use is not recommended and specialist design is required (AS/NZS 2012). A GTS may also be designed specifically for nutrient removal, if required by regulatory authorities.

Greywater from permanently installed systems without disinfection, needs to be reused subsurface to provide a barrier that reduces the potential for human exposure. GTS performance criteria ensure that the irrigation system does not block. Suitable sources of greywater are given in Box 1.

Surface discharge to land and reuse for toilet flushing require GTS to produce effluent of a high quality, with low solids and organic contaminant concentrations and disinfection as the potential for people to be exposed to the greywater is greater. Disinfection may also be required by councils for discharge to the surface which has minimal covering of material such as soil, bark or mulch, if the soils don't meet requirements of AS/NZS 1547:2012, or if intense rainfall events are likely to wash away the covering. Disinfection is typically achieved through chlorination or UV treatment. Both these systems require very high quality effluent to be effective. Solids and organic contaminants consume chlorine, so the added chlorine is not available to kill pathogens, and also reduce the effectiveness of UV disinfection (AS/NZS 2008a). In the presence of organic matter (BOD_5) chlorine disinfection produces by-products which are strong respiratory irritants (WHO 2004).

The different types of greywater reuse in New Zealand and the corresponding appropriate sources of greywater are summarised in Box 1. Standards for treatment and reuse of greywater are discussed in more detail in the next section. Reuse options for high-risk activities such as for cold water supply to the washing machine or car washing are not covered in New Zealand guidelines but are covered in AS 1546.4:2016.

Box 1. Minimum treated greywater effluent quality and standards for on-site wastewater treatment

UNTREATED OR MINIMALLY TREATED GREYWATER

SOURCES: Washing machine, bath, shower

Manual application of greywater onto garden e.g. bucket or hose from washing machine.

- Must be stored for **less** than 24 hours so it does not produce odours.
- No chemicals which are toxic to the environment.
- Not from washing/soaking faecally soiled clothes or linen.

Subsurface irrigation using Greywater Diversion Device (GDD)

- Filtered to remove solids and lint so irrigation system doesn't block.
- Must be stored for **less** than 24 hours so it does not produce odours.
- No chemicals which are toxic to the environment.
- Not from washing/soaking faecally soiled clothes or linen.

TREATED GREYWATER

SOURCES: Washing machine, bath, shower, basin, laundry tub. Kitchen greywater may only be used if system is specifically designed for this source. Dishwashers should not be connected due to high pH.

TREATMENT: Water quality criteria and standards are given in Legislation, Regulation, Standards and Guidelines section (Box 3).

SUBSURFACE IRRIGATION OR DRIP COVERED IRRIGATION AFTER GREYWATER TREATMENT SYSTEM

- Removal of BOD_5 and TSS so irrigation system doesn't block from solids or biological growth.
- No kitchen greywater unless the system is specifically designed to treat it.
- No chemicals which are toxic to the environment or a biological greywater treatment system.

Surface irrigation after Greywater Treatment System

- High level of removal of BOD_5 and TSS so irrigation system doesn't block due to solids or biological growth and so disinfection process is effective.
- Disinfection to remove pathogens and prevent microbial regrowth.
- No chemicals which are toxic to the environment or a biological greywater treatment system.

Toilet flushing after Greywater Treatment System

- High level of removal of BOD_5 and TSS so disinfection process is effective.
- Disinfection to remove pathogens
- Free available chlorine to prevent microbial regrowth
- Higher level of removal of BOD_5 and TSS so chloramines are not produced from chlorination process.
- No kitchen greywater unless the system is specifically designed to treat it.
- No chemicals which are toxic to the environment or a biological greywater treatment system.

LEGISLATION, REGULATION, STANDARDS AND GUIDELINES

Greywater reuse in New Zealand is covered by a number of Acts and Regulations, as shown in Table 1.

The key regulators are:

- regional and unitary councils, which manage discharges to land, air and water
- territorial local authorities, which manage building consents.

Table 1. Responsibilities under New Zealand legislation and regulations

Legislation	Coverage
Health Act 1956	Avoid public health nuisance
Building Regulations 1992	Building Code: B1 Structure B2 Durability G1 Personal Hygiene G12 Water Supplies G13 Foul Water G14 Industrial liquid waste (which includes on-site foul water)
Resource Management Act 1991 (RMA)	Discharges to land, water and air
Local Government Act 2002	Authority for territorial authorities
Plumbers, Gasfitters and Drainlayers 2006	Plumbing and drain laying

RMA

Most regional councils or unitary authorities in New Zealand permit greywater discharge to land under certain conditions. However, these conditions vary between councils. If discharge of greywater to land does not comply with the conditions of the permitted activity, a consent is required.

Building Regulations 1992

A building consent is required for permanent greywater reuse systems, including for any changes to plumbing e.g. greywater diversion devices, reuse of greywater for toilet flushing. While websites may have information about greywater reuse requirements, it may be incomplete so contact with the regulatory council is required.

Plumbing Standards

There are New Zealand Standards which apply to plumbing (Table 1) and support the Building Code (sections G12 and G13). AS/NZS 3500:2021 Part 1 (Water supply) includes sections on non-potable water supply (AS/NZS 2021a) and GTS and AS/NZS 3500:2021 Part 2 (Sanitary plumbing and drainage) provides information on greywater diversion devices (AS/NZS 2021b). Registered plumbers and drainlayers are required to install permanent greywater systems and irrigation lines (NZPDG nd).

Domestic Wastewater Standards

New Zealand has no standards specifically for greywater however the Australian national standard AS 1546.4:2016 On-site domestic wastewater treatment units Part 4: Domestic greywater treatment systems is specific to greywater, specifying GTS performance criteria for different reuse activities (AS 2016). Certification of GTS performance is undertaken using greywater which has a different composition to wastewater, potentially containing lower levels of nutrients (Leonard 2021). A precautionary approach is also required to ensure high removal of microbial pathogens in the GTS due to the potential for cross connection.

The series of on-site wastewater systems standards (AS/NZS 1546 and AS/NZS1547) provide information on treatment and land application of wastewater, including GTS performance, water balance, soil and site evaluation, installation, commissioning, operation and maintenance.

AS/NZS1546.3:2008 *On-site domestic wastewater treatment units. Septic tanks* (AS/NZS 2008b) provides information on septic tanks which are primary biological treatment systems.

AS/NZS 1546:3 2008 *Part 3 Aerated wastewater treatment systems* (AS/NZS 2008a) provides information on secondary biological treatment systems and includes disinfection.

AS/NZS 1547: 2012 On-site domestic wastewater management uses a risk management framework to manage domestic wastewater discharges to land from on-site systems. It can be used to support design for greywater subsurface discharge to land, but it excludes direct discharge of greywater to the land surface by spray irrigation for small systems due to higher risks of exposure and because continuous disinfection on a small scale can be inconsistent. It also comments that spray irrigation is environmentally more insecure in wet climatic conditions. A more precautionary approach would be required for spray irrigation (AS/NZS 2012).

AS/NZS1546.3:2008a and AS/NZS 1547: 2012 give *E. coli* performance criteria of <10 MPN/100 mL after disinfection. The Australian greywater standard AS1546.4:2016 (AS 2016) covers disinfection for surface reuse and include stricter performance criteria with 90% of samples being less than, or equal to, 10 mg/L BOD_5, 10 mg/L TSS and 10 or 1 MPN/100 mL *E. coli*.

A precautionary approach would be to use the lower *E. coli* concentration as cross connections are a significant risk. The level was estimated as 1/1000 in the AGWR risk assessment on wastewater reuse (NRMMC et al 2006). The AGWR also reported four incidents of cross connections in a residential development, one incident affecting 80 households, as well as householders using recycled water to fill swimming pools (NRMMC et al 2006).

A summary of standards and water quality criteria are given in Box 2.

Box 2. Minimum treated greywater effluent quality and standards for on-site wastewater treatment

SUBSURFACE IRRIGATION OR DRIP COVERED IRRIGATION AFTER GREYWATER TREATMENT SYSTEM

Standards

- AS/NZS 1546.1:2008 (AS/NZS 2008a) – primary treatment
- AS/NZS 1546.3:2008 (AS/NZS 2008b) – secondary treatment
- AS/NZS 1547:2012 (AS/NZS 2012)

Effluent quality criteria for secondary treatment

- BOD_5 <20mg/L
- TSS < 30 mg/L or TSS<100mg/L depending on irrigation system

SURFACE IRRIGATION AFTER GREYWATER TREATMENT SYSTEM

Standards

- AS/NZS 1546.3:2008. Performance criteria are for secondary treatment, not advanced secondary treatment. Testing is based on treating domestic wastewater not greywater.
- AS/NZS 1547:2012 excludes direct application of greywater onto land. It notes :
  - there are higher health risks from spray irrigation
  - continuous disinfection on a small scale can be inconsistent

  spray irrigation is environmentally more insecure in wet climatic conditions.

Effluent quality criteria

- BOD_5 <20mg/L
- TSS < 30 mg/L
- *E. coli* <10/100 mL
- If chlorinated, free available chlorine (FAC) 0.5-2.0 mg/L

TOILET FLUSHING AFTER GREYWATER TREATMENT SYSTEM

Standards

- AS/NZS 1546.3:2008 for disinfection management only. Performance criteria are for secondary treatment, not advanced secondary treatment. Testing is based on treating domestic wastewater not greywater.
- AS 1546:4 (2016) for *E. coli*, BOD_5 and TSS criteria, so chloramines are not produced from chlorination. Performance criteria are based on advanced secondary treatment and disinfection of domestic greywater.

Effluent quality criteria

- BOD_5 <10mg/L
- TSS < 10 mg/L
- *E. coli* <1/100 mL
- Turbidity <2 NTU
- FAC >0.5 mg/L

AS/NZS 1547:2012 is an acceptable solution for on-site wastewater treatment and disposal under the Building Code Regulations Auckland Regional Council's design manual *On-site wastewater systems: design and management manual Technical Publication 58* may be an alternative solution (TP 58 2004).

Greywater reuse systems are described in some regional guidelines or manuals and may include design criteria, with information on soils and geology specific to the area, installation, commissioning and operation. However, there is no specific information about best practice for bucketing greywater onto the garden. Australian state guidelines such as the New South Wales (NSW) guidelines for greywater reuse in sewered, single household residential premises (DEUS 2007), is a useful resource. The Australian Guidelines (NRMMC et al 2006) are a useful resource for small and large greywater reuse systems as the risk framework methodology is adaptable to both situations.

As New Zealand guidelines focus on specific uses the purpose of this document is to collate information on best practice for common types of greywater reuse.

RISK ANALYSIS FRAMEWORK

This framework is presented to help assess if the health and environmental risks associated with greywater reuse are adequately addressed in Regional Plans and Rules and where consents are required. The framework has been developed based on New Zealand and Australian guidelines and standards. The AGWR (NRMMC et al 2006) are used internationally and referenced as the quantitative risk assessment model in ISO 20426 (2018). A recent international literature review also identifies potential health hazards in greywater and assesses health risk (Leonard 2021).

The risk framework is described in detail in the AGWR with 12 elements (NRMMC et al 2006), but the focus of this document are the following system assessment and management elements:

1. risk assessment (hazard identification, exposure pathway, probability of becoming infected, consequence)
2. risk treatment – preventive control measures that prevent exposure to hazards
3. operational procedures and process control
4. verification (assurance) of performance
5. review.

As the purpose of this document is to assess that the appropriate preventive control measures are in place it is unlikely that there will be monitoring data for verification and review unless it is an application for an existing consent. Instead the assessor can look to processes that support the preventive control measure which give assurance that the measure is likely to be effective.

The Australian Guidelines have comprehensive information on hazard identification and hazardous events (pathways), with assessment of the risks of greywater reuse to human health and the environment (NRMMC et al 2006). The guidelines cover installations ranging from domestic on-site greywater to off-site reuse of treated wastewater. As risks increase due to the concentration of hazards in the wastewater, the volume of water to be reused and the size of the population potentially affected, more extensive risk treatment, monitoring and verification is required. Risk management plans would be developed for larger greywater reuse schemes to provide information about the greywater reuse system and how it should be operated, managed and monitored.

The Australian guidelines are a useful resource for quantitative microbial risk assessment for larger applications of greywater reuse such as multi-dwellings, residential facilities, camping grounds, childcare facilities, elderly care facilities or other commercial activities which produce domestic greywater.

Figure 1 (see page 11) presents a risk framework for greywater reuse. For high risk systems there will be extensive treatment, monitoring and reporting, but for simple reuse activities such as bucketing greywater or a GDD, other processes are used to provide assurance that the risk treatment measures work.

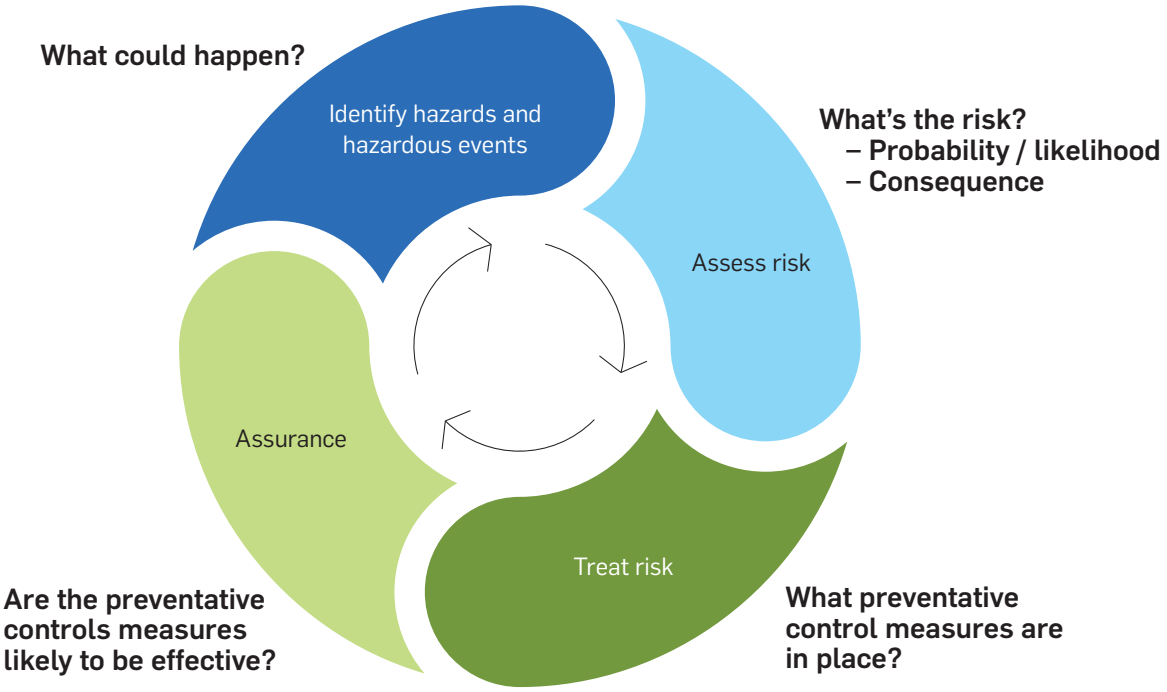

Figure 1. The key elements of a risk framework for single dwelling on-site greywater reuse

HAZARDS

Identification of hazardous agents

To determine what risk treatments are appropriate for the different types of greywater reuse, it is useful to summarise the hazards associated with the greywater, both in terms of contaminants and events. For human health, hazardous contaminants are mainly microbial pathogens. The potential sources of pathogens include showering, bathing, hand washing, food preparation and faecally contaminated laundry. As well as the AGWR (NRMMC et al 2006), the literature review by Leonard (2021) highlights the potential for the presence of pathogens in domestic greywater as well as the potential for regrowth of micro-organisms including bacterial pathogens. Contaminants in greywater also support microbiological growth which can cause anaerobic conditions creating nuisance odours.

Hazardous environmental agents include:

- chemical elements such as boron, sodium and pH which can damage plant and soil health and reduce soil permeability
- oils, fats and grease from kitchen greywater leading to poor soil drainage which may adversely affect soil and plant health
- nutrients which can contaminate surface and groundwater
- other household chemicals such as dye, paint or cleaners which can be toxic in the environment.

Hazardous events (pathways)

While hazardous contaminants can present a health or environmental risk, there needs to be an event or pathway in order for a person to become exposed or for adverse effects on the environment to occur. Understanding the potential events/pathways informs appropriate preventive control measures for risk treatment.

People may become ill through direct or indirect ingestion of water containing pathogens. Children, the elderly and people who are immuno-compromised are particularly vulnerable. Pathways include:

- food that has come in contact with greywater, which is eaten raw, including dropped fruit
- root vegetables
- drinking from a tap connected to a greywater system
- contact with a surface which has been wetted by greywater e.g. playground equipment, followed by hand-to-mouth activity
- ponding which creates a source of pathogens
- poor hygiene practices from maintaining a greywater system, including smoking, drinking or eating without washing hands
- use of contaminated groundwater or surface water as drinking water.

Plant and soil health can be affected by high or low pH or a build-up of chemicals in the soil. Aquatic environments can be adversely affected by elevated concentrations of nutrients, or toxic household chemicals, migrating off-site by leaching to groundwater or as surface run-off. They may also contaminate drinking water sources posing a health hazard. Ponding and runoff can arise from:

- high volumes of greywater incompatible with disposal area or treatment system
- poor drainage
- over watering
- reduction in soil permeability from contaminants.

Hazardous agents and events are identified in Tables 2-23 for different reuse activities.

RISK ASSESSMENT

Risk is the likelihood of a hazardous event occurring and its consequences. Assessment of the level of risk is undertaken for the hazards and hazardous events identified. A qualitative risk assessment (ISO 2018) may be used for activities with low risk factors such as:

- low volume of greywater reused
- no people exposed
- subsurface irrigation.

For larger activities the quantitative risk assessment methodology in the AGWR (NRMMC et al 2006) is useful. Risk assessment is an iterative process. Risks should be re-assessed when a preventive control measure is implemented to determine if the level of risk is acceptable or if further risk treatment is required, and in response to monitoring, review or emergencies. For larger activities risk management plans are developed from the risk assessment process.

PREVENTIVE CONTROL MEASURES FOR TREATMENT OF RISK AND ASSURANCE

Identification of the hazardous contaminants and events inform the selection of the appropriate preventive control measures. Depending on the system, these can be simple measures such as source selection for greywater reuse by the householder, or complex measures such as continuous monitoring of disinfection levels.

In the context of domestic greywater reuse for single dwellings, preventive control measures typically used to reduce risk are likely to include:

- management of greywater source by the householder
- management of the volume of greywater reused
- design of treatment system and reuse system
- implementation of barriers to minimise contact between greywater and residents
- continuous disinfection with residual chlorine to prevent biological growth or regrowth
- restricting access of people, pets and animals
- maintenance contracts for GTS.

When greywater is not treated there is a greater reliance on household management practices, including minimising contaminants, controlling the volume so there is no runoff, and not using products that adversely affect plant and soil health. Informing the householder on Best Practice is therefore a key preventive control measure. Kāpiti District Council (KDC 2017) and the NSW guidelines for greywater reuse in sewered, single household residential premises (DEUS 2007) have useful checklists.

For larger greywater reuse schemes there will be increased emphasis on:

- design and installation of reuse system
- selection of GTS
- monitoring and reporting
- restricting access and/or activities
- withholding periods for die-off and to allow irrigated surfaces to dry out
- buffers and vegetative screens
- spray irrigation control
- health signage.

Multiple barriers provide additional assurance in the event that one preventive control measure fails.

Where greywater is treated, assurance processes that give confidence that the preventative control measures will and do work include:

- measurement and monitoring
- certification of equipment[1] or robust commissioning and field testing
- use of approved or appropriately qualified or experienced designers and installation by an authorised person (registered plumber and licensed drainlayer)
- design based on site and soil evaluation with balanced hydraulic design
- maintenance contracts.

Monitoring is particularly important for larger reuse schemes and where disinfection is required. It needs to be able to detect a failure in the preventive control measure (e.g. chlorination) and enable timely action to be taken e.g. continuous monitoring of chlorine will alert the homeowner to replace the chlorine tablet before the concentration of chlorine is below the criteria. Regular review of data allows trends to be identified and action to be taken. Councils may have specific criteria for design based on local soil and geology.

Examples of preventive measures for different reuse activities are presented in Tables 2–23.

The following sections describe each type of greywater reuse, the hazardous agents and events and gives examples of preventive control measures and assurance processes. The assurance processes give confidence to a person assessing greywater policies, rules or a greywater reuse scheme, that the preventive controls are appropriate to manage risk. As different councils have different policies, guidelines and rules the assurance processes may be more precautionary than council guidelines.

The different reuse options covered are:

Untreated greywater for:

- surface watering of garden by bucket or hose from washing machine
- subsurface irrigation by GDD.

Treated greywater for:

- subsurface applications
- surface applications
- toilet flushing.

Greywater reuse may also occur in multi-dwellings, at higher volumes or other commercial or residential facilities e.g. aged care facilities, schools, child-care, camps, restaurants, in which case risks would be increased and preventive control measures increased. The Australian standard AS1546:4 2016 (AS 2016), is a useful resource for larger operations.

[1] Certification of on-site wastewater treatment plants was undertaken by the New Zealand On-site Effluent Testing (OSET). However, in 2021 testing was suspended.

USE OF UNTREATED GREYWATER FOR IRRIGATION

Watering the garden manually

A bucket or a hose attached to the washing machine outlet is used to manually water the garden.

The risk is considered low and managed by the occupant selecting suitable greywater sources and able to observe any adverse effects in real time and mitigate them. Greywater is only used as required and the duration of the activity is limited, usually to drought conditions.

Table 2–6 presents examples of preventive control measures for different potential hazards of reuse by bucketing greywater to the garden. A range of approaches are proposed to provide assurance that these controls will be effective. The examples are not exhaustive. For manual greywater reuse the key method of assurance is through householder education, so wide-spread dissemination of the information is important.

Regulation:

Manual bucketing of greywater is not generally regulated, but checks should be made with the councils.

Sources:

✓ **Potentially suitable:** bath, shower, washing machine (rinse cycle water is best as it contains less contaminants).

Don't:

✗ **Don't discharge:** toilet, kitchen sink, dishwasher as it is highly alkaline, any source containing urine, laundry tub, water used for soaking clothes.

✗ **Don't discharge** into waterways or swimming or ornamental pools

✗ **Don't use** for any activity where there may be direct contact e.g. washing cars, house or paths.

Manually using greywater to water the garden – examples of preventative control measures and assurance systems to manage risks.

Table 2. Manual watering: Hazard and hazardous event – Ingestion of pathogens through direct or indirect contact with greywater

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Only when plants require water	Householder education
✓ Check for ponding	
✓ Good hygiene practices are used	
✓ Access and activities are restricted until soil is dry	
✓ Activities are restricted to allow area to dry before using	
✗ Not used if someone in household has gastroenteric illness	
✗ Not used if generated from soaking or washing faecally contaminated items	
✗ Not used in children's play areas	
✗ Not used on vegetables or fruit drop areas	
✗ Kitchen greywater is not used	
✗ It is not applied when it's raining or soils are saturated	
✗ No over-watering of any area	

Table 3. Manual watering: Hazard and hazardous event – Odour is generated from ponding, reduced soil permeability or anaerobic activity

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Check for ponding	Householder education
✗ Kitchen greywater is not used as fats oils and grease can reduce soil permeability	
✗ Don't store greywater longer than 24 hours to prevent odour from anaerobic microbial activity	
✗ Not used when it's raining or soils are saturated	
✗ No over-watering of any area	

Table 4. Manual watering: Hazard and hazardous event – Chemicals contaminate water, or adversely affect plant and soil health

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Specialist laundry detergents are used which have low concentrations of salts, sodium, boron, chloride and phosphate ✓ Observational monitoring e.g. plant and soil health, ponding, run-off ✓ Setback distances to surface and groundwater are maintained ✓ Different areas are watered ✓ Rinse cycle has lower concentrations of laundry contaminants ✗ No kitchen or laundry tub greywater is used ✗ Not used when toxic chemicals are present e.g. cleaners, hair dyes, paints, oils	Householder education

Table 5. Manual watering: Hazard and hazardous event – Contaminants flow overland off the property or to water

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Setback distances to surface and groundwater are maintained ✓ Check there is no run-off ✗ Not used when it's raining or soils are saturated ✗ No over-watering of any area	Householder education

Table 6. Manual watering: Hazard and hazardous event – Physical injury from carrying greywater

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Backet is not too full or heavy ✓ Spills are wiped up	Householder education

Greywater Diversion Device

A greywater diversion device (GDD) is a permanent installation which discharges untreated greywater below ground via a filtration system, when required for irrigation. A filter is used to remove solids and a non-surge attenuator to manage high flows.

Tables 7–11 present preventive control measures for different potential hazards for reuse for subsurface disposal to land using GDD. A range of approaches are proposed to provide assurance that the controls will be effective. The examples are not exhaustive.

For GDD there is significant reliance on householder education, so wide-spread dissemination of information is important to support good practice. Assurance is provided by use of suitably qualified or experienced designers to ensure there is a suitable depth of soil (to act as a barrier and prevent exposure) and to ensure there is no storage for longer than 24 hours. The system must be installed by a registered plumber and licensed drainlayer and is connected to the sewerage system.

Regulation:

- Building Regulations 1992.
- Plumbers, Gasfitters and Drainlayers Act 2006.
- RMA 1991 – resource consent may be required unless the conditions of the permitted activity are met.

Sources:

✓ **Potentially suitable:** bath, shower and washing machine (rinse water is best due to fewer contaminants)

✗ **Not suitable:** toilet, kitchen sink, dishwasher as it is highly alkaline, any source containing urine, laundry tub.

Don't:

✗ **Don't** discharge into waterway or swimming or ornamental pools

✗ **Don't** use for any activity where there may be direct contact e.g. washing cars, house or paths

✗ **Don't** include urine (it must be treated by wastewater system).

Example of greywater diversion device

Examples of preventative control measures and assurance systems to manage risks from subsurface irrigation using raw greywater such as GDD

Table 7. GDD: Hazard and hazardous event – Ingestion of pathogens through direct or indirect contact with greywater

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Complies with plumbing standards including backflow prevention, no cross connections, pipes separated and differentiated from potable water and labelled ✓ Health warning signage is used ✓ A surge tank is installed to manage flows ✓ Irrigation system is installed at prescribed depth below soil ✓ Good hygiene practices are used when cleaning and maintaining system ✓ Access is restricted so children do not play in irrigated area ✓ Activities are restricted so vegetables are not grown nor fruit collected in irrigated area ✗ Irrigation system is not installed in children's play areas, where vegetables are grown or in fruit drop areas ✗ No kitchen or laundry greywater is connected ✗ It is not used if someone in household has gastroenteric illness	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500:2021 **AND** Designed and installed by approved or suitably qualified or experienced person AS/NZS1547:2012 does not cover greywater diversion. ✓ AGWR (NRMMC et al 2006) cover untreated greywater Council guidelines, rules or consent conditions Risk management plan Householder education

Table 8. GDD: Hazard and hazardous event – Anaerobic microbial activity may cause odours

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
• Greywater is not stored longer than 24 hours	Installed by a registered plumber ✓ AS/NZS 3500:2021 **AND** Designed and installed by approved or suitably qualified or experienced person Council guidelines, rules or consent conditions Householder education

Table 9. GDD: Hazard and hazardous event – Ponding may expose people to pathogens through direct or indirect contact, and/or create odour

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ GDD default setting is to drain to the sewer ✓ GDD automatically diverts to sewer during rain events or blockages ✓ Soil moisture meter is installed and checked ✓ Drippers have large openings to avoid blockages ✓ Site and soil evaluation and water balance is undertaken ✓ Only used when irrigation is needed ✓ Regular maintenance of system is undertaken according to manufacturers' instructions ✓ Monitoring is undertaken e.g. plant and soil health, ponding (may be observational for small systems) ✓ Specialist laundry detergents are used to avoid adverse effects on soil structure ✗ It is not connected to kitchen greywater ✗ It is not used when it's raining or soils are saturated ✗ The irrigated area is not over-watered	Installed by a registered plumber ✓ AS/NZS 3500:2021 **AND** Designed and installed by approved or suitably qualified or experienced person AS/NZS1547:2012 does not cover greywater diversion ✓ AGWR (NRMMC et al) cover untreated greywater Council guidelines, rules or consent conditions Householder education
✓ Reliable system performance	Certified system or proof of performance Council guidelines, rules or consent conditions Manufacturers' instructions

Table 10. GDD: Hazard and hazardous event – Chemicals contaminate water, or adversely affect plant and soil health

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Specialist laundry detergents are used which have low concentrations of salts, sodium, boron, chloride and phosphate ✓ Monitoring is undertaken e.g. plant and soil health, ponding (may be observational for small systems) ✓ Setback distances to surface and groundwater are maintained ✗ It is not connected to kitchen or laundry tub greywater ✗ Not used when toxic chemicals are present e.g. cleaners, hair dyes, paints, oils	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500:2021 **AND** Designed and installed by approved or suitably qualified or experienced person AS/NZS1547:2012 AS/NZS1547:2012 does not cover greywater diversion. ✓ AGWR (NRMMC et al 2006) covers untreated greywater Council guidelines, rules or consent conditions Risk management plan Householder education Householder maintenance plan Manufacturers' instructions

Table 11. GDD: Hazard and hazardous event – Contaminants run off designated area, or to surface or groundwater

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ GDD automatically diverts to sewer during rain events or blockages ✓ Soil moisture meter is installed and checked ✓ Site and soil evaluation and water balance is undertaken ✓ Setback distances are maintained e.g. to surface and groundwater water, property boundaries ✓ Monitoring is undertaken e.g. ponding, run-off (may be observational for small systems) ✓ Low phosphate laundry detergents are used ✗ GDD is not used when it's raining or soils are saturated ✗ The irrigated area is not over-watered ✗ GDD is not installed where soils are highly permeable and the aquifer is sensitive to contamination	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500:2021 **AND** Designed and installed by approved or suitably qualified or experienced person AS/NZS1547:2012 does not cover greywater diversion. ✓ AGWR (NRMMC et al 2006) covers untreated greywater Council guidelines, rules or consent conditions Risk Management Plan Householder education Householder maintenance plan

Use of treated greywater for irrigation

Subsurface irrigation – GTS but no disinfection

A GTS stores and treats greywater to reduce TSS and BOD_5 before subsurface discharge to land. The level of treatment required depends on how the greywater is reused.

Tables 12–15 present examples of preventive control measures for different potential hazards for reuse for subsurface disposal to land using GTS. A range of approaches are proposed to provide assurance that the controls will be effective. The examples are not exhaustive and cover a range of different sized schemes. Therefore not all examples will be appliable to all greywater reuse schemes. Emergency events are not covered in the table, but contingency planning should be assessed for larger activities.

For GTS and subsurface irrigation most of the assurance is provided by processes which confirm that the GTS, design and installation are appropriate. The GTS should be certified that it produces effluent of a suitable quality for the method of irrigation or have robust on-site and/or commissioning testing. The system is installed by a registered plumber and licensed drainlayer, the land application system is designed by suitably qualified or experienced persons. Without disinfection there must be a barrier to avoid the potential for exposure. Householder education ensures that only appropriate chemicals are discharged to the system, schedules routine maintenance and observation to ensure that there are no adverse effects. Provision should also always be made for emergency events.

Irrigation systems include:

- covered drip irrigation (some councils may require disinfection)
- subsurface irrigation.

Regulation:

- Building Regulations 1992.
- Plumbers, Gasfitters and Drainlayers Act 2006.
- RMA 1991 – resource consent may be required unless the conditions of the permitted activity are met.
- Some councils may require disinfection for covered drip irrigation.

Sources:

✓ **Potentially suitable:** bath, shower, washing machine, laundry tub, bathroom sink

✗ **Not suitable:** toilet, kitchen sink (unless the design specially treats the oil, fat and grease and elevated concentrations of BOD_5 and TSS present in kitchen greywater), dishwasher as it is highly alkaline, any source containing urine.

Don't:

✗ **Don't use** where there is a municipal sewerage system, unless approved by council

✗ **Don't discharge** into waterway or swimming or ornamental pools

✗ **Don't** use for any activity where there may be direct contact e.g. washing cars, house or paths.

Examples of preventative control measures and assurances systems to manage risks from subsurface irrigation from GTS without disinfection.

Table 12. Sub-surface irrigation: Hazardous event and agent: Ingestion of pathogens through direct or indirect contact with greywater

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Complies with plumbing standards including backflow prevention, no cross connections, pipes separated and differentiated from potable water and labelled ✓ Health warning signage is used ✓ Irrigation system is installed at prescribed depth below soil ✓ Good hygiene practices are used when cleaning and maintaining system ✓ Access is restricted where covered drip irrigation is used ✓ For drip irrigation the soil, bark or mulch cover is maintained ✓ Disinfection may be required for covered drip irrigation ✓ Monitoring is undertaken e.g. plant and soil health, ponding (may be observational for small systems) ✗ Irrigation system is not installed in children's play areas, where vegetables are grown or in fruit drop areas	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500:2021 **AND** Design and installation by approved or suitably qualified or experienced person Small on-site systems: ✓ AS/NZS1547:2012 Large systems: ✓AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education Householder maintenance plan

Table 13. Sub-surface irrigation: Hazardous agent and event – Ponding may expose people to pathogens through direct or indirect contact, or create odour e.g. soil is saturated, soil permeability is reduced or irrigation system blocks

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Water quality criteria from GTS is appropriate for the type of irrigation system ✓ Regular maintenance of system is undertaken according to manufacturers' instructions ✓ Site and soil evaluation and water balance is undertaken ✓ Monitoring is undertaken e.g. plant and soil health, ponding (may be observational for small systems) ✓ Specialist laundry detergents are used to avoid adverse effects on soil structure ✓ Residual FAC prevents biological regrowth ✗ It is not connected to kitchen greywater unless the GTS is specifically designed to treat kitchen greywater ✗ It is not used when soils are saturated ✗ The irrigated area is not over-watered	Design and installation by approved or suitably qualified or experienced person Small on-site systems: ✓ AS/NZS1547:2012 Large systems: ✓ AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education Householder maintenance plan Manufacturers' instructions Maintenance contract(s) Maintenance certificate(s)
✓ Reliable performance of the system ✓ GTS effluent meet performance criteria	Certified system or proof of performance ✓ Validation monitoring – AGWR (NRMMC et al 2006) Small on-site system: ✓ AS/NZS 1546.1:2008 ✓ AS/NZS 1546.3:2008 or AS 1546.3:2017 Large systems: ✓ AGWR (NRMMC et al 2006)

Table 14. Sub-surface irrigation: Hazard and hazardous event – Chemicals contaminate water, or adversely affect plant and/or soil health

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Specialist laundry detergents are used which have low concentrations of salts, sodium, boron, chloride and phosphate ✓ Monitoring is undertaken e.g. plant and soil health, ponding (may be observational for small systems) ✓ Setback distances to surface and groundwater are maintained ✗ It is not connected to kitchen greywater unless the GTS is specifically designed to treat kitchen greywater ✗ No toxic chemicals are discharged to biological systems e.g. cleaners, hair dyes, paints, oils	Small on-site systems ✓ AS/NZS1547:2012 Large systems: ✓ AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education Householder maintenance plan Manufacturers' instructions

Table 15. Sub-surface irrigation: Hazard and hazardous event – Contaminants run off designated area, or to surface or groundwater

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Site and soil evaluation and water balance is undertaken ✓ Setback distances are maintained e.g. to surface and groundwater water, property boundaries ✓ Monitoring is undertaken e.g. no runoff (may be observational for small systems) ✓ Low phosphate laundry detergents are used ✗ There is no irrigation if soils are saturated ✗ The irrigated area is not over-watered ✗ It is not installed where soils are highly permeable and the aquifer is sensitive to contamination	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500:2021 **AND** Designed and installed by approved or suitably qualified or experienced person Small on-site systems: ✓ AS/NZS1547:2012 Large systems: ✓ AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education Household maintenance plan

Surface irrigation – GTS and disinfection

A GTS removes BOD_5 and TSS before the disinfection process. A high level of treatment is required to remove organic contaminants and suspended solids and reduce turbidity so the disinfection system is effective against pathogens. See Note 1 below.

Tables 16-20 present examples of preventive control measures for different potential hazards for reuse for surface disposal to land using GST and disinfection. A range of approaches are proposed to provide assurance that the controls will be effective. The examples are not exhaustive and cover a range of different sized schemes. Therefore not all examples will be applicable to all greywater reuse schemes. Emergency events are not covered in the table, but contingency planning should be assessed for larger activities.

For surface irrigation there is a high risk of exposure so effective disinfection is critical. GST should be certified that they produce effluent of a suitable quality or have robust on-site and/or commissioning testing. Assurance is also provided by continuous monitoring of disinfection. A multi-barrier approach reduces risk if one barrier fails or is less effective. Design and installation ensure that aerosols and droplet deposition are managed appropriately and that ponding and runoff do not occur. For large schemes modelling of spray irrigation aerosols and droplet deposition and restricted access would be expected. The system is installed by a registered plumber and licensed drainlayer and the land application system designed and installed by suitably qualified or experienced persons.

Reuse options for GTS plus disinfection include:

- surface drip irrigation
- surface spray irrigation
- covered drip irrigation.

Regulation:

- Building Regulations 1992.
- Plumbers, Gasfitters and Drainlayers Act 2006
- RMA 1991 – resource consent may be required unless the conditions of the permitted activity are met.

Sources:

✓ **Potentially suitable:** bath, shower, washing machine, laundry tub, bathroom sink,

✗ **Not suitable:** toilet, kitchen sink, unless the design specifically includes kitchen wastewater, dishwasher as it is highly alkaline, any source containing urine.

Notes:

1) BOD_5 and TSS concentrations greater than 20 mg/L and 50 mg/L reduce the effectiveness of chlorine disinfection of greywater (Friedler et al., 2021). Organic matter in greywater has a chlorine demand which reduces the amount of chlorine available for disinfection (March and Gual, 2009) i.e. addition of the chlorine is NOT killing the pathogens. Chlorine also reacts with organic matter and forms disinfection by-products which are strong respiratory irritants (WHO 2004) and are hazardous to human health. Chlorine by-products can be toxic in the receiving environment (AS/NZS 2012).

2) AS/NZS 1547 2012 specifically notes that this reuse is not covered by the guideline due to higher health risks from spray irrigation and that continuous disinfection on a small scale can be inconsistent. It also comments that spray irrigation is environmentally more insecure in wet climatic conditions. The Australian greywater standard and guidelines do cover disinfection for surface reuse.

Where tablet chlorination is used, continuous monitoring addresses the risk associated with manual replacement of tablets.

Don't:

✗ **Don't** use where there is a municipal sewerage system, unless approved by council

✗ **Don't** discharge into waterways or swimming pools.

✗ **Don't** use for any activity where there may be direct contact e.g. washing cars, house or paths.

Examples of preventative control measures and assurances systems to manage risks from surface irrigation from GTS with disinfection.

Table 16. Surface irrigation: Hazardous agent and event – Ingestion of pathogens through direct or indirect contact with greywater

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Complies with plumbing standards including backflow prevention, no cross connections, pipes separated and differentiated from potable water and labelled ✓ Health warning signage is used ✓ Good hygiene practices are used when cleaning and maintaining system ✓ Access is restricted ✓ A withholding period allows land and surfaces to dry ✗ Irrigation system is not installed in children's play areas, where vegetables are grown or in fruit drop areas	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500:2021 **AND** Design and installation by approved or suitably qualified or experienced designer Small on-site systems: ✓ AS/NZS1547:2012 recommends AGWR (NRMMC et al 2006) Large systems: ✓ AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education Manufacturers' instructions
EFFECTIVE DISINFECTION	
✓ The GTS has high removal of BOD_5 and TSS to ensure effective disinfection ✓ The GTS meets these criteria ✓ Disinfection is continuous ✓ Parameters that ensure disinfection is effective are continuously monitored ✓ Regular maintenance of GTS and disinfection systems are undertaken according to manufacturers' instructions ✓ Alarms indicate electrical or mechanical faults, or if performance criteria are exceeded ✓ There is a response to alarms in a timely manner to rectify problems ✓ Residual FAC prevents biological regrowth	Certified system or proof of performance Validation monitoring – AGWR (NRMMC et al 2006) Small on-site systems: ✓ AS/NZS 1546.3:2008 ✓ AS 1546.3:2017[6] Or Large systems: ✓ AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education Householder maintenance plan Manufacturers' instructions Maintenance contract(s) Maintenance certificate(s) Robust alarm system

[6] AS 1546.3:2017 has been used to certify performance in New Zealand

Table 17. Surface irrigation: Hazardous agent and event – Inhalation of spray irrigation droplets or aerosols, or contact with deposited droplets or aerosols

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Sprinkler heads that produce large droplets which settle within a short distance and aren't aerosolised, with low throw and plume height are used ✓ Maximum wind speed and direction which prevent aerosols exceeding designated area are identified ✓ Buffer zones and/or vegetation screens are implemented so spray drift is within designated area ✓ Setback distances are maintained e.g. to surface and groundwater water, property boundaries ✓ Health warning signage is used ✓ Access is restricted ✓ A withholding period allows land and surfaces to dry ✓ Monitoring is undertaken (may be observational for small systems) ✓ Restriction to single dwelling reduces risk ✗ Irrigation is shut down if wind exceeds specific speed or is from direction which will exceed design that keeps spray drift in designated area	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500 **AND** Design and installation by approved or suitably qualified or experienced designer Small on-site systems: ✓ AS/NZS1547:2012 recommends AGWR Large systems: ✓ AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education

Table 18. Surface irrigation: Hazardous agent and event – Ponding may expose people to pathogens through direct or indirect contact, and/or create odour e.g. soil is saturated, soil permeability is reduced or irrigation system blocks

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Site and soil evaluation and water balance is undertaken ✓ Monitoring is undertaken e.g. soil health, ponding (may be observational for small systems) ✓ Specialist laundry detergents are used to avoid adverse effects on soil structure ✓ Residual FAC prevents biological regrowth ✗ It is not connected to kitchen greywater unless the GTS is specifically designed to treat kitchen greywater ✗ It is not used when soils are saturated ✗ The irrigated area is not over-watered	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500:2021 **AND** Design and installation by approved or suitably qualified or experienced person Small on-site systems: ✓ AS/NZS1547:2012 Large systems: ✓ AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education Householder maintenance plan
✓ The GTS has high removal of BOD_5 and TSS suitable for irrigation system ✓ The GTS meets these criteria ✓ Regular maintenance of GTS and irrigation system is undertaken according to manufacturers' instructions ✓ Alarms indicate electrical or mechanical faults, or if performance criteria are exceeded ✓ There is a response to alarms in a timely manner to rectify problems	Certified system or proof of performance ✓ Validation monitoring AGWR (NRMMC et al 2006) Small on-site systems: ✓AS/NZS 1546.3:2008 ✓AS 1546.3:2017 Large systems: ✓ AGWR (NRMMC et al 2006) Maintenance contract(s) Maintenance certificate(s)

Table 19. Surface irrigation: Hazardous agent and event – Chemicals contaminate water, or adversely affect plant and soil health

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Specialist laundry detergents are used which have low concentrations of salts, sodium, boron, chloride and phosphate ✓ Monitoring is undertaken e.g. plant and soil health, ponding (may be observational for small systems) ✓ Setback distances to surface and groundwater are maintained ✗ It is not connected to kitchen greywater unless the GTS is specifically designed to treat kitchen greywater ✗ No toxic chemicals are discharged to biological systems e.g. cleaners, hair dyes, paints, oils	Small on-site systems: ✓ AS/NZS1547:2012 Large systems: ✓ AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education Householder maintenance plan Manufacturers' instructions

Table 20. Surface irrigation: Hazardous agent and event – Contaminants run-off designated area or to surface or groundwater

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Site and soil evaluation and water balance is undertaken ✓ Setback distances are maintained e.g. to surface and groundwater water, property boundaries ✓ Monitoring is undertaken e.g. run-off (may be observational for small systems) ✓ Low phosphate laundry detergents are used ✗ There is no irrigation if soils are saturated ✗ The irrigated area is not over-watered ✗ It is not installed where soils are highly permeable and the aquifer is sensitive to contamination	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500:2021 **AND** Designed and installed by approved or suitably qualified or experienced person Small on-site systems: ✓ AS/NZS1547:2012 Large systems: ✓ AGWR (NRMMC et al 2006) Council guidelines, rules and consent conditions Risk management plan Householder education Household maintenance plan

Use of treated greywater for internal use

GTS with disinfection for reuse for toilet flushing

A GTS removes BOD_5 and TSS before the disinfection process. A high level of treatment is required to remove organic contaminants and suspended solids and reduce turbidity so the disinfection system is effective against pathogens. See Note 1 below.

Tables 21–-23 present preventive control measures for different potential hazards for greywater reuse for toilet flushing using GST and disinfection. A range of approaches are proposed to provide assurance that the controls will be effective. The examples are not exhaustive and cover a range of different sized schemes. Therefore not all examples will be appliable to all greywater reuse schemes. Emergency events are not covered in the table, but contingency planning should be assessed for larger activities.

For toilet flushing there is a high risk of exposure, particularly from cross connections. A multi-barrier approach reduces risk in the event that one barrier fails or is less effective e.g. continuous monitoring of chlorine residual ensures that the chlorine residual is correct in the event that micro-organism regrowth occurs. As reuse is within a building there is also the potential for inhalation of chemicals which are hazardous to health produced by the chlorination of organic matter, where the treated greywater quality is not adequate. The GTS should be certified that it will produce suitable effluent quality or have robust on-site and/or commissioning testing. Assurance is also provided by continuous monitoring of disinfection and a residual chlorine must be maintained even if UV has been used for disinfection.

The system is installed by a registered plumber.

Regulation:

- Building Regulations 1992.
- Plumbers, Gasfitters and Drainlayers Act 2006 and AS/NZS AS/NZS 3500 (AS/NZS 2021a, b) apply.
- RMA 1991 – resource consent may be required e.g. if part of an on-site wastewater treatment system.

Sources:

✓ **Potentially suitable:** bath, shower, washing machine, laundry tub, bathroom sink and kitchen sink if the system has been specifically designed for this source.

✗ **Not suitable:** dishwasher, toilet, dishwasher as it is highly alkaline, any source containing urine.

Don't:

✗ **Do not** have high concentrations of BOD_5 and TSS as these produce chloramines which are hazardous to health

✗ **Do not** use for any activity where there may be direct contact e.g. washing cars, house or paths

✗ **Do not** discharge into waterways or swimming pools.

Note:

1) BOD_5 and TSS concentrations greater than 20 mg/L and 50 mg/L reduce the effectiveness of chlorine disinfection of greywater (Friedler et al., 2021). Organic matter in greywater has a chlorine demand which reduces the amount of chlorine available for disinfection (March and Gual, 2009) i.e. addition of the chlorine is NOT killing the pathogens. Chlorine also reacts with organic matter and forms disinfection by-products which are strong respiratory irritants (WHO 2004) and are hazardous to human health.

Toilet flushing from a GTS with disinfection – Examples of preventative control measures and assurance systems.

Table 21. Toilet flushing: Hazardous agent and event – Ingestion of pathogens from direct or indirect contact

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Complies with plumbing standards including backflow prevention, no cross connections, pipes separated and differentiated from potable water and labelled ✓ Health warning signage is used ✓ Good hygiene practices are used when cleaning and maintaining system ✓ Residual FAC prevents biological regrowth ✓ Restricting small systems to single dwelling reuse reduces risk	Installed by a registered plumber ✓ AS/NZS 3500:2021 **AND** Design and installation by approved or suitably qualified or experienced person Large systems : ✓ AGWR Council guidelines, rules or consent conditions Risk management plan Householder education Householder maintenance plan Manufacturers' instructions Maintenance contract(s) and certificate(s)

Table 22. Toilet flushing: Hazardous agent and event – Ingestion of pathogens from direct or indirect contact as disinfection is ineffective

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ The GTS has high removal of BOD_5 and TSS suitable for effective disinfection ✓ The GTS meets these criteria ✓ Disinfection is continuous ✓ Parameters that ensure disinfection is effective are continuously monitored ✓ Regular maintenance of GTS and disinfection systems are undertaken according to manufacturers' instructions ✓ Alarms are installed which indicate electrical or mechanical fault, or performance criteria are not being met ✓ There is a response to alarms in a timely manner to rectify problems ✓ Residual FAC prevents biological regrowth ✗ It is not connected to kitchen greywater unless the GTS is specifically designed to treat kitchen greywater ✗ No toxic chemicals are discharged to biological systems e.g. cleaners, hair dyes, paints, oils	Installed by a registered plumber and drainlayer ✓ AS/NZS 3500:2021: **AND** Designed and installed by approved or suitably qualified or experienced person New Zealand doesn't have standards for internal greywater reuse. AS/NZS 1547:2012 effluent criteria don't apply to internal reuse Certified system or proof of performance – Validation monitoring AGWR (NRMMC et al 2006) Small on-site systems: ✓ AS 1546.3:2017 Advanced Secondary* ✓ AS 1546.4:2016 Large systems: ✓ AGWR (NRMMC et al 2006) Risk management plan Manufacturers' instructions Maintenance contract(s) and certificate(s) Householder education Household maintenance plan

* AS 1546.4 2016 has been used to certify wastewater treatment plant performance in New Zealand.

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Table 23. Toilet flushing: Hazardous agent and event – Production of hazardous chlorine gases from chlorination

EXAMPLES OF PREVENTIVE CONTROL MEASURES	ASSURANCE SYSTEMS INCLUDE
✓ Use a GTS which can produce effluent quality criteria with high removal of BOD_5 and TSS. ✓ The GTS meets these criteria ✓ Regular maintenance of GTS and disinfection systems are undertaken according to manufacturers' instructions	New Zealand doesn't have standards for internal greywater reuse Certified system or proof of performance – Validation monitoring AGWR (NRMMC et al 2006) Small on-site systems: ✓ AS 1546.3:2017 Advanced Secondary*. ✓ AS 1546.4:2016 for BOD_5, TSS and *E. coli* Large systems: • AGWR (NRMMC et al 2006) Council guidelines, rules or consent conditions Risk management plan Householder education Householder maintenance plan Manufacturers' instructions Maintenance contract(s) and certificate(s)

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