

Handbook for

**Reusing or Recycling
Reverse Osmosis Reject
Water from
Haemodialysis
in Healthcare Facilities**

A project by North West Dialysis Service

Created by	Atura Pty Ltd Suite 204, 198 Harbour Esplanade DOCKLANDS VIC 3008
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Abbreviations

AAMI	Australian Advancement of Medical Instrumentation
CAPEX	Capital Expenditure
CIP	Clean-In-Place
CSSD	Central Sterilisation Supply Department
DH	Department of Health
DHS	Department of Human Services
DSE	Department of Sustainability and Environment
GAC	Granular activated carbon
GOH	Greening Our Hospitals
HCF	Health Care Facility/Facilities
HD	Haemodialysis
MH	Melbourne Health
ML	Million litres (megalitre)
NWDS	North West Dialysis Service
OPEX	Operational Expenditure
RMP	Risk management plan
RO	Reverse Osmosis
RW	Reject water (from reverse osmosis)
SWF	Smart Water Fund
SAR	Sodium adsorption ratio
TDS	Total dissolved salts
WQ	Water Quality
WaterMAP	Water Management Action Plan

Foreword

This handbook was developed for haemodialysis service facilities as part of a Smart Water Fund Project grant obtained by the North West Dialysis Service. It aims to provide a simple framework for identifying and assessing reuse/recycling options for the reject stream from reverse osmosis (RO) machines that are used for water treatment in the provision of dialysis services.

The handbook outlines the opportunities for reuse/recycling of the reverse osmosis reject stream; an awareness of the safety issues; quality requirements and legislative requirements for reuse/recycling, as well as providing a cross section of case studies from the project reports.

The approach aims to be relevant to the variety of dialysis service delivery models in Victoria, from large metropolitan hospitals to smaller regional facilities. The approach is also relevant to dialysis service providers outside Victoria.

This document is based on Victorian guidelines and regulations.

This handbook also examines several case studies, mainly from Victorian sites where reuse of RO reject water is already underway. The manual details the successes of current practices, the scope of reuse applications already in use and some of the pitfalls when pursuing reuse opportunities of dialysis reject water. The experiences and lessons learned from these different cases provide valuable information for facilitating any future reuse opportunities.

The handbook aims to provide up to date and comprehensive information (when published) on the legislative framework in which recycling of RO reject water is classified, so that all reuse projects meet state guidelines and regulations. In addition, a suite of innovative as well as practical recycling options are addressed. The risk management framework used to undertake and report on the assessment complies with the appropriate Australian Guidelines (Standards Australia 2004; NRMCC & EPHC 2006; DH Victoria 2009).

This reference manual will be successful if it assists Health Care Facilities (HCF) in assessing reuse opportunities quickly and providing guidance to assess the costs and benefits of potential projects. The target audience is hospital engineers, HCF managers and planners, dialysis service providers and dialysis machine providers who may be interested in investigating reuse of RO reject water. It is important to note that the handbook provides general guidance. Local HCF staff must consult the appropriate technical experts (dialysis service providers and equipment suppliers) before making any changes.

This handbook acknowledges that there is a strong motivation in the community to save water. This is an admirable aspect of community spirit; however, water conservation and reuse should be well considered and justifiable. This reference manual aims to assist in providing a rational basis for such decision making.

It is also important to note that any decision to undertake a project to reuse/recycle RO reject ultimately belongs to the HCF and it should be emphasised that any reuse scheme should be undertaken in consultation with all relevant authorities. It is necessary for the HCF to undertake investigations to implement a reuse system, ensuring compliance with the latest guidelines. This handbook aims to provide some assistance in this process.

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1. INTRODUCTION

1.1 Purpose of this handbook

The purpose of this handbook is to provide a simple framework to enable Health Care Facilities (HCF) to identify and assess water reuse/recycling options for RO reject water and to consider these opportunities within the broader framework of water conservation efforts within their facilities.

The aim is to identify the key questions that need to be asked by HCF engineers and managers in order to determine whether RO reuse/recycling is viable and worth pursuing. The handbook then provides general advice to assist with answering these questions.

Finally, the handbook contains chapters on evaluating reuse options and making a business case for any proposals arising from the decision to reuse this water. It also provides useful information on how to demonstrate water savings that can be adopted to help promote the success of water conservation and recycling initiatives.

This document adopts the principles and approach detailed in the Water Reuse and Recycling Guidelines for Health Care Facilities (DH Victoria 2009). It also locates dialysis RO reject water reuse under the frameworks of the Australian Guidelines for Water Recycling: Managing health and environmental risks (Phase 1) (NRMMC & EPHC 2006).

The reader must ensure that the latest versions of the documents referenced are used to accompany this handbook and also check if other regulations apply, particularly if this handbook is being used outside Victoria.

It is also important to note that while this handbook may be of some value to individuals undergoing home dialysis; this is not the target audience. The regulatory environment and risk management requirements for HCF are different for individuals on home haemodialysis.

2. WATER CONSERVATION IN HEALTH CARE FACILITIES – REDUCING, REUSING, RECYCLING

2.1 The context

The Victorian Department of Health (DH) acknowledges that collectively its service providers consume 5 GL water per annum. This is approximately 1% of water used in Melbourne and 0.1% of water used in Victoria (DHS Victoria 2009). In the context of an extended period of drought in South East Australia over the last 13 years, there is significant motivation to reduce this potable water consumption.

This has led the Victoria State Government to develop a number of environmentally sustainable policy objectives including:

- > Victorian government aims to recycle 20% of water;
- > Victorian government aims for a 30% reduction in the volume of potable water consumed in the Central Region; and
- > Victorian state government departments (Department of Health, Department of Sustainability and Environment) are keen to achieve greater sustainability in terms of water and energy consumption.

The Department of Health is committed to reducing the environmental impact associated with its service delivery and aims to lead the Victorian Government's goal of reducing long term potable water consumption and reducing the environmental footprint (DH Victoria 2009). This has led to a significant project, titled Greening Our Hospitals (GOH), funded by the Victorian Water Trust (Bending 2007; DSE Victoria 2008). This programme has provided \$3.9M over 4 years (from 2007-2010), allowing hospitals and aged care facilities to install water efficiency measures through retrofits and develop innovative water reuse and recycling projects, including reuse from engineering and process systems such as reverse osmosis (RO). One significant outcome of this particular project is that several applications for funding to reuse RO reject at several sites were made under the GOH program.

In addition to this policy context, there is a strong community view that water conservation is important. This is largely the result of 13 years of below average rainfall in South East Australia. In this environment, many people are taking it upon themselves to reduce potable water consumption, and there is significant enthusiasm for water saving projects. Many HCF have internal policies and goals to enhance water conservation.

There is strong support for water conservation and reuse

2.2 Water audits (the starting point)

To assist HCF with reaching these water conservation and recycling targets, the Victorian Government, through the Department of Sustainability and the Environment (DSE) and water authorities have developed the WaterMAP (Water Management Action Plan). The WaterMAP is for consumers of more than 10 million litres of water per annum in Victoria (Our Water Our Future 2007). This will assist larger HCF in accounting for water consumption and provides a basis for determining priority areas for water conservation and reuse/recycling within their facilities.

The objective of the WaterMAP is for large consumers of water to:

- > assess water usage;
- > identify inefficiencies and opportunities for water savings;
- > prepare an action plan to implement water conservation activities; and
- > report annually on the implementation of water conservation activities.

For smaller facilities where there are no current WaterMAP requirements, there has been a concerted effort by the Greening Our Hospitals (GOH) program to audit these HCF across Victoria. This had resulted in at least 69 audits being conducted by the end of 2009.

Audits of water and energy within HCF lead to the identification of areas of resource waste. They also allow for subsequent strategies to minimise wastage and attempt to reuse or recycle where possible.

2.3 Typical patterns of water usage in HCF

A key outcome of a water audit is a detailed understanding of the patterns of water usage within a specific HCF. It is also useful to understand the pattern of water usage compared with other HCF. This benchmarking approach may provide opportunities and limits for water conservation and reuse. Table 1 provides an indication of how water is typically used within a HCF.

Table 1 Summary of proportional water uses within HCF in Victoria (based on water audits)

Water use	%
Ablutions (basins, showers, sinks)	20-40%
Sanitary Flushing (toilets, pan sanitisers)	15-30%
Process water (sterilisers, laboratories etc)	15-40%
Food Preparation (kitchen)	5-25%

Source: (DH Victoria 2009)

There are significant potential demands (cooling towers, Muller coolers, boilers, toilets, sterilisers) for RO reject water and larger opportunities for water savings at hospitals (Figure 1). Dialysis services represent on average 4% of water used in hospitals/HCF (Figure 1). This can amount to substantial volumes of water (several million litres) per annum at larger facilities.

Undertaking a water audit is the first step.

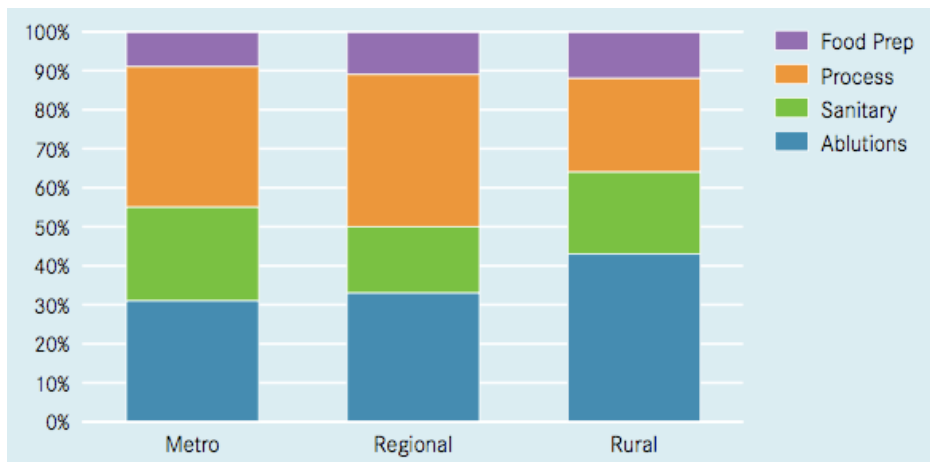


Figure 1 Sources and uses of water in hospitals (DHS Victoria 2009).

Based on the typical performance of RO units (assuming a conservative water recovery of 50%) around 2% of water supplied to hospitals is available for reuse from RO units alone. This is important to note because it provides an indication of the extent of opportunities in terms of total volume.

Dialysis is one of many services using water at a typical HCF site (Figure 1). At some HCF sites where dialysis is one of the main services it will account for a much higher percentage of water consumed. Reuse or recycling of the RO reject water could save as much as 6% of the potable water supplied to the HCF (Deere et al. 2008).

The typical volume of RO reject water at metropolitan or large regional dialysis centres is approximately 1 million litres (1 ML) per annum (Section 6.1). This is approximately half an Olympic sized swimming pool.

Reuse and recycling of RO reject water presents one of many potential opportunities for HCF and does not necessarily represent the largest volume or source of water that could be reused. Of course, reuse refers strictly to the reject of the reverse osmosis unit, and not to any by-products of the dialysis process itself, which is termed dialysate effluent. The terms reuse and recycle are defined as:

**Reduce, Reuse,
Recycle.**

Reuse = Direct use of harvested water for the same or a different function, without treatment.

Recycle = Using harvested water for the same or a different function, after treatment.

2.4 The Waste Management Hierarchy

Fundamental to the pursuit of any water conservation project is an understanding of the waste hierarchy (DH Victoria 2009) (Figure 2). It is imperative that the hierarchy is adopted as opportunities to reduce water consumption should be considered before reuse and recycling. In line with the waste hierarchy, the opportunities to reduce water consumption should be pursued first. When the 'reduce' opportunities have been exhausted, reuse of RO reject water presents new opportunities. Recycling of water generally implies a level of treatment so that the water is fit for the purpose of the intended reuse (NRMMC & EPHC 2006).

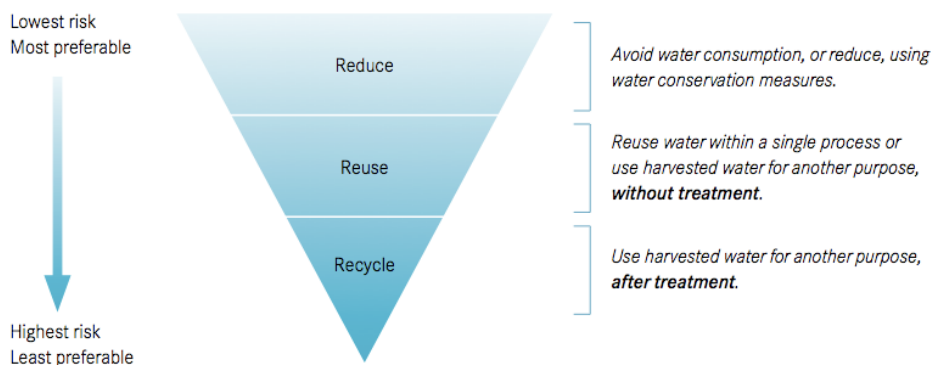


Figure 2 Key steps in water conservation (DH Victoria 2009).

Reverse osmosis reject water represents a significant opportunity for reuse in HCF water conservation efforts. However it is typically not the first priority. There are easier gains to be made such as installing dual flush toilets and low flow showers to reduce water consumption.

2.5 Cascading Water: a philosophy of reuse

An extension of the idea of the waste hierarchy is that there are opportunities to 'cascade' water reuse throughout the HCF. This is shown diagrammatically in Figure 3 where high quality water is cascaded through a cooling system and then to lower quality end uses such as toilet flushing and irrigation.

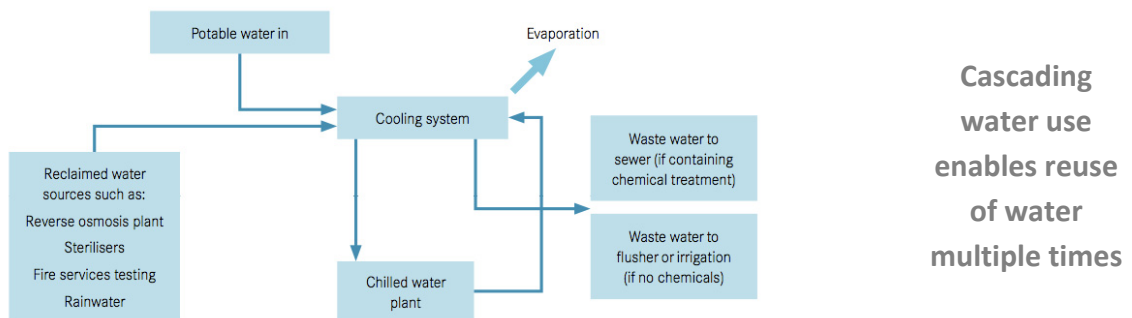


Figure 3 Example of cascading water reuse in a HCF (DH Victoria 2009).

The aim is to cascade the water use from highest quality through to lowest quality to ensure that all water is 'fit-for-purpose'.

While this handbook focuses on the opportunities to reuse RO reject water, it is important to consider opportunities beyond the reuse of RO reject water alone and how the reuse of RO reject is situated within the context of the waste hierarchy.

It is important to note that this philosophy of cascading water reuse based on 'fit-for-purpose' quality is far easier to implement in the design of a HCF as a Greenfield site in contrast to retrofitting within an existing facility. The opportunity to cascade water reuse throughout a building should be explored in the planning of more environmentally sustainable HCFs for the future.

2.6 Water reuse with a sound foundation

There is a strong feeling in the community that water reuse and recycling is inherently good. Unfortunately, this doesn't mean every water reuse/recycle project is viable or sensible. The aim of this handbook is to help decision makers identify projects that are worth pursuing and to determine the limitations in any potential reuse or recycling project.

Reverse osmosis is a required water pre-treatment process for dialysis. The nature of reverse osmosis is that it generates a waste stream of water. Typically this is high quality water that may be suitable for reuse. However, this does not mean that reuse should be undertaken at any cost. There are a range of questions to be answered to establish the viability of reuse.

Water use is demand driven. Understanding the demand volume, profiles and quality requirements are critical for establishing sound water reuse/recycling projects.

This handbook provides HCF with a tool to quickly assess whether RO reject reuse is viable or not. For projects that are identified as potentially viable, the handbook provides guidance on the next steps required to help implement reuse/recycling schemes.

2.7 Project drivers for HCF

Finally, it is important to understand the wide range of drivers for water conservation projects in HCF including reuse of RO reject water. Some of these project drivers are non-financial and it is clear that HCF have leadership roles in the community when demonstrating and advancing water conservation and improved environmental sustainability. These principles need to be balanced with financial drivers whilst ensuring that patient care is not compromised. These are the challenges for HCF managers, engineers and maintenance staff.

Encourage
viable and
sensible reuse
only

3. REUSING RO REJECT FOR DIALYSIS SERVICES

3.1 Overview

The process of haemodialysis requires large volumes of water in compliance with Australian Advancement of Medical Instrumentation (AAMI) recommended Standards (2009). Potable or mains water does not achieve the required standard, so treatment of this water is needed. This treatment may involve pre-filtration, softening, filtration through activated carbon and RO. These methods form the most effective treatment process train to achieve water of suitable quality for dialysis (AAMI 2009).

A key step in this treatment process is RO which removes ions and very small contaminants from the potable water. This is a well-established process that is widely used for seawater desalination, industrial process water treatment and wastewater recycling.

The challenge and opportunity that RO presents is that it generates a significant reject stream where the salt and contaminant concentrations are typically 2-3 times higher than their original concentration in the potable water. For most Victorian water supplies increasing the salt and contaminant concentration 2-3 times still provides relatively high quality water which is fit-for-purpose to many end uses.

However, it is critical to understand that once the water has left the potable supply system it is not guaranteed potable, and reusing it may add risks to HCF operations that require assessment and management.

3.2 Reject streams from dialysis

A dialysis system (Figure 4) has two reject streams:

- > Reverse Osmosis reject; and
- > Waste from the dialysis machine (dialysate effluent).

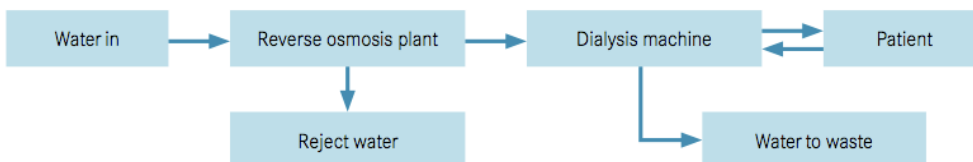


Figure 4 Simplified configuration of water use for dialysis (DH Victoria 2009).

It is critical to note that this manual *only considers reuse of RO reject water*. It does not recommend reusing dialysate effluent from patients. As a product of dialysis treatment, dialysate effluent is a very high risk water source because it is potentially contaminated with biologically hazardous products. The separation of RO reject water and dialysis effluent is fundamental to any reuse project.

3.3 The current situation in Victoria

Guidelines for the reuse and recycling of water in HCF were developed in 2009 as part of a broader government strategy to encourage water conservation across healthcare services. In early 2009 an advocate for reuse of RO reject water in Victoria (Agar et al. 2009) had made the following statement:

“Despite this dire situation (the prolonged drought in South East Australia), current hemodialysis (HD) service designs neither specify nor routinely include a recycled water-saving methodology, despite its simplicity and affordability, nor do health departments mandate water conservation policies for current or establishing dialysis facilities.”

Fortunately this situation is changing rapidly. There are many positive signs that efforts to identify opportunities to reuse RO reject water are occurring, alongside such initiatives as this handbook. For example:

- > There have been a number of projects already undertaken in Victoria reusing RO reject water from dialysis services. The efforts of these organisations are to be applauded. Section 14 details several of the significant projects that have been undertaken; and
- > The providers of dialysis and RO machines have made significant progress in increasing the water recovery of RO machines and reducing the volume of reject water. This approach is consistent with the waste hierarchy. There remain RO machines in-service that do not have these water saving features, but with asset renewal, water efficient units are becoming predominant.

NWDS alone estimates that currently around 12.8 ML of reject water from its service goes to sewer, representing substantial volumes of high quality water. In 2010 NWDS provides 27 % of the dialysis services in Victoria.

There have been commendable efforts by dialysis services and HCF to reduce water usage and undertake reuse projects.

The aim of this handbook is to draw on these developments and provide a framework for the structured assessment of reuse opportunities within a water conservation strategic plan.

RO reject water is high quality water: not potable yet fit for many purposes

4. OVERVIEW OF THE STEP-BY-STEP APPROACH TO RO REUSE AT HCF

Previous sections define RO reject reuse from dialysis within the broader context of HCF water conservation efforts. The remainder of this handbook focuses on the details of investigating RO reject reuse opportunities and the necessary steps to develop RO reject reuse projects.

This handbook utilises a step-by-step approach to identify the actions and decisions required to develop a reuse project for dialysis RO reject water. Steps in this section are provided to use as a walk-through, to quickly identify whether reuse is feasible both in terms of cost, volumes produced, matching demands and the key issues (Table 2).

Table 2 Steps to quickly identify reuse feasibility at Health Care Facilities

Step No.	Description	Section in Handbook
1	Undertake review of water audit	5
2	Confirm operation of dialysis service	5
3	Confirm volume of RO reject water available	6
4	From water audit, identify possible reuse opportunities	7
5	Match reuse options with available supply	8
6	Check water quality is fit for purpose	9
7	Undertake design and costing for reuse options	10
8	Develop Risk Management Plan (RMP)	11
9	Undertake project plan and confirm business case	12

Special case: It is important to also consider this process in the planning and design of a new HCF.

Step 1: Review the water audit or ensure that one has been undertaken (Section 5)

Prior to investigating a specific option involving the reuse of dialysis RO reject water, it is necessary to undertake a water audit or review one that has been recently undertaken, and explore projects that involve reducing potable water consumption directly.

This preliminary step is important to provide a context and ensure that the waste hierarchy is adopted. It is important that the priorities are identified and that any efforts to reuse dialysis RO reject water are seen in the context of a larger water conservation effort.

Step 2: Confirm the future operation of the dialysis service (Section 5)

If a dialysis reuse project is to be successful, it is necessary to ensure that the dialysis service is continuing in its present form or expanding. There are examples where changes to dialysis services are planned and any investment in water reuse projects is unlikely to achieve the payback period due to projected modifications of the service.

Step 3: Confirm the volume of RO reject water generated (Section 6)

It is essential to establish the volume of RO reject water being generated. There are significant economies of scale in the reuse of RO reject water, and leads to more complex opportunities at metropolitan and large regional hospitals.

There are several regional sites which generate relatively small volumes of reject water. This is due to the small number of chairs and limited operating hours per week.

Step 4: Identify and list possible dialysis RO reject reuse opportunities (Section 7)

There are a wide range of potential uses for RO reject water within a HCF setting. One of the first tasks is to identify the potential reuse options for the specific site. This should involve some lateral yet visionary thinking as well as keeping in mind the complexity of the reuse option and benefits of keeping the project simple.

Typical reuse opportunities at most sites are toilet flushing, garden watering, cooling water for sterilisers, cooling tower water and washdown (general cleaning) water.

This section also provides some general rules of thumb as to situations where some identified options are not viable based on a survey of 20 Victorian HCF providing HD services. The objective here is to accelerate screening out of non-viable projects where possible.

Step 5: Matching opportunities for reuse with the available supply (Section 8)

The viability of a reuse scheme depends very much on suitable match between supply of and demands on the use of RO reject water. These reuse options are demand driven. No demand means no reuse is warranted. It is critical that the volumetric demand and demand profile are well understood. For example, toilet flushing water is an excellent reuse opportunity. It provides a constant demand profile over the entire year and is a significant user of water. By contrast, using RO reject water for irrigation can lead to an under utilisation of the reject water as there may be little demand through winter months.

Step 6: Confirm Water quality (Section 9)

Once a good match between supply and demand has been established with respect to volume and demand profile and the supply of RO reject water, it is necessary to confirm that the RO reject water is fit-for-purpose.

Whilst of high quality, RO reject water is no longer potable. It contains more salt (up to three times the salt concentration of the potable feed water), has been dechlorinated and may have been in contact with RO membrane cleaning fluids or other hazards.

Typically RO reject water is fit for many reuse purposes, but needs confirmation at any site. If it is found not fit for the specific end use it can usually be treated or shandied with other water to make it fit-for-purpose. This treatment and dilution can come at a cost and may reduce overall project viability.

Step 7: Preliminary Design and Costing (Section 10)

In order to assess the viability a potential reuse project, it needs to be designed and cost estimated. The preliminary design is also required to enable completion of a health and environmental risk assessment. This work is typically undertaken by the hospital engineering department following internal business procedures. This handbook does not attempt to provide any guidance on how the design and costing will be undertaken as these will be defined internally by the specific organisation undertaking the assessment.

Step 8: Assess and manage the human and environmental risk (Section 11)

In order to comply with the Guidelines for Water Reuse and Recycling in Victorian Health Care Facilities (DH Victoria 2009), it is necessary to undertake a Risk Management Plan (RMP) for any water reuse project. This should be undertaken prior to project approval to ensure that the project achieves an acceptable risk profile and any costs associated with the monitoring and verification for the project are included in the business case. This step details the inputs for these risk assessments following the Guidelines. It should be noted that in other states of Australia, other guidelines may need to be followed.

Step 9: Confirming the business case (Section 12)

To go ahead, the potential reuse project needs to secure HCF approval. This is an internal business process outside the scope of this handbook. However, project viability may hinge on the availability of additional funding, and confirming key project drivers. This section details potential funding sources that may improve the financial viability of the project, details on non-financial project drivers and provides an overview of the key elements of success for established reuse projects.

5. REVIEWING THE WATER AUDIT AND ESTABLISHING FUTURE DEMAND

This section details emphasis on:

- > water audits such as WaterMAP;
- > the importance of establishing RO reject as an ongoing source of water for any potential reuse application; and
- > Considering the future life of the RO machine and facility.

This step is important for calculating and demonstrating payback periods and good project management.

Prior to investigating a specific option involving the reuse of dialysis RO reject water, it is necessary to undertake a water audit and explore projects that involve reducing potable water consumption directly.

For organisations currently using more than 10 million litres (ML) of water per annum, Victorian government water authorities require a WaterMAP as a form of audit and breakdown of water use across the site (Our Water Our Future 2007). If a WaterMAP has been completed, it is likely that use of the RO unit has already been identified as an area for improving efficiency or as a water source for potential reuse. In this case, it is still important to consider the waste hierarchy and determine whether initiatives such as purchasing more efficient equipment or devices, or even purchasing more efficient RO units is a more viable and sensible long term option/solution than would be achieved by undertaking water recycling.

The water efficiency of RO units depend upon the system configuration, membrane, and water quality and is only one aspect of the complex function that dialysis services need to optimise. The membrane life, asset renewal program and power, pre-treatment costs and energy consumption are all considerations in determining which RO unit should be installed. Life Cycle Assessment of the various factors is undertaken by the dialysis service.

If a dialysis reuse project is to be successful, it is necessary to ensure that the dialysis service is continuing in its present form or expanding.

While the national average growth rate of patients undergoing dialysis is increasing at 6% per annum¹, it is necessary to confirm the short to medium-term future of the dialysis centre. For example, urban/regional demographic and planning factors may also determine whether dialysis services are likely to close, be relocated, or agglomerate in the future.

¹ Kidney Health Australia Launches National Survey on Dialysis Services Media Release, 12 June 2009 <http://www.medialaunch.com.au/1033/>

The key outcome of this assessment is to confirm that the RO systems in place will continue to operate at current conditions, ensuring at minimum that there will be viable volumes for recycling into the foreseeable future and allowing for payback of the project.

6. VOLUMES OF RO REJECT WATER GENERATED

Once demands are identified, it is fundamental to confirm volumes of RO reject water being generated, as there are significant economies of scale in the reuse of RO reject water. Consequently, there are more significant opportunities at metropolitan and large regional hospitals than at small regional sites.

Several of the regional and rural sites generate limited volumes of reject water. This is due to the small number of chairs and limited operating hours per week.

The volume of RO reject water generated is a function of the feed water quality, number of HD treatments and type of RO unit. Not all sites will generate sufficient reject water to enable viable reuse schemes.

6.1 Different dialysis sites

Dialysis is conducted at different types of facilities. Based on a survey of 20 dialysis sites in Victoria, the reject volumes ranged from 20 to 1,700 kL per annum (Table 3).

Table 3 Typical volumes of RO reject water for different sites

Dialysis Facility	Typical RO reject volumes (kL/annum)
Central RO at Acute Metropolitan Hospitals	870-1,420
Central RO at Satellite Centres	820-1,200
Central RO at Major Regional Hospitals	700-1,700
Regional/Rural HCF with Single RO	20-270

Volumes vary considerably (Table 3), for example:

- > The volumes of RO reject water generated at sites with central RO units are generally sufficient to consider reuse opportunities; and
- > There is a significant variation in the volume of RO reject water generated at sites with single RO units.

For further information on calculating the quantity of water, refer to section 13.2 in the Appendices.

6.2 Cut off volumes for project viability

As a rule of thumb, if the volume of reject water is less than 2,000 L/week, consider only the most basic of standalone reuse options, such as gravity feeding of water to an immediately adjacent demand with minimal infrastructure requirements.

If the volume of reject RO is less than 2,000 L/week and infrastructure is required to separate the RO reject and the dialysate effluent, the reuse project may not be financially viable. A 'Greenfield' site (new development) may provide an exception to this rule of thumb where there may only be a small incremental cost in the design and construction of a new facility. Note that the cut-off volume will change if the cost of potable water increases significantly.

7. IDENTIFYING THE POSSIBLE DEMANDS FOR REUSE OF RO REJECT WATER

Different HCF have different demands for water. Large regional and metropolitan hospitals are complex facilities using water for a wide range of purposes, while satellite dialysis centres typically have minimal water demands with the exception of dialysis itself. In contrast, regional HCF with attached aged care facilities typically have gardens that require watering.

One of the key tasks in developing a water reuse scheme is identifying the wide range of potential reuse options. Many of these uses require some level of treatment and approval from regulatory bodies. Feasibility also depends on the scale and scope of works undertaken. There are a wide range of possible reuse options for RO reject water (considered in Table 6 to Table 9) including:

- > Toilet flushing
- > Irrigation
- > Steriliser water
- > Laundry makeup water
- > Fire hydrant makeup water
- > Muller 3C / cooling tower water
- > Macerator/pan sanitiser water
- > Dead-leg flushing (non potable supply)
- > Heating/closed loops systems
- > Boiler makeup water
- > Chiller feed water
- > Pump sealing water
- > Industrial kitchen/dishwasher water
- > Swimming pools (would require EPA approval)
- > Environmental flows (would require EPA and water authority approval)
- > Return to potable supply (would require water authority and Department of Health approval)

7.1 Reuse and recycling options for RO reject water

The task of identifying up to 5 potential reuse options is best undertaken by the HCF engineer or someone very familiar with site operations. Think broadly and strongly prioritise the options based on a perceived cost/benefit ratio.

It is important to consider:

- > That it is preferable to identify proven and established reuse options.
- > The distance between the reuse option and the RO unit. Significant distances (>100 m) make project viability unlikely especially if there is a requirement to run new piping through the HCF building.
- > The demand profile. Aim for constant and significant demands where possible.
- > Aim for potable replacement for the reuse option. If the garden is currently not watered with potable water, then technically using RO reject water on the

garden does not save water, but rather it generates a new demand. However, if there is a strong driver to enhance the garden in a project, this might be preferred.

- > There are significant benefits in maximising the use of existing infrastructure as it reduces capital expenditure (CAPEX.)

The tables below are organised on the basis of whether they are a demonstrated and established reuse option or as potential options identified across Victoria and interstate.

Table 4 Actual sites where reverse osmosis (RO) reject reuse is in place

Reuse Option	Sites	Demand comment
Toilet flushing	Craigieburn Bendigo Box Hill Melton Barwon	Well established and proven demand for RO reject water at a number of dialysis sites. Constant demand. Clear potable replacement. Made easier by the presence of flusher tanks in older hospitals or Greenfield sites.
Steriliser cooling water	Barwon	Well established and proven demand for RO reject water at a number of dialysis sites. All year round demand. Clear potable replacement. This is an alternative to installing a chiller for steriliser cooling water which is popular. If a chiller is already in place, the demand for water will be low.
Irrigation Hospital garden	Donald Mansfield Maryborough Wangaratta Barwon	Well established and proven demand for RO reject water at a number of dialysis sites. Seasonal demand. May not be potable replacement if the garden is not watered with potable water.
Irrigation water offsite	Barwon	Potential source of water during Stage 4 water restrictions. Will need to compete with other sources of recycled water. Not all year round demand. Also this option involves additional regulatory compliance and consultation with outside organizations.
Janitor water	Barwon	Small demand. May be considered an adjunct to a larger demand.

Table 5 Other proposed reuse options in Victoria

Reuse Option	Proposed	Demand comment
Car wash	Barwon	Significant demand for water, but proximity to car wash critical.
Fountains / Water features	Barwon	Small demand and may not involve potable substitution. Also through water restrictions may not be appropriate for HCF to have water features.

Table 6 Novel reuse options developed interstate

Reuse Option	Proposed	Demand comment
Return RO reject water into hospital potable supply (tanks)	Adelaide (QEH)	Significant demand but involves significant treatment and risk assessment. This would be difficult and costly to implement under the Safe Drinking Water Act in Victoria. This has not been undertaken in Victoria (Not recommended) (See Section 14.5 for details on this scheme).

Table 7 Reuse/recycling of reverse osmosis (RO) reject water for process water applications

Reuse Option	Demand comment
Equipment Washdown water onsite	Washing down is not under taken at all hospitals, but can present a significant demand over the entire year. Likely to involve potable substitution.
Cooling Towers and Muller 3C make up water	Large volume of water required and is likely to involve potable substitution. Muller 3C are increasingly popular and their demand for water is seasonal typically 20% of year, compared with traditional cooling tower. Need to consult cooling tower water treatment service provider
Fire Service Make Up Water	Periodic requirement for water only. Likely to involve potable substitution. May involve the need for significant additional storage.
Boiler Make Up Water	All year round demand. Volume variable dependent on the extent of condensate return. Water quality considerations critical, additional treatment may be required. Need to consult cooling tower water treatment service provider
Laundry Hot Water Make Up Water	All year round demand. Significant demand that may involve potable substitution.
Pump sealing water	Often the best approach is to reduce demand for sealing water. All year application. Often required for sterilisation unit (CSSD) vacuum pumps.
Heating hot water (closed loops)	Winter demand. Involves potable substitution.
Chilled water (closed loops)	Summer demand. Involves potable substitution.
Water for Macerators/pan sanitisers	Small volumes only. All year round demand. Likely to involve significant piping to individual macerators.
Dead leg flushing	Small volumes and periodic only. Difficult to justify as a specific end use.

Table 8 Possible reuse options requiring more investigation

Reuse Option	Demand Comment
Return into non-potable supply	A few towns in Victoria do not have potable mains water supply. In these instances it may be possible to return the RO reject to this supply. If the town's supply becomes potable this option is no longer viable.
Filling swimming pools	Hydrotherapy at HCF requires water to make up for losses through filter backwashing. Risk assessment is required to ensure that human health risk is acceptable. The risk is different to use of water for showering, as it's a relatively small addition of water to a larger volume of chlorinated water. More complex end use requiring further investigation

This list of potential uses discussed above is not exhaustive and other reuse options may be viable. However, it is important to note the more complex the reuse option, the more time and effort will be required. There is an enormous benefit in identifying an established and well-known option (Table 4). It is strongly recommended that these options are explored first.

There were a number of other options considered, however, they proved too complex and difficult (Table 9).

Table 9 Reuse options deemed too difficult to consider

Reuse Option	Difficulties
Environmental flow	RO reject water is high quality and could be used to contribute to environmental flow in nearby waterways. The EPA considers RO reject as process water, this if not reused must be rejected to sewer and not the stormwater system.
Shower water	Showers represent a significant demand for water in HCF; however, there is potentially human health risk associated with the use of RO reject water for this demand.
Water for kitchen washing	Kitchen washing represents a significant demand for water in HCF, however, there are potential human health risks associated with the use of RO reject water for this demand.
Treatment and return to the potable supply	While this occurs at Queen Elizabeth Hospital in Adelaide, this option is considered in this investigation as too difficult. Such a scheme involves costly treatment and detailed, ongoing risk assessment and management.

7.2 Summary

The reuse identification process should identify up to five reuse options at or nearby the HCF. From these five it is likely that one or two will be easily identified as the preferred options.

8. MATCHING SUPPLY AND DEMAND

In Section 7 the possible demands for RO reject water around the HCF were identified; the next step is to quantify the demands and demand profile and determine the extent of supply-demand match.

8.1 Demand driven

If there is no demand, no RO reject water is required. The supply and demand profiles should be compared to maximise the reuse/recycling opportunity and minimise the storage volumes.

One of the significant features of the RO reject stream is that it is reasonably predictable and is generated during the working day over the entire year. It is well matched, for example, with the demand for toilet flushing water.

By contrast, the RO reject stream is not as well matched with the demand for gardening or irrigation water which is typically seasonal, having a high demand for four to six months of the year in most parts of Victoria. Another limitation of garden irrigation is that it may not represent potable water substitution if a garden is not currently being watered with potable water.

A key element of the success of projects reusing RO reject water is to confirm the match between the supply profile and the demand. Viability of the project should be assessed based on the volume or percentage of reject water utilisation, not the volume of reject water generated.

This section of the handbook provides the tools to enable the calculation of the volume of water required for different uses and their demand profiles.

8.2 Utilising the water audit and understanding its limitations

As previously detailed (Section 2.2 and 5), the water audit undertaken at the hospital/HCF provides insight into the potential demands for different reuse and recycling opportunities. However, one significant limitation with many water audits undertaken is that water consumption is often classified into aggregated demands. For example, the demands might be listed as bathroom, kitchen, laundry, cooling tower, and boiler makeup water, sterilisation unit (CSSD), outdoor, garden and watering; some water audits also aggregate water usage simply as 'process water'. The implication of this is that it may not give sufficient detail of the demand profile, and may not enable an assessment of the match between supply and demand. For example, fire service make up water might be required infrequently but still be a significant demand in terms of volume. Perhaps all the toilets near the dialysis centre maybe used infrequently; actual toilet use may not have been monitored. These factors all impact on the viability of replacing potable water with RO reject water.

Information from the water audit is vital to assess the overall water usage, yet there are two significant limitations:

- > Collated data at an aggregate level may not be helpful for matching supply with a specific demand. For example, identifying a toilet flushing demand in *part* of the HCF will require details of the volume from that flusher tank only – not all water usage in toilets across the HCF.
- > It may lack sufficient detail on the demand profile. Demand profile data is critical for understanding the opportunity to match the supply of RO reject water with demand.

Ideally the water audit should be undertaken in sufficient detail to enable extraction of this data. This provides a sound foundation to enable the matching of supply of RO reject water with actual demands. In the absence of this information there are two options:

1. Estimate or calculate demands (Section 8.3); or
2. Install flowmeters and measure the real demand, periodically recording the volumes used to determine the demand profile as well.

Actual measurements should be undertaken in preference to estimating demand. Section 8.3 below provides some general guidance on estimation of demand.

8.3 Estimating volume demand for established reuse options

There are a number of established demands detailed in Table 4. These represent the most likely and feasible reuse projects to be undertaken. Approaches to directly estimate the demand volumes for these reuse options are described below.

8.3.1 Toilet usage estimates

The major benefit with toilet flushing is that in many cases, the demand profile matches the supply profile of the RO reject water. In older hospitals it is also typical to have a toilet flusher tank. This makes retrofitting more viable, as the only requirement is for a return line to the main flusher tank; toilets do not require individual re-plumbing, nor is the purchase of a tank specifically for holding this water necessary.

The volume of water required for toilet flushing is determined by the frequency of use and the volume of water per flush.

A simple calculation assumes:

- > a 1 star toilet (WELS rating 9/4.5 litre); and
- > toilet usage during a 9 hour working day is 1 full flush and 3 half flushes or 22.5 L/person/day (BCC 2007).

This will vary in a hospital environment between staff, patients and visitors. It is also necessary to confirm the number of people who will access the toilets considered for connection to the RO reject supply.

It should be noted some hospitals still have flushometer type toilets that are less water efficient, and consideration should be given to replacing these toilets with more water

efficient toilets if possible (based on the waste hierarchy approach: Section 2.4). One star toilets should be considered for replacement with the latest WELS 3 star-rated toilets (www.waterrating.gov.au).

If there is uncertainty in the estimate of the demand for toilet flushing and it is possible that the supply of RO reject water will significantly exceed the demand, it would be useful to directly measure the demand for a period of time with an inline flow meter.

8.3.2 Garden water requirements calculator

Irrigation water demand varies substantially across different regions of the state (Table 10). This is an important consideration in understanding the demand to reuse RO reject water and the potential potable water savings gained. Figure 5 below highlights this variation.

Table 10 Estimates of median irrigation requirements/demand for gardens and cool season turf in town and cities in Victoria.

Town/city	Monthly irrigation requirement (kL/10 m ²)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Melbourne	1.3	1.1	0.8	0.3	0.0	0.0	0.0	0.0	0.3	0.5	0.9	1.1	6.2
Mildura	1.9	1.7	1.3	0.6	0.2	0.1	0.1	0.3	0.6	1.2	1.6	1.8	11.3
Warrnambool	1.1	0.9	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.7	0.8	4.6
Wodonga	1.6	1.3	1.0	0.3	0.0	0.0	0.0	0.0	0.1	0.5	1.0	1.3	7.2
Bendigo	1.6	1.4	1.0	0.4	0.0	0.0	0.0	0.0	0.1	0.6	1.1	1.3	7.6
Sale	1.1	0.9	0.5	0.2	0.0	0.0	0.0	0.0	0.2	0.5	0.7	0.7	5.0
Horsham	1.8	1.5	1.2	0.5	0.0	0.0	0.0	0.0	0.3	0.7	1.2	1.6	8.8

This table assumes a high water demand garden or cool season turf, moderate plant density and moderate sun/wind exposure. All values are medians based on 1961 to 1990 data. Based on the typical rainfall reduction in the last 13 years (30% reduction) an additional irrigation demand of 10% is required. Values will vary depend on site conditions and should be managed accordingly on site.

Table 10 can be utilised to determine the irrigation requirement for a specific hospital garden of a given area. For example, at one Victorian regional site, the estimated volume of RO reject was approximately 20 kL/month (240 kL/year). Assuming a garden demand similar to Mildura and garden area of 150 m² (15x11.3 kL =170 kL total demand), a 10-20 kL tank (approximately) would be required to ensure that the summer demand was met, and on average 70 kL (240 – 170) of RO reject water would **not** be utilised.

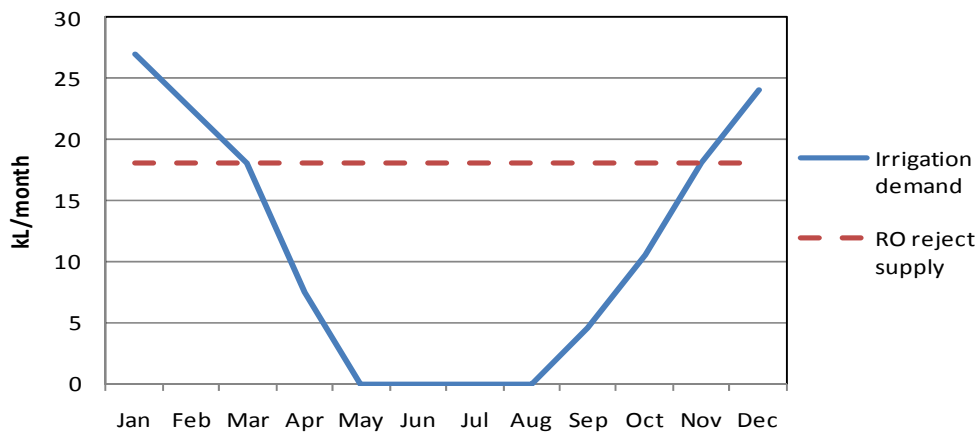


Figure 5 Comparison between RO reject supply profile and annual irrigation demand profile

There is a significant difference in the demand profile for irrigation and the supply profile for RO reject water (Figure 5). Without storage capacity or alternative uses, particularly during winter there is an under utilisation of the RO reject water.

It is important that the project viability (business case) is based on the actual reuse volume (extent of potable substitution), not on the volume of water RO reject water supplied.

8.3.3 Steriliser Cooling Water (including vacuum pump sealing water)

Sterilisers provide a large and constant demand over the entire year. This can be well matched with the supply of RO reject water.

Generally a sterilising unit (CSSD) works by a process where the steam condensate leaves the sterilisation process at 80° C and after being cooled by cold water in a condenser fitted to the steriliser, is discarded as waste via the sewerage system. The rate of this waste is approximately 11 L/min during each 35-minute cycle. This waste water can often be better used. An additional 11 L/min of cold water is used by the liquid ring vacuum pump to maintain a seal. This is also normally discarded as waste (Western Health 2005). This volume of water typically exceeds the volume of water generated by a typical central RO unit, and would still require potable or other suitable water source to make up the rest of demand.

There are essentially two approaches to save potable water in this application:

- > Install a chiller and recirculate cooling water and vacuum pump sealing water; or
- > Utilise suitable non-potable water (e.g. RO reject water) for cooling water and pump sealing water.

In order to calculate the volume of water used in the steriliser the following information is required:

- > Flow rate of cooling water (L/min) (CW)
- > Vacuum Pump Sealing Water (L/min) (SW)
- > Time for each cycle (min) (T)
- > No of cycles per day per unit (C)
- > No of sterilisers used daily (N)

The total estimate of the volume of water required = (CW+SW) x T x C x N.

This is typically a substantial volume of water. However, there is a growing trend in HCF to include a chiller and recirculate the cooling water instead of utilising an alternative water resource, such as RO reject water.

It is important that the hospital engineer considers the energy/water nexus and the relative resource tradeoffs between reusing RO reject water and installing a chiller.

8.3.4 Off-site irrigation

Satellite dialysis centres may not be physically part of a broader HCF. In metropolitan areas, the satellite centres generate similar volumes of RO reject water as do the dialysis services in large hospitals. Typically there are very few demands for the reject water at these centres. Storing and transporting the RO reject water is one option.

For example, during Stage 4 water restrictions in Geelong, two satellite centres installed 30 kL storage tanks (18 station satellite) and one 30 kL storage tank (6 station satellite). Over summer, the City of Greater Geelong and local sporting club water tankers collected and carted between 2 and 3 times weekly to local sporting ovals, bowling greens, cricket pitches, and golf courses as well as to the aged care facility gardens of Barwon Health (Agar et al. 2009).

One limitation of the demand profile for off-site uses is that irrigation tends to be seasonal, and may become redundant in the event of other water supply augmentations (i.e. 3rd pipe schemes) or increases in rainfall. This introduces a significant project risk and uncertainty in assessing the benefits of the project.

Another project complexity detailed in the Guidelines (DH Victoria 2009) is that if through a water reuse or recycling project the HCF is considering supplying water off-site or to third party users then it is recommended that further advice be sought from local or state authorities. Off-site supply of recycled water derived from sewage, greywater or industrial process water may need approval from the EPA for volumes greater than 5,000 L/day (EPA Victoria 2009).

In metropolitan areas it is often difficult to secure sufficient space for the footprint of large storage tanks. Alternatively, there may be opportunities to supply RO reject water to adjacent buildings. This may add complexity through addition of external/offsite stakeholders but it can also present interesting opportunities for community collaboration. In most circumstances it will be more challenging to identify viable reuse options at stand alone satellite dialysis centres.

8.3.5 Janitor water

The volume demand for janitor water is small. This is not deemed sufficient to warrant measurement and does not constitute a stand alone reuse option.

8.3.6 Estimation of other demands

There is a range of other potential demands listed in Table 7. In these cases it is necessary for the HCF engineer to estimate or measure the demand for water. Preferably this demand should be recorded with a flowmeter and measured periodically, providing details of the totalised volume and demand profile. Knowledge of the demand profile is critical. For example, it is important to note that Muller 3C coolers typically only require water 20% of the time, compared to traditional cooling towers which require water virtually all year round.

9. WATER QUALITY ASSESSMENT AND MANAGEMENT: FIT-FOR-PURPOSE

RO reject water is high quality water that is fit for many reuse opportunities. Typically water quality was not considered as a barrier to the reuse projects investigated. However, it is critical for project success and risk management that it is confirmed as fit-for-purpose at each specific site assessed.

With respect to water quality:

- > This handbook **only** considers the reuse of RO reject water **not** dialysate effluent. The RO reject and dialysate effluent must be completely separated and risks managed to ensure that there is no possibility of cross-connection or contamination; this is critical.
- > The quality of the RO reject water is a strong function of the feed water quality, the presence of water softeners, and the water recovery of the RO unit. Knowledge of these process parameters is required to predict the quality of RO reject water.
- > RO reject water has been dechlorinated. This introduces risks of biological regrowth. This risk must be assessed and managed for different reuse options.
- > RO reject water has been potentially in contact with membrane cleaning agents (CIP (Clean-In-Place) process fluids), water rejected from the dialysis line heat sterilisation process, water softening agents and other potential hazards. Technical services group staff members should be consulted for further advice.

In order to assess whether RO reject water quality is fit for the reuse option identified (purpose), it is necessary to first establish the water quality and then compare it to relevant regulations, guideline or recommended values.

9.1 Confirming the quality of RO reject water

The quality of the RO reject stream can be established in three ways:

3. Direct measurement of the reject stream for specific contaminants relevant to the identified reuse opportunity. This is the best way of confirming the quality of the RO reject water and is recommended particularly for applications where the consequences of poor water are profound.
4. Estimation of the RO reject water quality can be made based on knowledge of the water recovery from the RO unit using local water authority published water quality data.
5. Estimation of the RO reject water quality can be made based on knowledge of the water recovery from the RO unit using feed water quality data supplied by the dialysis service provider.

Note: It is also important to understand that changes to the water supply or changes to the RO unit may alter the quality of the RO reject water. For example, if a town's supply shifts from surface water to ground water, this may alter the composition of the RO reject stream. Similarly, introducing higher recovery RO units or settings will

increase the salt concentration in the reject stream. The risk management plan must address these possible changes in the quality of the RO reject stream.

9.1.1 Understanding the RO pre-treatment and filtration system

There are a number of pre-treatment steps to ensure that the water is suitable for treatment by reverse osmosis prior to the reverse osmosis process for removal of salts and nano-scale contaminants (Figure 6).

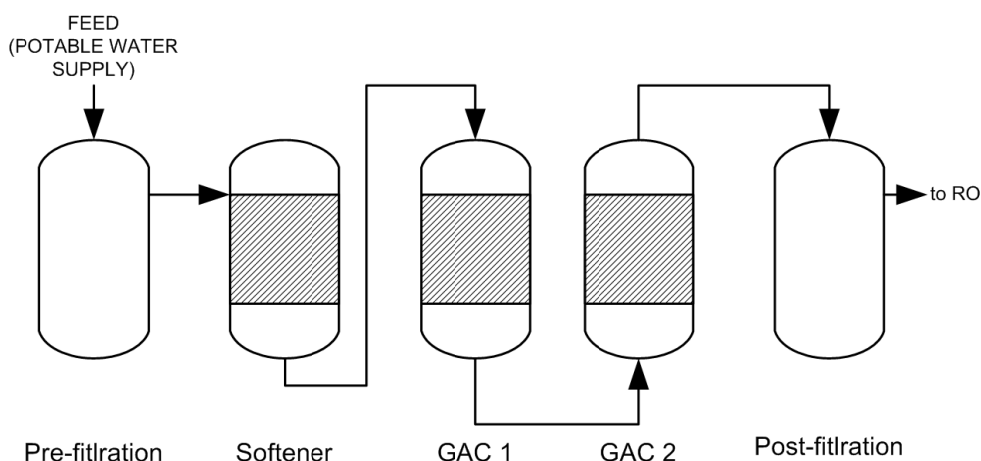


Figure 6 Typical pre-treatment of feed water prior to reverse osmosis (RO) unit with granular activated carbon (GAC) filters.

Prefiltration: This is a cartridge filter for removing suspended solids and protecting the RO unit. This is required particularly where there is an unfiltered supply such as the case for Melbourne. However, small colloidal material may pass through this filter.

Softener: Typically a softener is not required in Victoria. However, there remain several sites where due to the hardness of the water, softening is undertaken to reduce the potential for scaling on the RO membranes. Softeners can be operationally difficult and costly to run. It is also important to understand that softening will increase the sodium content of the water and reduce the magnesium and calcium concentration. This can have a significant impact on the irrigation risk as it changes the sodium adsorption ration (SAR) of the water.

GAC1 and GAC2: Two granular activated carbon filters are provided in series, in order to prevent the passing of chlorine, monochloramine and some organics. The removal of chlorine is required to achieve the standard for the product water supplied to the patient, and to protect the RO membrane from oxidation. Removal of monochloramine is required to achieve the standard for the product water to the patient. These filters are in series (GAC1 and GAC2) as the adsorption to the carbon is irreversible and after extended operation chlorine will breakthrough GAC1 and then be adsorbed by GAC2. Daily routine testing for chlorine between GAC1 and GAC2 is undertaken to determine when GAC1 needs replacement.

Post-filtration: This is a cartridge filter to protect the RO membrane particularly from any carry of granular activated carbon that might breakdown.

Understanding the impact of these treatment steps on the composition of the RO reject stream is important. For example, the RO reject water will be dechlorinated (due to the GAC filtration), this will impact on the potential for biological fouling in some reuse applications.

9.1.2 Using feed water quality data to estimate the RO reject quality

As part of the reporting requirement under the Safe Drinking Water Act 2004 (DH Victoria 2010), water authorities publish data on water quality parameters. The water authorities also provide information on the water catchment and treatment process that can be used to assist in the hazard assessment. This provides an excellent overview of the general water quality and any specific hazards that might be of concern. For example, whether the supply is fluoridated will determine if fluoride is a potential hazard or whether the water has elevated levels of total dissolved salts (TDS).

One limitation with using local water authority data is that it will not address any deterioration of water quality in the hospital distribution system prior to the RO unit and will not include the impact of water softening which will increase the sodium levels of the feed water and reduce the hardness.

The dialysis service provider also periodically measures RO permeate quality and the feed water quality to demonstrate compliance against the Association for the Advancement of Medical Instrumentation (AAMI) or other relevant standards. The feed water quality measured immediately prior to the RO unit can be used to calculate the RO reject composition with knowledge of the water recovery of the RO unit.

The parameters measured in the feed water to ensure compliance with the AAMI standard are: Aluminium (Al), arsenic (As), cadmium (Cd), calcium (Ca), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), mercury (Hg), sodium (Na), zinc (Zn), chloride (Cl), fluoride (F), nitrate (NO₃), nitrite (NO₂), sulphate (SO₄), total chlorine, total hardness, total dissolved salt (TDS) 105°C, electrical conductivity and pH.

This provides a good overview of the ionic composition of the feed water.

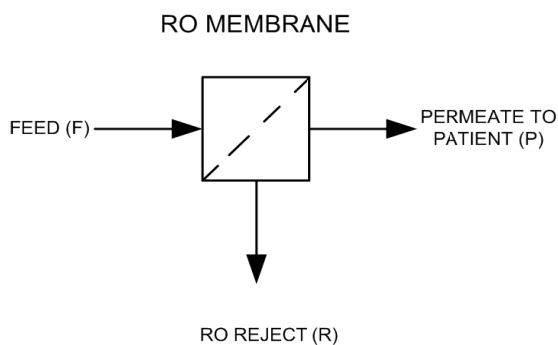


Figure 7 Diagram of reverse osmosis (RO) mass balance

Assuming that 100% of the salt is rejected (typically 96-99% is rejected), mass balance is therefore:

$$[reject] = \frac{[feed]}{\left(1 - \frac{P}{F}\right)}$$

where P/F is the ratio of water recovery of the RO unit (Figure 7).

Table 11 Typical water recoveries and associated concentration factors

RO unit	Typical water recovery	Concentration Factor (CF)
New generation single RO unit	66%	2.94
Older single RO unit	40%	1.66
Central RO unit	50-65%	2-2.85

Note: The recovery rate is often limited by feed water quality. For example, much of Melbourne's water supply is unfiltered, resulting in presence of colloidal material in the feed water that can lead to membrane fouling. In order to prevent RO membrane fouling, the unit is operated at a lower recovery to limit concentration polarisation. To increase the recovery would potentially reduce the membrane life and add to the overall dialysis cost.

The concentration factor is the factor to multiply the feed concentration by to estimate the reject concentration. It is important to note that there is a significant increase in the concentration factor (CF) with new single RO units compared with previous versions.

Sample Calculation

For example, an RO unit with a recovery of 66%, and a feed concentration for sodium of 150 mg/L, will result in an RO reject sodium concentration of 661.5 mg/L.

$$\text{Concentration Factor (CF)} = \frac{150}{(100 - 66)} = 4.41$$

$$\text{RO Concentrate} = 4.41 \times 150 \text{ mg/L} = 661.5 \text{ mg/L}$$

It should be noted that this is an upper limiting approximation. Not all hazards are equally well rejected from RO membranes. For example, boron is poorly rejected (see Section 15).

When possible, the calculation can be undertaken to determine if there is a likely problem for the concentration of specific contaminants. This is an estimate only but a useful indication if further analysis is required.

9.1.3 The need for direct measure of reject quality

The advantage of the mass balance calculation is that it is simple and utilises existing and available data. However, not all relevant hazards are recorded. It may be necessary to directly measure the concentration of hazards to confirm the fitness-for-purpose of the RO reject water.

There are also some parameters (pH, turbidity and colour) that cannot be calculated by simple mass balance. Although based on the survey of 20 sites in Victoria, pH, turbidity and colour are not typically concerns for RO reject water quality.

Measuring the temperature of the RO reject water may also be important for some reuse opportunities. For example, if it is proposed to be used for cooling water, it is important to confirm whether the temperature is above ambient temperature. There was one site in Victoria, where the feed water supply line for the RO unit was piped immediately below a hot roof. The result was warm feed water, and warm RO reject water. This may affect the performance of the RO unit directly, and also impact on the microbiological regrowth potential in the RO reject stream.

The need to measure the composition of the RO reject water quality directly is also impacted by the critical nature of the end use. For example, if the operation of a cooling tower, or boiler could be impacted by the use of RO reject water, and there are manufacturer specifications defining the required water quality it is necessary to measure the RO reject water quality directly, not estimate it by mass balance calculation. Whereas if the RO reject water is to be used for irrigation, estimates of the concentration by mass balance calculation are sufficient.

9.2 Assessing the risk to assets through scaling and corrosion

The use of feedwater that has elevated salt concentration (up to three times higher than the potable water supply) introduces some additional risks to assets; particularly if the potable water supply already has elevated TDS or is hard. In assessing this water quality risk, two key considerations are the potential for **scale** and **corrosion**.

9.2.1 Scaling

The concentration of contaminants particularly in boilers or heat transfer equipment can lead to potential for deposition and scaling. Scale can take a number of forms based around calcium, magnesium (hardness), silica, aluminium, or iron salts (VU & CSIRO 2008, p84).

Accumulated scale can impact on the performance of process equipment and can be expensive to remove. Monitoring the extent of scaling is typically part of preventative maintenance and asset management.

9.2.2 Corrosion

Corrosion is a physicochemical process where a metal interacts with its environment resulting in changes to the metal properties and often loss of material to the surrounding environment.

There are a range of different mechanisms of corrosion. There are a wide range of water quality parameters that need to be considered when assessing the potential for corrosion:

- > Corrosion can impact significantly on asset life and performance; and
- > Monitoring the extent of corrosion is typically part of preventative maintenance and asset management.

Seek advice from the HCF's water treatment service provider for more information.

Table 12 Key parameters influencing corrosion rates associated with RO reject water

Parameter	Effect	Significance for RO reject water
pH	Low pH may increase corrosion rate.	Unlikely to be an issue with RO reject.
Alkalinity	Low alkalinity may increase corrosion rate.	Unlikely to be an issue with RO reject; higher alkalinity than feed potable water.
Dissolved oxygen (DO)	Tends to increase corrosion rate.	Possibly an issue with RO reject.
TDS	Higher TDS tends to increase conductivity and corrosion rates	Potentially an issue with RO reject water if the feed water TDS is significantly elevated.
Chloride and sulfate	High levels increase corrosion of copper, iron galvanised and stainless steels.	Potentially issues with RO reject water if the feed water chloride/sulfate concentration is significantly elevated.

Source: Adapted from Table 2.13 (VU & CSIRO 2008)

9.3 Assessing the irrigation risk (plants and soil)

The use of feedwater that has elevated salt concentration (up to three times higher than the potable water supply) introduces some additional risks if the reject water is used for irrigation. This is particularly so if the potable water supply already has elevated TDS or softening is undertaken to reduce the hardness.

While different soil and plant types have varying tolerances, there are a number of Australian Guidelines and Handbooks which provide details on the values of the main physical-chemical parameters (ANZECC & ARMCANZ 2000; NRMCC & EPHC 2006; Stevens et al. 2009).

Regular monitoring of garden health at the HCF should be undertaken as outlined in Stevens et al. (2009).

9.4 Assessing the biological hazards in RO reject water

The assessment of RO reject water quality has focused on fitness-for-purpose based on chemical hazards. It is also necessary to consider biological hazards. There are three main biological hazards to consider:

1. Elevated biological hazard in the feed water. For example, at one site surveyed, rainwater had been used as feed water on occasion due to poor quality of the town supply. At another site, a boil water notice had been issued for the town, suggesting that the feed water may have had elevated *E coli*. These examples highlight the need to understand the water supply.
2. The dechlorination of the feed water prior to the RO unit means that there is potential for biological regrowth in RO reject water. There is also potentially an increase in nutrient concentrations which may aid regrowth, although most potable water is low in phosphorus and nitrogen.

3. There is potentially above-ambient temperature of the RO reject water and this may enhance biological activity, including *Legionella pneumophila*.

Minimising the risk associated with biological hazards where water is used involves reducing aerosol formation. Anything that causes turbulent motion of water has the potential to produce an aerosol. In industry and commercial situations equipment that can cause this includes but is not limited to:

- > Cooling towers
- > Washing hoses and nozzles
- > Toilets
- > Fountains and water features

These biological hazards need to be included in the risk assessment; however, where possible it is preferable if this hazard is managed through reducing the opportunities for regrowth via periodic chlorination, rather than routine monitoring. Routine biological monitoring would introduce significant compliance costs and render many reuse projects unviable. However, if the risk assessment undertaken (Section 11) deems that biological monitoring is part of the RMP, then it must be undertaken and included as a project operational expenditure (OPEX) cost.

9.5 Understanding water quality guidelines and limits for different end uses

For different reuse options there are different relevant guidelines and key water quality parameters that need to be confirmed (Table 13, Table 14 and Table 15).

Table 13 Key water quality parameters for established reuse options

Reuse Option	Water Quality Requirements	Key Water Quality Parameters and Guideline Limits
Toilet flushing	AGWR	Turbidity, colour, odour, biological regrowth, pH
Steriliser cooling water (CSSD)	IWRG, AGWR	Turbidity, biological regrowth, hardness, TDS, pH
Irrigation – Hospital garden	AGWR, ANZECC	Sodium, Chloride, Fluoride, EC, TDS, Boron, Alkalinity, pH, SAR (For a full description of the values in the ANZECC Irrigation Guidelines see – Section 15.1)
Janitor water	AGWR	Hardness, TDS, Turbidity, Colour, Odour, biological regrowth, pH

AGWR - Australian Guidelines for Water Recycling (NRMMC & EPHC 2006)

IWRG - Industrial Waste Resource Guidelines (EPA Victoria 2009)

ANZECC - Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 3, Chapter 9. Primary Industries (ANZECC & ARMCANZ 2000)

Table 14 Guidelines and key water quality parameters for proposed reuse options

Reuse Option	Water Quality Requirements	Key Water Quality Parameters and Guideline Limits
Car wash	AGWR	Hardness, TDS, Turbidity, Colour, Odour, biological regrowth, pH
Fountains/water features	AGWR	Turbidity, colour, biological regrowth, pH
Chilled Water	AGWR	Turbidity, hardness, TDS, EC, biological regrowth, pH

AGWR - Australian Guidelines for Water Recycling (NRMMC & EPHC 2006)

Table 15 Guidelines and key water quality parameters for process water demands

Reuse Option	Water Quality Requirements	Key Water Quality Parameters and Guideline Limits
Fire Service Make Up Water	IGWR, AGWR AFEA Guidelines (May 2007)	Turbidity, TDS, biological regrowth, pH
Boiler Make Up Water	IGWR, AGWR VU/CSIRO Guidance Manual Manufacturers recommendation	Silica, manganese, iron, copper, TDS, TSS, calcium, magnesium, (hardness), alkalinity, bicarbonate, pH, turbidity (for description of typical values see Section 15.3)
Laundry Hot Water Make Up Water	IGWR, AGWR VU/CSIRO Guidance Manual Manufacturers recommendation	Turbidity, hardness, TDS, biological regrowth, pH
Pump sealing water	IGWR, AGWR VU/CSIRO Guidance Manual Manufacturers recommendation	Turbidity, hardness, TDS, biological regrowth, pH
Heating hot water (closed loops)	IGWR, AGWR VU/CSIRO Guidance Manual	Turbidity, hardness, TDS, biological regrowth, pH
Chilled water (closed loops)	IGWR, AGWR VU/CSIRO Guidance Manual	Turbidity, biological regrowth, hardness, TDS, pH
Water for Macerators/pan sanitisers	IGWR, AGWR VU/CSIRO Guidance Manual	Turbidity, hardness, TDS, biological regrowth, pH
Washdown water onsite	IGWR, AGWR VU/CSIRO Guidance Manual	Turbidity, hardness, TDS, biological regrowth, pH
Dead leg flushing	IGWR, AGWR VU/CSIRO Guidance Manual	Turbidity, hardness, TDS, biological regrowth, pH
Cooling Towers make up water for recirculation	IGWR, AGWR VU/CSIRO Guidance Manual Manufacturers recommendation Legionella (DH Victoria 2007) and Cooling Towers guidelines (DH Victoria 2008)	Hardness, Silica, Alkalinity, Bicarbonate, Manganese, Iron, Sulphate, Calcium, Magnesium, TDS, TSS, Chloride, pH, Turbidity (For a full description of the typical values see Section 15.2.

Note: When considering replacing potable water for RO reject water for any process water applications, it is necessary to consult the manufacturer and ensure that the RO reject water supplied meets the manufacturer's requirements.

AGWR - Australian Guidelines for Water Recycling

IWRG - Industrial Waste Resource Guidelines (EPA Victoria 2009)

VU & CSIRO - Guidance for the use of recycled water by industry (VU & CSIRO 2008)

9.5.1 General Water Quality parameter limits

The preceding tables detail a number of trigger values for common assessment parameters in many reuse options (turbidity, odour, hardness, TDS, biological regrowth, pH). If the reject water quality is below the trigger values, it will most likely be fit for intended end uses (Table 16). These values are only provided as an indicator to give general guidance to the HCF engineer.

Table 16 Trigger values for typical parameters assessed for reuse reject water

Parameter	Unit	Proposed limit for HCF reuse
Turbidity	NTU	5
TDS	mg/L	500 (ADWG, AGWR)
Odour		No odour detected
Hardness	mg/L as CaCO ₃	200 (ADWG)
Colour	HU	25 (based on acceptability to most people, ADWG 2004)
pH	pH units	6-8 (ADWG, AGWR)
Biological regrowth	There are no specific guidelines for this, however, if the water is stored at temperatures between 20-60°C then the ADWG should be consulted regarding regrowth and Legionella ²	

ADWG - Australian Drinking Water Guidelines (NHMRC & NRMCC 2004)

AGWR - Australian Guidelines for Water Recycling (NRMCC & EPHC 2006)

Further risk assessment may be warranted if these values are exceeded for a specific proposed application. For example, there are several sites in Victoria where the hardness for the RO reject water is likely to exceed 200 mg/L as CaCO₃, if water softening is not used in pre-treatment (raw water is hard at Ballarat and Edenhope, and relatively hard at Mildura); however, water in Victoria is generally relatively soft.

If there are more specific limits based on manufacturer and industry guidelines for a specific reuse option, the more specific guideline value should take precedence.

The major concern for these general uses of RO reject water is the possibility of biological regrowth, particularly of opportunistic pathogens in dechlorinated water that is stored for extended periods (see the Australian Drinking Water Guidelines (NHMRC & NRMCC 2004) and below).

9.5.2 Opportunistic and bacterial pathogens

While the risk to human health associated with the reuse of RO reject water is low (DH Victoria 2009), some larger HCFs undertaking RO reject reuse have installed ultraviolet (UV) disinfection to reduce the risk of opportunistic pathogen regrowth. This raises a key question on whether the inclusion of UV (or other disinfectants) is a required step in other smaller reuse projects, and whether inclusion of additional disinfection will become the default requirement because it has been undertaken by other larger HCFs.

² www.nhmrc.gov.au/publications/synopses/eh19syn.htm

There is little specific guidance for the HCF to simply assess the risk to human health of RO reject reuse posed by regrowth of opportunistic pathogens. This is particularly the case given that HCFs contain immuno-compromised and susceptible individuals. Undertaking a site specific Quantitative Microbial Risk Assessment (QMRA) is not a suitable approach given the relative costs and benefits.

A report recently undertaken by the CRC for Water Quality and Treatment (Research Report 79, 2009) highlighted that potential risks include sites such as dead-legs of distribution systems, particularly at elevated temperatures associated with warmer climates, generally in excess of 25°C. The report also notes that:

“At present there is only circumstantial evidence of a causal relationship between the occurrence of various strains of aeromonads, mycobacteria and pseudomonads in water distribution systems and human disease. According to the ADWG, the low infectivity of these organisms does not warrant standards or eradication programs...” (2009 p. 67).

It is also noted that, “though health based targets have not been set for opportunistic pathogens, organisms such as *B. pseudomallei*, *L. pneumophila* (Types 1 – 4) and *N. fowleri* should be absent from a distribution system.”

One salient point to note is that the presence of UV disinfection does not guarantee adequate management of opportunistic pathogens and this is a hazard in all water sources that need to be managed, not only RO reject water. Historically, parts of Melbourne’s water supply have operated with very low chlorine residuals and this may provide similar conditions for regrowth as dechlorinated RO reject water. Operating the water supply system in this manner has been deemed as acceptable under the Safe Drinking Water Act.

As noted in a recent report by Don Bursill (2009) with respect to disinfectant free water supply systems:

- > They have been operating successfully in Europe for more than 20 years;
- > Their main characteristics are good quality source water, excellent and appropriate treatment, small distribution systems (<10 days detention) and cold water temperatures (usually <10°C but some operate up to 18°C); and
- > Water systems with moderate and higher organic nutrient content, long detention times and high water temperatures are not likely to be able to operate without a disinfectant residual.

Based on these reports, it is reasonable to highlight that in all RO reject reuse projects, a risk assessment is needed. Management of risks for regrowth of opportunistic pathogens is best managed by system design, including low detention times (< 1 day), low temperatures (less than 18°C), elimination of dead legs and mixing with some chlorinated water. Based on the reports, if these controls are in place, the risk of opportunistic pathogens can be managed without additional UV disinfection. Additional controls should be considered where there are higher water temperatures, long detention times and dead legs. Consideration of such additional controls should extend to all the internal water supplies of the HCF, not just the RO reject stream.

If UV disinfection is considered a necessary control and is included in the RO reject reuse project as a critical control point, it is important that the performance of the UV system is validated against the target opportunistic pathogen, and the ongoing performance of the UV system is verified. The cost of validation and verification may be considerable, and must be included in the project budget.

The decision to include or not include additional disinfection should be based on the AGWR and the Victorian Guidelines for Water Reuse and Recycling in Health Care Facilities (NRMCC & EPHC 2006; DH Victoria 2009).

9.6 Controls for mitigating the water quality risk

If the RO reject water does not meet the water quality requirements of an identified end use, there are a number of control actions that may be considered.

Table 17 Potential control measures for identified hazards using RO reject

Hazard	Risk	Potential Control	Example of use of control
Fouling and biological regrowth (FBR)	Health risk (bacterial regrowth and opportunistic pathogens incl. Legionella)	UV disinfection	Craigieburn, Barwon
FBR	Health Risk	Periodic use of chlorinated potable water	
FBR	Health Risk	Rechlorination of RO reject water or use of biocide	
FBR	Health Risk	Reduce detention to less than 24 hours	Bendigo
FBR	Health Risk	Temperature reduction through storage design and location	
Algal growth	Health Risk	Prevent light penetration and limit turbulence of water	Barwon ³ , Bendigo
Scaling due to hardness	Asset functionality/ Asset life	Softening water prior to RO unit or anti-scalants	Ballarat, Portland
Concentration of salt in RO reject water	Asset functionality/ Asset life	Blending with other water sources	Craigieburn, Bendigo
Sediment deposits	Asset functionality/ Asset life	Filtration	Craigieburn
Corrosion	Asset functionality/ Asset life	Selection of materials that are corrosion resistant or corrosion inhibitors	
Human consumption of RO reject water	Health Risk	Separate plumbing with “recycled water” signage; Management of cross-connections Education that water is non-	Barwon

³ Personal Communication – Mr David Speirs, Barwon Health.

Hazard	Risk	Potential Control	Example of use of control
		potable No taps accessible to public or staff	
Elevated TDS, SAR, Cl, Na, B in irrigation water	Plant and soil health	Adopt AGWR and ANZECC irrigation guidelines Application of gypsum if SAR elevated	Barwon, Craigieburn, Donald
Ingress of contaminants and insects into storage	Health Risk	Design of system, plumbing standards	Barwon, Craigieburn, Donald

While it is evident that there are a wide range of controls that can be utilised to ensure that water quality is fit for purpose, it is important to aim for simple reuse options where the compliance and treatment costs are minimised.

9.7 Monitoring to mitigate impact on water quality risk

As an outcome of the risk assessment it is necessary to monitor these controls and ensure they are functioning effectively. This may include regular water quality testing and active asset management can also be undertaken to minimise any long term impacts due to poor water quality, particularly scale and corrosion on process equipment and soil and plant impacts.

10. CONCEPT DESIGN AND PRELIMINARY COSTING

When a specific RO reject reuse project has been identified, it is necessary to undertake a preliminary design and costing. This preliminary design and cost is required for the business case and to complete the risk assessment required under the Victorian Guidelines for Water Reuse and Recycling in Victorian Health Care Facilities (DH Victoria 2009).

The development of the concept design and preliminary costing is undertaken based on the HCF's own internal procedures with the aim to highlight relevant issues.

As detailed in the guidelines (DH Victoria 2009), this should also include compliance with plumbing regulations; legionella regulations and off-site supply of water regulations (see Section 11 for more details).

It is important that the preliminary costing is compliant with these guidelines and regulations (DH Victoria 2009) to ensure that there are no significant costs or operational surprises. Depending on the outcome of the risk assessment and the development of the risk management plan (Section 11), it may be necessary to modify the design and costing prior to the business case.

10.1 Some Design & Cost Considerations

In order to provide a starting point for understanding the cost of an RO reject reuse/recycle scheme it is useful to highlight some potential cost and design issues. For example:

- > separation of RO reject and dialysate effluent in single RO units;
- > collecting RO reject from central RO units;
- > transferring, and storing RO reject water;
- > treatment of water if not fit for purpose (not discussed here as not commonly required); and
- > potable water or other back up supplies.

10.1.1 Separation of RO reject and dialysate effluent in single RO units

The typical configuration of a small rural dialysis facility is a room with 1-4 dialysis chairs. The RO unit is supplied feed water (that has been pre-treated with GAC and possibly softening) from piping in the wall, and the RO reject water and the dialysis effluent from the patient are returned to a common tundish in the wall and then into a common pipe.

In order to pursue reuse opportunities, it is necessary to separate the RO reject and dialysate effluent waste streams and have two separate reject lines (currently both the RO reject and dialysate effluent going into a single tundish and a single pipe) so new

tundishes and a new pipe is required in the wall. Then the RO reject can be collected and transferred to a storage tank as a reuse option.

There is an argument that if new installations are made “RO reject water capture ready” through separating the two streams, the future option of RO reject water reuse will be much more viable.

There is considerable variation in the cost of separating the RO reject and the dialysate effluent depending on the internals of the wall and other plumbing.

There is also an additional cost of fittings to ensure that there is no possibility of a cross connection between the dialysate effluent and the RO reject streams. In order to achieve this, different fittings that are not interchangeable must be used.

In many cases with very small regional dialysis sites, the cost of separating the RO and dialysate effluent streams can make reuse projects financially unviable even if there are nearby identified demands for the water.

10.1.2 Collection and transfer of RO reject

The collection of RO reject stream from central RO units can be complex. At established sites in Victoria where reuse from central units has been undertaken (i.e. Barwon Health and Bendigo Health), there is a room or space immediately below the RO unit. This enabled the location of a small intermediate storage tank for the collection of the RO reject water.

Alternatively at Greenfield sites (i.e. Melton and Craigieburn) piping was installed prior to the concrete slab being poured, enabling the RO reject water to be diverted to a suitably sized sump (Figure 8). Both of these approaches were considered viable.

At some sites the RO reject line is near the external wall of the building and it would be relatively simple to locate a suitable sump outside the building. However, at many other sites this is not an option. The RO reject water is discharged into a sewer pipe in the slab on the ground floor (Figure 8). This makes the collection of RO reject water costly.



Figure 8 Discharge from central unit of RO reject water

There can be no backpressure on the discharge line (usually specified by the RO manufacturer) and as a result the RO reject line cannot simply be discharged into an adjacent storage tank. There are several options to collect the RO reject water in this situation:

- > Lift the RO unit on a plinth to enable the simpler collection of the RO reject stream in a tank. This might introduce other operational difficulties. This has been undertaken at least one HCF.
- > Discharge the RO reject stream into a shallow sump (~ 300 mm) with a small pump with level control. This will require consultation with the RO manufacturer as to whether this configuration is acceptable. It would also be necessary to assess the energy use involved in reclaiming a relatively small volume of water.
- > Modification to the concrete slab or piping to enable the RO reject stream to be discharged into a suitably sized sump.

Establishing a cost effective and operationally sound way of collecting the RO reject water from central RO units is critical.

10.1.3 Transfer and storage of RO reject water

The respective locations of the RO unit(s) and the demand for RO reject water impact significantly on project viability. There can be a very high price for running new pipe through an existing hospital building. An accurate estimate of this cost is required. Also it is critical to identify reuse options that do not involve extensive piping to be laid.

The volume of storage required is also an important design issue. Minimising the volume reduces detention times, possibility of biological regrowth in the dechlorinated water, subsequently reducing the cost. However, the ability to reduce the size of the storage depends very much on the demand profile for the reuse option. For example,

if the reuse option is off-site requiring trucking, a 20-30 kL tank that collects the reuse water could be emptied once a week. By contrast, if the demand is well matched with supply (toilet), the required storage volume may only be 3-5 kL. The optimisation of storage also requires consideration that there may be a significant cost penalty if the storage is oversized to attempt use of all the RO reject water. It may be more cost effective to use some potable water to assist meeting peak demands.

There should also be provision for the overflow of RO reject water from the storage to the sewer. This requirement can be complicated if the RO reject water is being used to supplement rainwater tank supplies which are already connected to the stormwater system. It would be necessary to consult the EPA to determine if this is acceptable, as RO reject water is considered process water which should be directed to the sewer.

10.1.4 Potable water or other back up supplies

A key consideration in the design of any reuse scheme is ensuring hospital service continuity and minimal disruption to HCF operations. For these cases, all designs must include provision for the failure of the RO unit to supply, such as a backup system reliant on mains water in the event of supply failure. In these instances it is necessary that potable water (or other fit-for-purpose water) will automatically replace the RO reject water and provide continuity of supply. However, for some services such as irrigation, continuity of service is not critical, and simpler back up systems can be utilised. Appropriate cross-connection controls are also required by water authorities.

11. HUMAN, ENVIRONMENTAL AND ASSET RISK ASSESSMENT AND MANAGEMENT

It is the responsibility of health care service providers to exercise duty of care and ensure that the use of alternative water supplies is protective of public health. Managing risks associated with water reuse and recycling schemes in a HCF requires a long-term commitment by the CEO and Board to ensure the protection of human health and the environment.

In order to assist HCF, the Department of Health has developed within the **Guidelines for Water Reuse and Recycling in Victorian Healthcare Facilities** advice on risk management plans for water reuse (DH 2009, Chap.5). These Guidelines should be adopted in the development of a RO reject reuse project.

The aim of this handbook is not to repeat the contents of these Guidelines. It is the responsibility of the HCF to adopt these guidelines or develop its own risk management approach to exercise a duty of care.

In addition to the Guidelines for recycling in Victorian HCF, it is also important to note there are other relevant guidelines that govern reuse of RO reject water:

- > Industrial Water Reuse Guidelines (VU & CSIRO 2008);
- > Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (NRMMC & EPHC 2006); and
- > Cooling towers and recycled water (DHS Victoria 2008; Sydney Water 2008).

These are also other regulations that must be adhered to in the development of RO reuse schemes including:

- > Plumbing codes
- > Legionella
- > Off-site supply of water

It is also important to note that the EPA classifies the reject water from reverse osmosis units as a type of industrial process water and as such any reuse must comply with the associated regulative and risk management obligations. All industrial water reuse schemes should undergo a preventive risk assessment and management process to ensure they exercise due diligence and manage the risks, from an environmental, public health, and business and worker safety point of view.

With all of these guidelines and regulations, it is important to note that the Guidelines state, "The potential human health risks associated with RO reject water would be considered extremely low" (DH Victoria 2009 p. 21).

The risk to human health associated with RO reject water is considered extremely low

11.1 Integrating this Handbook with the Guidelines

Section 9 of this handbook has provided a detailed review of the water quality requirements for different reuse options and details on controls that can be utilised to reduce the risks associated with the reuse of RO reject water.

However, Section 9.2 only provides the background to undertake the risk assessment and develop a risk management plan. The HCF must undertake its own risk assessment and develop its own risk management plan specific to the site and end use.

The Guidelines for Recycling in Victorian Healthcare Facilities (DH Victoria 2009) provide a Risk Management Plan template and guidance note. Download them from:

www.health.vic.gov.au/environment/water/recycle.htm

11.2 Some examples of important risk assessment issues

This handbook was developed in conjunction with a survey of 20 dialysis sites in Victoria. Through this survey a number of critical issues were identified that are relevant to the risk assessment process.

- > Cross connections between the toilet flushing tank and the potable supply were considered a significant risk to reuse of RO reject water at one large HCF. Any point where RO reject or other non-potable water supplies are likely to come in contact or mix with potable supply will present a problem. This highlights the need for a detailed system understanding amongst the risk assessment team and importance of control measures.
- > In order to fully capture the benefits of some reuse projects, it is necessary to combine different sources of water utilising the same infrastructure. For example, rainwater, stormwater, other process water and RO reject water may be combined. The risk management plan (RMP) undertaken needs to consider the risks associated with all sources.
- > A fundamental hazard that has already been noted in this Handbook is the risk to human health associated with dialysate effluent. It is crucial that everyone involved understands the critical nature of keeping the dialysate effluent and RO reject separate. This requires an education component of the RMP and checks in place before commissioning and auditing the RMP. These control measures are an essential component in the development of an RO reuse project with single RO units.
- > As part of all RMP it is necessary to include a further education component to highlight that RO reject water is high quality, but potentially not potable and that there are a range of uses for which it is not suitable.
- > Storage of dechlorinated RO reject water presents a number of risks that need to be identified in all RO reuse projects. Section 5.15 in *Storage and Plumbing Systems* of the Guidelines (DH Victoria 2009) provides an excellent summary of some identified risks and possible controls, especially for *Legionella* for example with long storage periods and subsequent spray irrigation or cooling tower operation applications.
- > The risk assessment process needs to address normal operation of the RO unit and additional processes. For example, it is necessary to assess the fate of CIP membrane cleaning fluids and the waste streams from the heat disinfection

processes. These are maintenance procedures that need to be included in the risk assessment process. These examples demonstrate the importance of having someone in the risk assessment team with a detailed knowledge of the RO process and other operational processes. Ideally this would be part of the technical support from the dialysis service provider.

This list is not exhaustive and has been included to highlight some issues that were identified during the site survey that may be commonly found during the reuse of RO reject water at HCFs.

12. MAKING A BUSINESS CASE FOR THE PREFERRED OPTION

Project approval is a decision entirely for the HCF. While a range of other organisations (such as dialysis service providers, Department of Health, Department of Sustainability and Environment, water authorities, local community organisations), might promote the reuse of RO reject water, it is ultimately a decision for the HCF.

The business case is made using the internal procedures of the HCF. This Section aims to provide some supporting information for the project proponents in the developing a business case.

12.1 Using the WaterMAP framework

The WaterMAP process provides a useful overview of the process to develop a business case for water conservation (detailed in Section 13.1.1).

12.2 Calculating cost saving of reuse

One central financial argument for the reuse of RO reject water is that it may be suitable to substitute for potable water or some other sources of water. The extent of this substitution is typically the critical calculation of the payback on the project.

This requires a calculation of the saving achieved by using RO reject water. There are a number of complications with this calculation.

There are significant changes to the price of water due to the cost of new water supply infrastructure:

- > Water prices can be tiered based on increased usage. Typically hospitals, as significant water users, are on the highest tier.
- > If RO reject water is reused onsite it reduces potable consumption and also the cost of disposal to the sewer. Hospitals are typically charged for sewage disposal assuming that 90% of the water metered as coming into the property goes into the sewer (DHS Victoria 1999). In effect, reducing the cost of water is nearly doubled when the sewage disposal charge is taken into account. The option to directly measure sewerage flows is operationally difficult and costly.
- > There maybe additional trade waste costs for the hospital based on the composition of the trade waste.
- > In some cases the RO reject water may replace irrigation water or trucked water that has a specific price.

It is important to be clear about what incremental cost savings are achieved by the HCF by reuse of RO reject water. This is best achieved by utilising the water bill to the HCF and estimates of the predicted increases in water pricing.

For example, Yarra Valley Water Authority supplies water to the Northern and Broadmeadows hospitals based on the pricing determination of the Essential Services Commission. The non-residential water usage water tariff is \$1.3504/kL and the non-residential sewerage tariff is \$1.4687/kL (ESC 2009). Therefore excluding fixed service

charges, and other trade waste components, the price for potable water usage in 2009/10 is \$2.672/kL.

This cost of water can vary significantly around Victoria, and it is important the HCF business case is based on the actual usage charge for the supply and disposal of the water that will be replaced by RO reject water.

The pricing of water is regulated in Victoria by the Essential Services Commission, and price increases need to be justified. Typically where capital expenditure has been undertaken to provide a more secure water supply, there have been significant increases in the cost of water.

The increasing cost of water will improve the financial viability of RO reuse projects and it is important that projects deemed as unviable are revisited in the future as potable water prices increase (Melbourne Water Corporation 2009)⁴.

12.3 Integration with other recycling schemes

In addition to the potential savings in potable water through reuse of RO reject water (and reduced volume of water to the sewer), it is also important to consider the complete fate of the water. For example, it may be more efficient and cost effective to discharge the RO reject water to the sewer if 'third pipe' or Class A recycled water is already available to the property via a recycled water scheme.

12.4 Project cost: the need for a quotation

The success of the project depends on accurate costing of the proposed reuse scheme. This requires a detailed site specific quotation. Using generic estimates for a business case is not sufficient and likely to lead to cost overruns. Typically the Engineering Department of the HCF has a list of suitably qualified plumbers and contractors who can quote on the job.

12.5 The financial argument: payback times

Payback times are a common project viability assessment tool. A simple payback calculation may assess the CAPEX and the cost saving through reduced potable water consumption. Other performance measures maybe be utilised by the HCF, such as \$ CAPEX/kL of water saved.

The limitation with these simple calculations is that while they provide some overall indication of project viability it is important to include an estimation of the annual operation and maintenance costs; these may be typically small. For example, pump replacements will be required. Also any compliance activities resulting from the RMP

⁴ Metropolitan Melbourne. Water price review 2009. Yarra Valley Water determination. 1 July 2009 – 30 June 2013.

(Appendix B of the Guidelines (DH Victoria 2010)) will need to be included in the final payback calculations. Similarly, if the reuse project identified is novel or complex, the cost of developing a RMP and compliance may make the project unviable.

It is critical that the payback calculation of other project assessment is undertaken based on realistic figures and all hidden costs accounted for.

12.6 Non financial criteria

There are a wide range of motivations to develop water reuse projects. The motivations are often not purely financial. For example, if a town is gripped with prolonged drought, the HCF may undertake a project to demonstrate community leadership and promote water reuse and conservation. In other cases, the garden is deemed of significant social and therapeutic value.

12.7 Assessing project costs and benefits

When combining financial and non-financial criteria it is important that the business case is clear in its assessment of the costs and benefits that the reuse project can offer. A description of the potential benefits and costs are detailed below:

1. Potential for potable substitution.

A major aim is to reduce potable water consumption through substituting RO reject water. However, if the reject water is used for a new demand (such as watering a garden that had not previously been watered) this does not impact on the volume of potable water supplied.

2. Potential to maximise reuse volumes.

A key requirement to optimising the reuse of water is matching the demand and supply profiles. In the case of dialysis RO reject water, the reject water is generated during the day for a specific number of hours and a specific number of days of the year. Ideally the demand profile should be constant throughout the year and if the water can be used more than once the reuse option gives greater benefit.

3. Potential to utilise existing assets.

A significant opportunity to enhance project viability is the utilisation of existing assets. For example, RO reject water can be added to existing rainwater tanks. It should not be added to potable supply assets

4. Highest social value.

During a drought, available water can have a high social value. For example, sporting fields are an important community resource requiring water (Speirs 2009).

5. Beneficial to the environment.

One of the significant benefits of local reuse is compared with other water resources is that there is a lower environmental impact due to reduced pumping and treatment (if

it is used before entering the sewer). For example, if reuse water is trucked from the hospital to an alternative site, there is a relatively high energy cost to move the water.

6. Ease of operation of HCF/dialysis centre and ease of installation.

HCF are complex organisations focused on the care of patients. The opportunities to reuse RO reject water must not compromise this function. Where possible the reuse water will not add additional operational and maintenance tasks to the hospital. If the reuse option identified for the reject RO water is critical, backup potable water supply is required. Automatic backup and replacement with potable water may be required to minimise the disruption to hospital services.

7. Potential cost.

Capital (Capex) and ongoing maintenance (Opex) costs remain a critical issue for project viability. A comment on the costs and benefits outlined above should be included in the business case and how they relate to HCF aims and objectives.

12.8 Project risks and opportunities for RO reuse

Some of the project risks and opportunities that have been identified in existing RO reuse projects are summarised below. Many of these risks and opportunities may also be relevant to developing HCF reuse schemes.

12.8.1 Cultural/psychological barriers

There is a perception from some members of the public that recycling RO reject somehow involves the dialysate effluent or other by-product fluids from haemodialysis itself. It is critical in communicating the project to be clear that only the RO reject water is reused.

It is also important from a risk management point of view to highlight that while the water quality is high, it is not guaranteed as potable water now and should not be treated as potable water unless it has been reassessed and determined to be potable using the Australian Drinking Water Guidelines (NHMRC & NRMMC 2004). It should ultimately be described as **fit for the purpose** it will be used for.

12.8.2 Physical constraints and opportunities

One of the major difficulties in developing reuse opportunities is accessing the RO reject stream. Typically it is combined with dialysate effluent in single RO unit dialysis systems, and it is rejected at a low discharge point in central RO schemes. This can add significantly to the cost and must be accurately included in the estimated project cost.

There are significant benefits in utilising existing infrastructure (e.g. rainwater and flusher tanks) in the development of an RO reject reuse project. There are also significant benefits in combining RO reject water with other sources of non-potable water (such as rainwater).

12.8.3 Financial difficulties

Healthcare facilities provide a critical service to the community and there are limited health care funds. Any investment in water conservation and reuse must be cost effective and justifiable on the basis that it is not drawing funding away from patient care. As a result of this, the required payback calculation is typically less than 5 years. In some cases, securing external funding is one way to assist the financial viability of the project.

12.8.4 Overestimating real demand for water

One of the key project risks is that the demand for RO reject water is over estimated. As a result the benefits of the project are not realised. From surveying a number of RO reject reuse projects undertaken in Australia it was evident that the demand has been overestimated in many cases. In order to assess this project risk, it is necessary for the business case to include some assessment of the robustness of demand and the impact if the demand is less than expected. It is also important that the project includes a post-implementation step where the actual water and dollar savings are confirmed.

**Demand is
often
overestimated**

A significant example of over estimating demand is the case of trucking water offsite. The demand may be high during Stage 4 water restrictions, but if the drought breaks or other sources of water are available the demand for trucked water will reduce significantly. This is an important project risk that must be addressed.

12.9 Possible funding sources

The viability of many water conservation and reuse projects hinges on external funding. Governments have long taken a role in pilot project funding to open up new ways of doing things. For example:

- > Greening Our Hospital program funded by the Victorian Water Trust and administered by the Department of Health (The Greening Our Hospitals program has been a significant source of funding for a wide range of water conservation and reuse projects);
- > Water authorities as a funding source of and promoter of reuse opportunities identified;
- > Commonwealth funding (e.g. National Water Commission, Save Water);
- > Local councils as the first point of contact to explore offsite uses of the reject water;

Other funding sources identified are:

- > Community Water Grants (Commonwealth)
- > Environmental Improvement Fund Retrofit Project Funding (Brant Rowe & Sustainability Victoria 2008)
- > Melbourne Sustainable Fund
- > Partnerships with Water Retailers/ Local Government / Local Businesses
- > Community Grants from the Australian Government Water Fund, (such a grant was used by the (Royal Adelaide Hospital) Renal Dialysis Satellite Unit to recycle and reuse RO reject to irrigate Hampstead Rehabilitation Centre gardens and lawns)

- > Savewater.com.au efficiency service. This process has been conducted at Northern Hospital and Broadmeadows HCF.

12.10 Greenfield sites: planning for the future

The development of a new health facility or planned renovations present a significant opportunity to develop water reuse opportunities, providing more attractive business cases for the collection and reuse of RO reject water.

There are several examples of Greenfield developments in Victoria including Craigieburn, Melton and Donald HCF.

With respect to Greenfield sites, there is also a strong argument that installing a flusher tank could somewhat future-proof the site and allow for a range of non-potable water source to be used for toilet flushing.

12.11 Developing RO reject reuse readiness

Greenfield sites also provide the opportunity to develop a site that is ready to reuse RO reject water in the future. The difficulties with existing infrastructure are evident at both single RO sites, and central RO units. In regional centres with single RO units, both the RO reject and dialysate effluent are rejected to the same tundish. Reuse options can only be explored after the two streams have been separated. This retrofit can be costly, whereas if it is possible to separate the two streams as part of a Greenfield site, future developments are much simpler and less costly.

With central RO units, the point of discharge is at the ground and for sites without a lower floor, collection of the RO reject is complex. In order to achieve RO reject reuse readiness, it is necessary to ensure that the water can be discharged into a suitable sump for transferring to storage. Without this preparation, it can be difficult to collect the RO reject stream and it may involve the expense of putting the RO unit on a plinth or discharging into a shallow pump and having a small pump pumping on level control.

12.12 Post-project implementation review

The business case should include a commitment to a post-project implementation review. Many recent projects undertaken to reuse RO reject water from dialysis are typically demonstration projects as these projects have only been pursued in the last 5 years during a period of unprecedented drought in South East Australia.

While this type of local reuse remains novel, it would be very advantageous if it was possible to fully assess the costs and benefits of the project and provide this information to other HCF and hospital engineers through industry forums, such as the Institute of Hospital Engineers Association (IHEA).

13. APPENDICES

13.1 Water auditing tools

13.1.1 WaterMAP

This section outlines the use of WaterMAP (DH Victoria 2009) for assessing opportunities for improvement, helping identify areas of water wastage, reuse opportunities and associated cost. A copy of the WaterMAP brochure and handbook (DSE Victoria 2007) is available from the Victorian Government's Our Water, Our Future Website⁵.

The major components of WaterMAP include:

1. Assess opportunities for improvement

Once a list of improvement opportunities have been developed, it's a good idea to further analyse them to help determine what measures, if any will be implemented. This will also help you understand the technical and financial feasibility of their implementation.

2. Investigate opportunities for improvement

The actions required to improve water efficiency may not have been clear during an initial walkthrough. A technically based walkthrough or audit may need to be carried out, perhaps using the assistance of a specialist. For example, in identifying the cooling towers as an opportunity for improvement, a technical review of their operation to determine exactly what improvements can be made may be required. In this case a cooling tower specialist could be engaged to review the water efficiency of cooling tower operation.

Another example of a potential improvement that requires further investigation could be the collection and use of rainwater instead of drinking water for certain processes. How this could be achieved needs to be investigated.

3. Feasibility

The feasibility of implementing any proposed improvement measures should be demonstrated by benefits to the business. It should show how they can increase shareholder value, competitive advantage or profits, and/or reduce risk.

Look at the technical viability of each opportunity (is it practical to implement?), as well as the financial viability or cost benefit analysis (is the payback period within the organisation's recommended payback period?). Most organisations have an existing method for determining the feasibility of projects and it makes sense to follow

⁵ www.ourwater.vic.gov.au/saving/industry/watermap

whatever method is already used. The simplest method is to carry out a cost benefit analysis by calculating payback or return on investment.

To carry out a cost benefit analysis:

1. Identify the costs involved

Record both direct and indirect costs, including equipment, operating (including power and waste discharge), financial interest, insurance and other costs. Include the costs for implementing the measure as well as any ongoing costs.

Non-monetary costs such as social and environmental costs that may not directly affect the financial bottom line but affect the business should also be considered. Any measures implemented should be consistent with the organisation's policies.

2. Identify the benefits

Record the monetary benefits of reduced water consumption, including trade waste and chemical costs (if applicable).

Also include other benefits, such as an improved business reputation.

3. Investigate funding options

Consider the various funding options available from the water corporation and the Victorian Government that can aid water saving projects.

4. Calculate the payback period

Calculate how long it will take for the benefits of implementing the measure to outweigh the costs. The business can then assess whether it is feasible to implement. Typically, businesses implement measures if the determined payback period is less than three years, however social and environmental aspects of the project should also be taken into account.

Payback period is calculated by dividing the cost of implementation by the savings achieved. For example, if a water efficiency project costs \$10,000 to implement and it saves \$2,500 in water and sewage discharge costs per year, it has a payback period of four years (10,000/2,500). Consider ordering projects into short, medium and long-term based on the payback period and ease of implementation.

13.1.2 Greenstar Rating

The Green Building Council of Australia has a Greenstar rating for hospitals⁶. (Greenstar – Healthcare v1). This provides an overall assessment of the impact on the environment and a tool to assess water and energy usage. However, the approach does not provide guidance or specific information about dialysis RO reject reuse opportunities.

⁶ <http://www.gbca.org.au/green-star/green-star-healthcare-v1/1936.htm>

13.2 Calculating the quantity of water

13.2.1 Central RO units

The totalised volume of RO reject water from central RO units can be calculated based on the totalised volume of feed water supplied to the RO unit, the water recovery rate and the hours of operation:

F = Totalise feed water supplied to RO unit (kL)

R= Water recovery (%)

T= Run time operation of RO unit (hours)

All these parameters are recorded electronically on the RO unit.

$$\text{Volumetric flowrate of RO reject water (kL/hr) or } V = \frac{F \left(\frac{100 - R}{100} \right)}{T}$$

This volumetric flow rate can be multiplied by the hours of operation per week to calculate the volume of RO reject water generated per week.

This estimate can also be checked through direct measurement of the volume of water rejected.

13.2.2 Single RO units

To calculate the volume of RO reject water from a site with single RO units, it is necessary to have the following information:

- > Number of RO units (N)
- > Hours of operation of each RO unit (H)
- > Type of RO unit and water saving setting (water recovery)
- > The volumetric flowrate of the unit can be calculated based on the type of RO and the water saving setting utilised (V).

$$\text{Volume of RO reject per week} = N \times H \times V$$

This estimate can also be checked through direct measurement of the volume of water rejected.

These calculations assume that the recovery will remain relatively constant. If there are operational changes to the recovery or water saving setting this could significantly change the volume of water rejected.

13.3 Compliance Checklist

Below is a checklist of procedures that should be completed as part of a reuse scheme (Table 18).

Table 18 Example of check list for assessing a RO Reject reuse scheme

Check list item	Circle answer
WaterMAP or water audit complete	Yes/No
Established long term operation of dialysis service	Yes/No
Volume of RO reject water confirmed	Yes/No
Identified RO reuse opportunities	Yes/No
Confirmed demand and demand profile for reuse option	Yes/No
Confirmed RO reject water quality fit-for-purpose	Yes/No
Concept design and preliminary costing	Yes/No
Risk assessment and Risk Management Plan develop (Proforma template from the Guidelines)	Yes/No
Business case made to HCF	Yes/No
Project approval	Yes/No

13.4 Contact List

Greening Our Hospital Program, Department of Health
Sustainability Unit, Capital Management Branch

Sarah.bending@dhs.vic.gov.au

03 9096 2049

Environmental Health Unit, Guidelines for Water Reuse and Recycling in Healthcare
Facilities, Department of Health

For further information on use of recycled water in cooling towers and Legionella risk
management

1300 768 874

www.health.vic.gov.au/environment/contacts.htm

Environment Protection Authority, Environmental Strategies

EPA Information Centre

03 9695 2700

www.epa.vic.gov.au

Plumbing Industry Commission

Standards and regulatory requirements for plumbing:

1800 015 129

www.pic.vic.gov.au

Greenplumbers Australia

1300 368 519

www.greenplumbers.com.au

Institute of Hospital Engineers Association IHEA,

03 8623 3013

info@ihea.org.au

Green Star Rating Tool – Green Building Council of Australia

02 8239 6200

www.gbca.org.au

Our water, our future

136 186

www.ourwater.vic.gov.au

Smart Water Fund

www.smartwater.com.au

14. CASE STUDIES

A number of pilot projects have been identified in Victoria for the reuse of dialysis RO reject water. These projects include both retrofitted dialysis facilities such as in regional Victoria (Bendigo Hospital, Barwon Health and Donald) as well as planned recycling of RO reject water in the new “superclinics” and “greenfield sites” (e.g. Melton, Box Hill, Craigieburn and Wangaratta). These sites have been investigated and reported on as case studies for this section of the handbook.

Other interstate reuse examples are at the Queen Elizabeth Hospital (Adelaide, SA) where RO reject water is rechlorinated, filtered and blended with feed potable water in tanks.

The case studies are useful for learning of the successes and pitfalls of undertaking reuse of RO reject from dialysis services. In the following case studies, it is important to note that:

- > Most sites are recycling substantial volumes of water;
- > the reuse schemes have involved integration/augmentation of the RO reject with another water supply such as rainwater, stormwater, or runoff; and
- > Thus, the economic viability of these reuse schemes is not costed on dialysis reuse alone, yet the reduction in potable water consumption remains significant.

14.1 Craigieburn, Victoria

14.1.1 Overview

Craigieburn Health Service is located on the northern fringe of Melbourne, Victoria. Craigieburn was developed as Greenfield site, representing a significant opportunity in terms of planning the integration of water saving and recycling measures into design and construction. The facility also adopted energy efficient and other sustainability measures by strategically considering the use of natural light, airflow, shade, rainwater, solar heating for water and natural ventilation into the design. The site combines rainwater/stormwater capture and RO reject collection, which has proven effective and simple. The water sources are captured in a pit at the rear of the facility and then pumped into two fire hydrant tanks adjacent to the HCF car park.

14.1.2 Identification and selection of reuse options

Identification and selection of reuse and recycling was incorporated from the outset into the design, and this is a major benefit of a greenfield site. The team responsible for the design of the Craigieburn Health Service took the challenge to reduce water consumption even further and built more water saving features into the design including:

- > solar assisted water heating;
- > AAA rated water efficient taps and AAAA rated water efficient toilets;

- > reuse of rainwater and clean waste water from the dialysis treatment plant for toilet;
- > flushing in the building and for irrigation of the landscape; and
- > using planted areas between car parking blocks to capture and control rainwater run off for use in the gardens.

Estimated savings from this design are expected to be a 50% reduction in the amount of water used when compared to business as usual.

14.1.3 Funding for works

As a greenfield site, funding for works was part of overall construction of the healthcare facility, so particular figures on the cost of the RO reject component alone are difficult to calculate.



Figure 9 Craigieburn Health Services (right) and storage tanks for fire hydrant water (left).

14.1.4 Lessons Learned

It is difficult to assess the overall impact of collecting the dialysis RO reject water because it is combined with the collection of rainwater and the tanks are also topped up with potable supply. One overall indicator of the performance of the Craigieburn facility is that it using 60% less water per patient than a comparable facility also operated by the Northern Health. This indicates the combined initiatives at Craigieburn have a significant positive impact.

One suggested alteration to the setup involves a separate tank for the fire service water. The current arrangement is such that the tanks may be topped up with potable water to ensure that sufficient fire service water is available. This can limit the value of collecting rainwater and RO reject water.

There is probably some scope to extend the post-implementation review of this project. The benefits of a greenfield site are acknowledged by Northern Health and there is consideration for additional schemes when greenfield opportunities occur.

For more information, contact: Sharon McNulty, Director of Facilities Management, Northern Health. Ph: 8405 8383

14.2 Barwon Health, Geelong

14.2.1 Overview

At Barwon Health in the City of Geelong, the engineering team and Haemodialysis Department have undertaken water recovery and reuse from various sources across several sites, integrating the reject RO from a dialysis unit into the hospital's other water demands. This has reduced the volume of potable water consumed by over 20 kL per week (estimated 1.1 ML per year or \$36,000 in water value). The water quality is high (Agar 2008; Agar et al. 2009). The reuse of several water sources to other end uses has required the installation of plumbing over several floors and serves as a good case study for retrofitting to reuse RO water within an older, pre-existing building.

Since 2005, the RO reject water and permeate from the dialysis department has been used for:

- > Sterilising cooling water;
- > On and offsite irrigation;
- > Toilet Flushing / Flusher tank water;
- > Makeup water for cooling towers; and
- > Water available for janitors / washdown equipment and cleaning water.

An important aspect of this reuse setup is that the project champions have attempted to adopt a waste hierarchy, so the reject RO water is used for several end uses where lower quality water can be used in conjunction with freshwater, thus reducing overall volumes of potable water consumed (Figure 10).

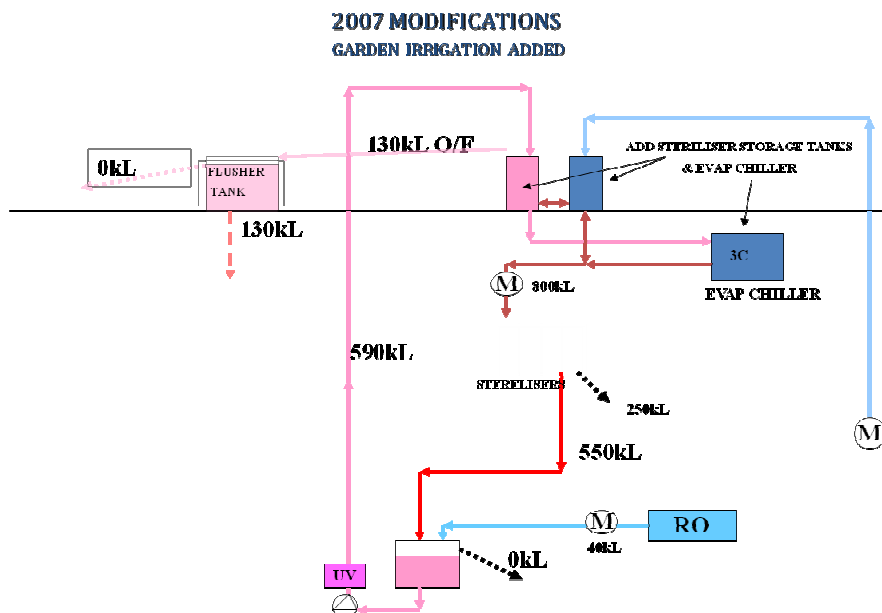


Figure 10 Schematic diagram of water reuse at Barwon Health, adopting the waste hierarchy for cascading reuse (reproduced without modification, Speirs 2009).

Some key features of the water reuse system in place are:

- > All the makeup water required for flushers and cooling towers is directed firstly through the sterilisers before being distributed for other uses (Speirs 2009);
- > Water for the steriliser is made up from jacket cooling steam condensate and the vacuum pump sealing water. To run the vacuum pumps, they are set 1/2 full of water, to maintain and act as a good seal, requiring no other oils or graphite lubrication; and
- > Steriliser cooling & vacuum pumps feed water is sourced from a tank which has a blend of between 40% to 60% fresh water, the balance is the recycled/recovered water which has been cooled to under 25°C, to achieve cooled water at 18-20°C. The recovered water is a combination of steriliser cooling water, RO backwash and permeate reject.

14.2.2 Selecting reuse opportunities

At Barwon Health, Professor Agar consulted the hospital engineer, Dave Speirs to determine a reuse solution to recycle the water throughout the hospital with a view to reduction of overall potable water consumption. The pair championed a model for reuse of the water, making a successful funding application to the Victoria Department of Health for plumbing works. From the initial reuse measures there have been subsequent works integrating other sources of water including rainwater capture.

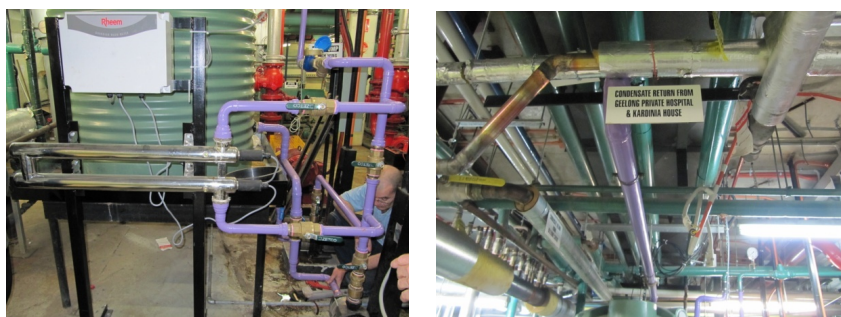


Figure 11 An engineer maintaining the recycled water system at Barwon Health after installation of the UV filter (left); and example of labelling and extensive piping (right).

14.2.3 Funding for works

Aware of their role as a large water consumer in the region, in 2004/5 Barwon Health undertook a comprehensive water audit to improve water use efficiencies. Barwon Health published the results in a local news publication and expressed intention to recycle water in the hospital. From this exercise, they gained publicity for their intention to recycle water and also managed to gain in kind support from another local major water consumer; Alcoa. Alcoa donated the tanks to Barwon Health, a substantial in kind gesture of support. Funding for \$75,000 of pipe works to reuse the RO reject in flusher tanks and for sterilising/cooling makeup water came from the Victorian Government Department of Health's Greening our Hospitals programme.

Whilst many hospitals may be unwilling to pay large costs upfront for projects that have a longer payback, Barwon Health argue that the estimated payback period in terms of water dollar savings can be as small as 18 months to a maximum of a few years where substantial volumes are being reused for several end uses. They have measured water saving volumes at approximately 100 KL/wk. This is made up of 65 kL/wk across all facilities (85 patients over three sites) and 35 kL/wk (20 patients) in their homes.

14.2.4 Lessons learned

The project champions at Barwon Health have been proactive in lobbying for water reuse. The primary objective for Barwon Health in reuse of RO reject stream is for potable substitution. However, as acceptance of recycled water has grown over recent years, the possibility of generating an income from reuse applications such as a car wash facility has gained some appeal. It was also noted that despite the water savings, the local water authority Barwon Water has subsequently increased service charges, so dollar savings do not quite equate with the litres of water saved annually.

Interestingly, the recoveries of the small dialysis units are low in this case study, probably due to their age (37% or 0.6L/min recovery/1.6 L/min feed) (Pers.com John Agar) compared with 50 to 65% (Table 11). With asset renewals, higher recovery units will replace these lower recovery units.

Onsite reuse: Barwon Health (Geelong City)

There is planned reuse for the dialysis clinic opposite the hospital in the near future. Currently this is the only dialysis facility that is not reusing water. Barwon Health currently produces more reusable water than can be reused onsite, which is why they have installed the 2 large storage tanks, from which community organisations can collect water at their own expense for irrigating playing fields, etc. There are also plans to run a pipe across Ryrie Street to a new building being established for Deakin University to extend uses of the water.

Satellite Reuse: South Geelong and Newcomb

Although not an example of RO reject water reuse for potable substitution, this is a useful example of water conservation and reuse project at a HCF. This is a new project where freshwater mains are supplied to kitchen and hand basins only, with rainwater tanks and deionised filters for treating greywater from showers; effectively operating two types of greywater for reuse at the facility. At these satellite sites, there are two x 30 kL tanks that are available for local sporting grounds for irrigation and at no cost to non profit organizations.

For more information, contact David Speirs, david.speirs@barwonhealth.com.au
Project Engineer, Barwon Health

14.3 Bendigo, Victoria

14.3.1 Identification and selection of reuse options

In light of severe water restrictions facing Bendigo in the past 5 years, water audits were conducted to determine water volumes and identify potential for water reuse and recycling onsite. Works were carried out to recycle the RO reject stream and to capture stormwater. The water rejected from the Reverse Osmosis unit is used to flush toilets within the Hyett and Phillips buildings onsite and is estimated to save approximately 1.7 ML of potable water annually. The reverse osmosis plant typically supplies 12L/min to patients and 5L/min of waste water. This waste water is stored temporarily in a 500L polytank, which when triggered, pumps the water to the first of two flusher tanks (the number one tank overflows to the second tank.) This tank also allows overflow to feed into the stormwater pit, which pumps water to a 22.5 kL poly tank at the Hyett block. This stormwater pit and tank are designed to capture any overflow from the number two toilet flushing tank and the backflushing of the microfiltration plant in level 5 Hyett.

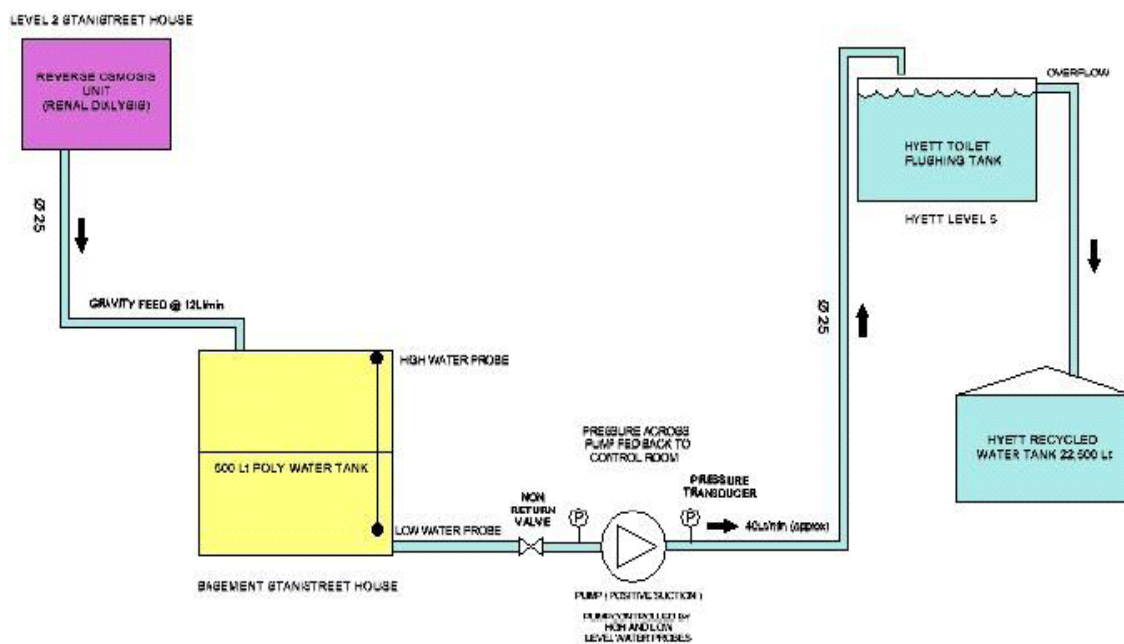


Figure 12 Schematic diagram of reuse of RO reject through storage tanks, Bendigo (Walker 2007).

14.3.2 Funding for works

The plant was funded under Round 4 of the Stormwater and Urban Water Conservation Fund. At the time that these works were undertaken, Bendigo was undergoing Stage 4b water restrictions, which was the primary driving force behind the water conservation projects.

14.3.3 Lessons Learned

Project champion Greg Ellis was also very keen on environmental projects, which highlights again the effectiveness of having a passionate and keen project champion in successfully completing such projects. Risk management for the water reuse and recycling systems required:

- > Involvement with the Infection, prevention and control unit
- > Risk management plans developed for each recycled water system
- > Adherence to EPA dual pipe guidelines for risk assessment
- > RMP requires routine maintenance, particularly of bearings and pump performance and periodic checks on pipe works and tanks for leaks.

For more information contact: Andrew Johns AJohns@bendigohealth.org.au
Energy Engineer, Buildings & Infrastructure, Bendigo Health

14.4 East Wimmera Health Service (Donald)

The case of Donald, in regional north west Victoria is interesting because it provides a case study of a small site where reuse has been pursued. The health service provides from 9 to 12 dialysis treatments per week, using efficient RO units (Table 11). There was a 500 L tank with a submersible pump that pumps into a 27,000 L tank that is used for garden irrigation. As the HCF at Donald was planned as a greenfield site, it also allowed for water reuse from the RO unit to be integrated with rainwater collection. From the RO unit, it is estimated that the Donald facility recycles approximately 1,000 L of water per week.

The cost of the recycling system was \$4,110 which was funded by a “Greening Our Hospitals” grant.



Figure 13 Storage tank for recycled water at Donald

14.5 Queen Elizabeth Hospital, Adelaide

14.5.1 Overview

Queen Elizabeth Hospital (QEH) in Adelaide, South Australia has implemented a sophisticated system for recycling of RO reject. In this case, mains water is held in storage tanks onsite, where it supplies hospital requirements, including the RO machine. Reject water from the RO plant is collected, filtered, rechlorinated and returned into these storage tanks which supply the hospital.

14.5.2 Identification and selection of reuse options

The water recycling initiative was made possible by the planned extensive renovations and rebuilding of the wing of the hospital where dialysis is provided. The so called 'green wing' contains a process plant for treating reclaimed rain water, installing a large 500 KL tank in the hospital car park where the RO reject is collected and blended with the stored rainwater. From there, this water is reprocessed by rechlorination, filtration and UV treatment. The treatment plant onsite is managed by Freshwater Ltd and treated water is held in two 100,000 L tanks.

The novel aspect of this recycling scheme is that it is the only case study that we are aware of in Australia where the RO reject water is blended with another source such as rainwater, retreated and chlorinated to be returned to 'potable' supply. QEH is included in this list of case studies, as an example of what is achievable with large scale planning in healthcare facilities, as it involves blending the RO reject with rainwater and returning this water to potable supply. This process involves filtration and treatment and hence the risk management and control measures are much more sophisticated than smaller scale scenarios.

14.5.3 Funding for works

Costs associated with the renovation and water conservation 'water recovery plan' are estimated to be between \$500,000 to \$1 million⁷. It is difficult to determine how much the RO reject capture component of these works alone cost.

14.5.4 Lessons learned

Although there are no water meters installed to measure the volumes returned to the 'potable' supply, QEH have installed a water meter on the water going into their treatment plant, and through this can demonstrate water savings of between 1.5-2 ML/annum.

⁷ Personal communication with Mike Connors, QEH November 2009

14.6 Other projects funded by Greening Our Hospitals for the reuse of dialysis RO reject water

There were another nine projects in Victoria where the Greening Our Hospital program has funded initiatives to assist in the development of projects to reuse RO reject water from dialysis services. These included:

- > Austin
- > Bairnsdale
- > Barwon
- > Colac
- > Donald
- > Echuca
- > Kyneton
- > Maryborough
- > Wonthaggi

15. SPECIFIC WATER QUALITY GUIDELINE VALUES

15.1 Irrigation water quality guidelines

Table 19 Australian irrigation and drinking water guidelines

Parameter	Abbrev.	Units	ADWG	Short-term trigger value for irrigation ^A	Long-term trigger value for irrigation ^A
Aluminium	Al	mg/L	0.2	20	5
Arsenic	As	mg/L	0.007	2	0.1
Cadmium	Cd	mg/L	0.002	0.05	0.01
Copper	Cu	mg/L	1	5	0.2
Iron	Fe	mg/L	0.3	10	0.2
Lead	Pb	mg/L	0.01	5	2
Manganese	Mn	mg/L	0.1	10	0.2
Mercury	Hg	mg/L	0.001	0.002	0.002
Sodium	Na	mg/L	180	460	115
Zinc	Zn	mg/L	3	5	2
Chloride	Cl	mg/L	250	700	175
Fluoride	F	mg/L	1.5	2	1
Nitrate	NO ₂	mg/L	50	nil	nil
Sulphate	SO ₄	mg/L	250	nil	nil
Hardness	CaCO ₃	mg/L	200		
Total Dissolved Solids	TDS	mg/L	500	640 ^B	400 ^B
Electrical conductivity	EC	µS/cm	~750	1000 ^B	600 ^B
Silica	SiO ₂	mg/L	n	nil	nil
Chromium	Cr	mg/L	0.05	1	0.1
Sodium Absorption Ratio ^B	SAR	mmolc/L ^{0.5}	nil	11	4

^A(ANZECC & ARMCANZ 2000)

^BPlant or soils specific see guideline

ADWG = (NHMRC & NRMCC 2004)

15.2 Water quality for cooling towers

The efficiency of cooling towers is reduced by the introduction of more saline water. However, given the low TDS of most potable water sources in Victoria, even when the TDS is three times higher in the RO reject stream, it is typically still suitable for cooling tower operation. In specific cases this should be confirmed with the cooling tower manufacturer and maintenance provider.

Table 20 Typical required composition for recirculation cooling tower

Parameter	Unit	Make up water	Comparison with surveyed dialysis sites
Silica	mg/L	50	Not measured
Calcium	mg/L	50	Achieved ~ 75% of sites
HCO ₃ (bicarbonate)	mg/L	25	Not measured
SO ₄ (sulfate)	mg/L	200	Achieved
Chloride	mg/L	500	Achieved ~ 90% of sites
Iron	mg/L	0.5	Achieved
Manganese	mg/L	0.5	Achieved
Total Dissolved Salts	mg/L	500	Achieved ~ 90% of sites
Total Suspended Solids	mg/L	100	Not measured
Hardness	mg/L as CaCO ₃	130	Achieved
Alkalinity	mg/L as CaCO ₃	20	Not measured (Lab results indicate difficult to achieve)

Source: (VU & CSIRO 2008), Trigger values for recirculation cooling tower and should be equal to or less than those quoted.

In all cases the cooling tower manufacturer and maintenance provider should be consulted regarding the required water quality of the makeup water, as some exceedances of these guideline values may be acceptable.

15.3 Typical Boiler Feedwater

Depending on the operation and type of boiler and the feed water quality, there is often significant pre-treatment of the feed water prior to the boiler. If this pre-treatment process is required and is in place, it is likely that the addition of RO reject water will be acceptable to pre-treat along with potable water.

This should be confirmed with the boiler supplier or maintenance provider.

Table 21 Typical composition of makeup water for low pressure boiler

Parameter	Unit	Low pressure Boiler Make up water
Silica	mg/L	10
Calcium	mg/L	0
Magnesium	mg/L	0
Manganese	mg/L	0.1
Copper	mg/L	0.05
Iron	mg/L	0.3
Bicarbonate	mg/L	120
Total Suspended Solids	mg/L	5
Alkalinity (CaCO ₃)	mg/L CaCO ₃	100
pH	unitless	8-10
Turbidity	NTU	5

Source: (VU & CSIRO 2008)

Several of these limits are difficult to achieve and significant pre-treatment is required to ensure that the RO reject water is fit-for-purpose as boiler make up water. Typically this pre-treatment is already in place.

In all cases the boiler manufacturer and maintenance provider should be consulted regarding the required water quality of the makeup water.

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