National Water Quality Management Strategy

GUIDELINES FOR SEWERAGE SYSTEMS

Use of Reclaimed Water

November 2000

Agriculture and Resource Management Council of Australia and New Zealand

Australian and New Zealand Environment and Conservation Council

National Health and Medical Research Council

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Executive Summary

Introduction

The *Guidelines for Sewerage Systems – Reclaimed Water* is one of a suite of documents comprising the National Water Quality Management Strategy. These Guidelines provide advice on reclaimed water quality, level of treatment, safeguards and controls and monitoring.

Reclaimed water is a valuable resource and these guidelines have been prepared to foster the use of reclaimed water in a way that provides safeguards for public health as well as community and environmental benefits. Use of reclaimed water can provide economic benefits and assist in the conservation of water resources.

The guidelines address effluent arising from municipal (ie community) wastewater plants, however they do not consider reclaimed water from individual household systems or undiluted liquid wastes of industrial origin.

While there is a high level of public acceptance towards reclaimed water use in Australia and there are many reclaimed water schemes in operation, the overall proportion of wastewater reuse is small.

Examples of reclaimed water include indirect potable use of reclaimed water and irrigation of urban landscapes, sporting and recreational areas and agricultural crops.

Microbiological Water quality

It is recognised that the major risk of human contact with wastewater is infection from viruses, bacteria, protozoa and helminths. Due to the human contribution to the wastewater stream, it may contain a wide range of potentially infectious microorganisms. To specify water quality fully in terms of those microorganisms is impractical. For practical applications it is possible to work to an acceptable level of risk to public health through surrogates such as counts of thermotolerant coliforms, turbidity and suspended solids (as indicators of process train performance).

Thermotolerant coliforms are recommended as general indicators of reclaimed water quality. Thermotolerant coliforms (also known as faecal coliforms) consisting chiefly of *E. coli* are found in the intestinal tract of humans and other warm blooded animals. Guideline values for thermotolerant coliforms fall into the following four main categories.

Guideline values for thermotolerant coliforms

Reclaimed Water use application	Thermotolerant coliforms per 100 mL (median)
Non-human food chain	<10,000
Low contact, eg. irrigation of open spaces with controlled public access	<1000
Medium contact, eg. drinking water for stock (except pigs*)	<100
High contact, eg. urban residential garden watering	<10

*Pigs excluded due to risk of *Taenia solium* infection

Chemical Water Quality

The main concern associated with chemical compounds in reclaimed water is their ability to cause adverse health effects after prolonged periods of human exposure. The probability of risk to health from chemical toxicants in domestic wastewater is very much lower than that from microbial infection, with the presence of harmful chemicals in municipal wastewater most likely to arise from industrial wastes.

Where it is known or suspected that chemical compounds are present at concentrations that may cause problems, the guidelines recommend specific monitoring to determine the concentration and source of contamination. Subsequent routine monitoring may also be necessary to provide quality assurance.

Treatment

Treatment requirements of reclaimed water for the protection of human health differ from environmental requirements where effluent is discharged to surface waters, groundwater or on land. The following commonly used primary and secondary treatment technologies and pathogen reduction methodologies have been addressed in these guidelines.

Secondary treatment processes:

- activated sludge with settling or clarification;
- trickling filters with settling or clarification;
- oxidation ditch with settling or clarification; and
- lagoons or oxidation ponds.

Tertiary treatment processes:

- microstraining;
- detention in polishing lagoons;
- filtration via sand, dual media or membranes - may include coagulant dosing;
- grass filtration; and
- artificial wetland processes.

Pathogen reduction processes:

- chlorine;
- chlorine dioxide;
- ozone (O_3); and
- ultraviolet (UV) irridation.

Safeguards and controls

Protection of public health is paramount in the management of wastewater reuse projects. Barriers that control human exposure to pathogens and contaminants include:

- multiple independent treatment processes or barriers;
- industrial waste controls;
- reliable and resilient treatment processes and trained operators;
- reliable disinfection systems;

- secure effluent transfer systems;
- application controls (spray systems); and
- crop restrictions.

Monitoring of processes and indicators is necessary to ensure maintenance of these barriers.

Further safeguards that are commonly employed to ensure public safety are:

- alternative storage and/or disposal options for effluent;
- plumbing practices and signage to prevent cross connection with potable supply;
- public access controls;
- minimisation of spray drift; and
- buffer zones.

Specific reclaimed water applications

The *Guidelines for Sewerage Systems - Reclaimed Water* classifies the use of reclaimed water into a number of specific applications, each with its own requirements for:

- type of reuse;
- level of treatment;
- reclaimed water quality;
- reclaimed water monitoring; and
- controls.

The order in which the specific applications are presented is from highest to least contact and does not represent any prioritisation or order of preference for reclaimed water use. The following reclaimed water use applications are discussed:

- direct potable;
- indirect potable;
- urban non-potable residential;
- urban non potable municipal;
- agricultural food production;
- agricultural non food crops;
- aquaculture;
- recreational;
- environment;
- industry; and
- aquifer storage and recovery.

Irrigation schemes

Because agricultural and municipal irrigation schemes comprise the most common use of reclaimed water, some broad principles of reclaimed water irrigation practice are included in the guidelines. Details of irrigation practices are not covered in the guidelines but some general principles are given.

Some important environmental criteria in the evaluation of a site for a reclaimed water irrigation scheme are:

- consideration of low application rates, in proportion to total irrigation, for uses in near pristine environments;
- the availability of sufficient land to accommodate any necessary storage requirements;
- the quality of underlying water in any unconfined aquifer;
- the crop cultivation area to be irrigated; and
- any additional statutory land requirements.

Traditionally, the philosophy underpinning land application of reclaimed water has been to focus on disposal of large volumes with a minimum of adverse effects. Treated reclaimed water is now widely regarded as a resource available for use, rather than a waste requiring disposal. With the protection of public health as an overarching principle, beneficial uses of reclaimed water should be encouraged where it is safe, practicable and economic to do so, and where they provide the best environmental outcome.

1. Introduction

1.1 Purpose of document

This document is one of a suite of documents forming the National Water Quality Management Strategy (NWQMS). Guidelines and documents forming part of the strategy are detailed in Appendix 1.

The series *Guidelines for Sewerage Systems* covers sewerage systems as a whole. Five separate documents deal with particular aspects of sewerage systems as set out in Figure 1. This document provides national guidelines for the use of reclaimed water. The focus of the document is to facilitate use of reclaimed water, a product resulting from the treatment of wastewater to a level acceptable for beneficial use. The document can be used by water resource managers and sewerage authorities to develop reclaimed water schemes after allowing for local conditions, and as a reference for the community, industry and environmental groups. It has been developed as a basis for a common and national approach throughout Australia.

Figure 1: Diagrammatic structure of the *Guidelines for Sewerage Systems*

Guidelines for Sewerage Systems				
Acceptance of Trade Waste	Sewerage System Overflows	Reclaimed Water	Effluent Management	Biosolids Management

1.2 Scope

In this document guidelines are provided for specific reclaimed water applications in terms of:

- type of reuse;
- level of treatment;
- reclaimed water quality;
- reclaimed water monitoring; and
- controls.

The guidelines deal with effluent from municipal (ie community) wastewater plants treating mainly domestic and some industrial wastes. Discharges from treatment plants for specific industries such as piggeries, tanneries, wineries and wool scouring are the subject of separate guidelines.

These guidelines do not deal with reclaimed water from individual household systems (eg. sullage, greywater or effluent from household or residential aerobic treatment units or septic tanks), undiluted liquid wastes such as those from abattoirs or wastes of industrial origin which are not components of municipal wastewater.

Use of reclaimed water within the boundaries of municipal wastewater treatment plants is covered by "in house" operational safeguards and practices and is outside the scope of these guidelines. The direct discharge and safe disposal of effluent from municipal wastewater treatment plants to land or water is dealt with in the NWQMS *Guidelines for Sewerage*

Systems - Effluent Management. (Appendix 1). The Reclaimed Water Guideline deals with the beneficial use of reclaimed water.

These guidelines apply to existing schemes as well as those proposed for the future.

It is not possible to set consistent broad national guidelines for reclaimed water applicable to all specific regions of Australia. It may be necessary to take into account local conditions and to consult with regulators such as the local health authority who may approve or require practices differing from those in this guideline. For example, there is cause for greater care in relation to hookworm in tropical regions.

Food hygiene concerns are not addressed in this guideline and individual industries should address food safety issues relating to the use of reclaimed water.

1.3 Background

Wastewater and effluent are a part of the total water cycle. Reclaimed water is derived from wastewater and treated to a level appropriate for its intended application.

Reclaimed water is a valuable resource, although only a small percentage is currently used in Australia. However, there is growing interest in using this resource mainly for agricultural and landscape irrigation including via groundwater recharge, and to a lesser extent for industrial purposes or for the augmentation of domestic supplies.

These guidelines have been prepared to foster the use of reclaimed water in a way that provides safeguards for public health and community and environmental benefits. The National Health and Medical Research Council (NHMRC), the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australian and New Zealand Environment and Conservation Council (ANZECC) will review them as required, to ensure advances in science, technology and community expectations are taken into consideration.

These guidelines supersede the 1987 NHMRC/AWRC *Guidelines for the use of Reclaimed Water* and should be used in conjunction with individual State or Territory Guidelines, as appropriate (eg. ACT Government, 1999; DHS and EPA, 1999; EHPD, 1996; NSW Recycled Water Co-ordination Committee, 1993).

1.4 The case for water reclamation

The expanding population and increasing urbanisation of Australia's towns and cities, along with increasing industrialisation have placed pressures on our limited and sometimes overcommitted water resources. Increasingly it is important to make best use of high quality water supplies. It is important to address the wider problems of the urban water cycle compounded by a legacy of our past approach to designs of once-through potable and wastewater reticulation systems.

Wastewater is becoming a more valuable resource for industrial, agricultural, municipal and domestic purposes. Its recycling allows a unit of water to be used for a number of times before discharge to the environment.

An awareness of the role that water plays in the natural ecosystem has lead to support for conservation of water resources. By reducing the volume of water which needs to be extracted from natural water bodies the use of reclaimed water can assist in the protection of natural ecosystems.

Nitrogen and phosphorus present in wastewater, which can cause eutrophication in receiving waters, can have beneficial effects on plant growth when used for irrigation in a planned and controlled manner. This benefit is of increasing importance where agricultural lands are nitrogen and/or phosphorus deficient.

The evolving understanding of the potential problems associated with reclaimed water has allowed development of health and environmental safeguards and regulatory practices. While existing treatment technologies can not be regarded as failsafe, where such safeguards are in place, the potential for adverse health effects or damage to the environment is extremely low.

Water used for irrigation need not be as high in quality as that used for drinking. The most advantageous reclaimed water projects are those that substitute lower quality water with minimum additional treatment for high quality potable water. The main benefits are conservation of naturally occurring high quality water resources and pollution abatement.

There is strong support for the development of reclaimed water use among special interest and community groups concerned with the environment.

The reuse of treated wastewater should be pursued within a wider environmental context including consideration of the principles of Sustainable Development, water cycle management and protection of public health. Total use of wastewater is only feasible in very unusual circumstances. Reclaimed water schemes in large urban situations will not eliminate the need for effluent discharges to the environment.

1.5 Existing uses

In Australia, Europe and the USA the overall proportion of wastewater reclaimed and used has been small up to now. However in areas such as California and Florida where water resources are very limited the use of reclaimed water for crops, urban green spaces and industry is widespread. Given the increasing pressure on water resources there will be increasing incentives for water agencies and entrepreneurs to more fully exploit opportunities presented by reuse.

In Australia the overall proportion of wastewater reclaimed and used is small. Local circumstances, particularly in dry inland areas, dictate the use of reclaimed water as a preferred practice. There are many reclaimed water schemes in operation. Examples include reuse for golf courses, racetracks, sports ovals, turf farms, vineyards, vegetable growing (restricted) hydroponics, woodlots, cut flowers, plant nurseries, pasture crops, wetlands nature reserves and cooling towers (industrial)(Eden, 1996), as well as reuse for domestic purposes, for toilet flushing and fire protection.

Indirect potable use of reclaimed water (either planned or unplanned) occurs in communities where surface water and groundwater receive treated effluent. Generally, the most common planned uses for reclaimed water are irrigation of urban landscapes, sporting and recreational areas and agricultural crops.

2. Principles

These guidelines cover wastewater from municipal treatment plants and:

- facilitate and promote the use of reclaimed water as a potentially valuable resource;
- provide safeguards for public health and the environment;
- accommodate existing practices previously demonstrated to be safe and beneficial; and
- encompass the current state of knowledge and international practice.

2.1 Public consultation

Public acceptance of reclaimed water use for a variety of actual and hypothetical applications has been widely surveyed. Public opinion towards reclaimed water use is determined by:

- cost/price;
- availability of other sources of water;
- level of human contact;
- health;
- environment;
- treatment;
- distribution;
- conservation; and
- community expectations.

A high level of public acceptance is essential for projects involving public contact with reclaimed water to be successful. Such acceptance requires confidence in sewerage system operations and trade waste controls. There is a high level of goodwill towards the concept of reclaimed water use and attitudes towards the practice are fairly consistent. Unfavourable attitudes are more likely with a higher level of human contact or proximity to the application. In such cases it is necessary to consult with the public about options for the use of reclaimed water.

Applications such as agricultural or municipal irrigation are more likely to receive public endorsement than contact recreational or non-potable domestic projects. In the absence of other major driving factors, low contact uses are a good first choice.

The *Implementation Guidelines* describe the steps in developing plans and taking action to manage water resources. The wider issues of community consultation in relation to effluent management are discussed in the *Guidelines for Sewerage Systems - Effluent Management.* (See Appendix 1 for details of NWQMS documents.)

2.2 Legal requirements

There are at present in Australia no federal legal requirements for reclaimed water to be substituted for fresh water. There is a generally agreed principle that "No higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade" (United Nations 1958). The use of reclaimed water may be governed by State and Territory legislation. Specific statutory obligations may be imposed under health, environmental, agricultural or food legislation or all four or may be a condition of land development.

Wastewater treatment plant owners, operators and end-users may be liable under common law and under the Trade Practices Act for the use of a wastewater product that causes harm.

To minimise exposure to legal and financial risks, it may be necessary to:

- ensure guidelines are followed;
- develop a system for alternative discharge or storage and further treatment of reclaimed water unsuitable for reuse eg. due to plant failure;
- ensure staff and contractors receive appropriate training to understand legal requirements and risks;
- archive reclaimed water records properly so that they can be retrieved at a later date;
- provide clear, accurate and comprehensive information to consumers on limitations or restrictions on reclaimed water uses and other relevant issues;
- develop, implement and audit a quality assurance program that describes procedures for monitoring, reporting, record keeping and auditing reclaimed water activities; and
- develop effluent management protocols which ensure that appropriate contractual arrangements are in place and that the responsibilities of the respective parties are clearly set out.

2.3 Contractual Arrangements and Provisions

In the operation of reclaimed water projects, the scope and responsibilities of the parties involved may be set down in an agreement covering the respective interests of suppliers, regulators and users. Agreement provisions could include quality, quantity of water supplied and used, safeguards, financial arrangements, liabilities and obligations etc.

Participation in reclaimed water schemes (other than indirect potable) is usually a voluntary arrangement. Experience has shown that although potential users show positive interest in using reclaimed water, they may resist after the facilities are built. Before an agency or a sponsor embarks on the significant cost of a reclaimed water project, it may wish to ensure participation of potential users through contractual agreements.

Factors to address in a user contract include:

- definition of responsibilities and obligations;
- regulatory requirements;
- cost;
- contract duration - term, conditions for termination;
- reclaimed water characteristics - source, quality, pressure;
- quantity and flow variations;
- reliability of supply - potential lapses in supply, backup provisions;
- commencement of use - when user can or will begin use;
- financial arrangement - pricing of reclaimed water, payment for access to the scheme;
- ownership of facilities - rights-of-way;
- responsibility for operation and maintenance;
- liabilities including risk allocation and insurance; and
- restrictions on use.

3. Essential Considerations

These guidelines are provided for specific reclaimed water applications under the following headings:

- water quality;
- level of treatment;
- safeguards and controls; and
- monitoring.

The guidelines cover wastewater of municipal origin.

3.1 Water quality

3.1.1 Microbiological

The major risk of human contact with wastewater is infection from the following micro-organisms:

- viruses;
- bacteria;
- protozoa; and
- helminths.

Viruses derived from human faeces are present in wastewater in numbers up to 100,000 infectious particles per litre. They can survive for prolonged periods in water systems. The issue of virus reduction/removal needs to be given detailed consideration, given the significance of these micro-organisms to public health (eg. Hepatitis A in oysters in Wallace Lake, NSW). Identification and enumeration of viruses in wastewater are hampered by low virus recovery rates, high cost and slowness of procedures. However, a significant body of information indicates that viruses are removed, destroyed or inactivated to low or undetectable levels by suitable wastewater treatment including filtration and disinfection (Adin and Asano, 1998; Asano and Levine, 1996; Crook, 1997).

Pathogenic bacteria can be excreted by an apparently healthy population, and many of the very large numbers of bacteria found in wastewater can cause disease. Some bacteria, particularly thermotolerant coliforms, are indicators of faecal pollution.

Protozoa can cause disease in humans and infective forms are known to be present in wastewater as cysts (Rose, 1997). Transmission of several protozoan infections by vegetables was reported to be due to use of contaminated water on the crops (Froese and Kindzierski, 1998) Three species of enteric protozoa are of particular importance and can cause moderate to severe enteritis. These are:

- *Giardia intestinalis = lamblia*
- *Entamoeba histolytica*
- *Cryptosporidium* spp.

Two groups of free living amoebae, *Naegleria* and *Acanthamoeba,* have been responsible for opportunistic human infections in Australia (NWQMS (1996) *Australian Drinking Water Guidelines*).

Parasitic helminths are of two types:

- roundworms (nematodes); and
- flatworms.

Their life cycle may be very complex, and many require an intermediate host. Helminths that can be transmitted to humans through wastewater and are endemic in some areas of Australia include:

- *Ascaris lumbricoides* (intestinal roundworm)
- *Trichuris trichiura* (whipworm)
- *Ancylostoma duodenale/Necator americanus* (hookworms)
- *Strongyloides stercoralis* (threadworm)
- *Hymenolepis nana* (dwarf tapeworm)
- *Taenia saginata* (beef tapeworm)
- *Taenia solium* (pig tapeworm - exotic)
- *Echinococcus granulosus* (hydatid tapeworm)
- *Toxocara canis*
- *Toxocara cati.*

The first three organisms are the most common. Taeniasis in cattle can be a major veterinary problem resulting in financial loss.

Because of the human contribution, wastewater can contain a wide range of potentially infectious microorganisms. To specify water quality fully in terms of those microorganisms is impractical. For practical applications it is possible to work to an acceptable level of risk to public health through surrogates such as counts of thermotolerant coliforms, turbidity and suspended solids (as indicators of process train performance).

Overseas epidemiological studies on populations exposed to untreated wastewater via crop irrigation show that bacteria and helminths present the highest health risks and viruses little or no actual risk. (WHO 1989)

For there to be a real risk of transmission of a specific disease through the use of reclaimed water, all of the following conditions must be met:

- exposure to pathogens in the field;
- the infective dose must reach a human host;
- the host must become infected; and
- the infection causes disease or further transmission.

(after WHO 1989)

Preventing disease associated with the use of reclaimed water requires that the first two conditions do not occur. This is achieved by providing both treatment for the removal of pathogens and safeguards in the form of barriers between human populations and wastewater. Relative reliance on these is dictated by practical and economic concerns.

Conventional treatment - primary and secondary followed by disinfection - does not ensure removal of microorganisms, in particular helminths and protozoa. Consequently, disinfected secondary effluent to be used for irrigation should either:

- derive from a population where helminth infection is non endemic; or
- undergo further treatment known to remove helminths such as storage in lagoons or filtration.

Where helminth infections are known to be endemic, epidemiological data indicate that the guideline quality of less than or equal to 1 egg per litre protects crop consumers, but not necessarily field workers and their families, especially children. In such cases a stricter guideline quality of less than or equal to 0.5 egg per litre may be required (Blumenthal et al, 1996).

No guideline is set for protozoa in reclaimed water. Methods for determination of protozoa numbers are complex and costly. Nor are removal of nematode eggs or bacteria reliable indicators of removal of protozoan cysts (Kindzierski, Rogers and Low, 1993; Rose, 1997). Use of turbidity as a surrogate is controversial (Rose, 1997). If there is reason to think that there is a significant risk of infection occurring, additional safeguards or treatment may be required to control these organisms. Advice should be sought from the local health authority. Effective filtration is widely regarded as efficacious in removal of protozoa, although extended storage retention, facilitating sedimentation and predation, and ozonation may also be useful.

Thermotolerant coliforms are recommended as general indicators of reclaimed water quality. Thermotolerant coliforms (also known as faecal coliforms) consisting chiefly of *E. coli* are found in the intestinal tract of humans and other warm blooded animals. Guideline values for thermotolerant coliforms fall into four main categories.

Table 1: Guideline values for thermotolerant coliforms

Reclaimed Water use application	Thermotolerant coliforms per 100 mL(median)*
Non-human food chain	<10,000
Low contact, eg. irrigation of open spaces with controlled public access	<1000
Medium contact, eg. drinking water for stock (except pigs)	<100
High contact, eg. urban residential garden watering	<10

* Refer to Section 3.5.1 Statistical treatment of data

These values are based on:

- a consensus of local practice which has been demonstrated to be safe; and
- consideration of the current status of scientific understanding and worldwide practice in reclaimed water use.

Where certain diseases are endemic, health or environmental regulators may include stricter requirements than those in the guidelines on a regional or site specific basis (eg. EHPD, 1996). Monitoring and demonstrated removal of specific organisms such as *Giardia, Cryptosporidium* and *Ascaris* may be required.
**Note: It has been recognised that non-thermotolerant coliforms may grow in water in tropical areas when the level of organic material is high. There is therefore the possibility that a marginal and false elevation in the thermotolerant coliform count may occur in samples taken at the point of effluent delivery in some parts of Australia, especially when the effluent has been exposed to elevated temperatures in an extended distribution system.*

3.1.2 Chemical

The main concerns associated with chemical compounds are their ability to cause adverse health effects after prolonged periods of human exposure. Various compounds are documented as being cumulative poisons, mutagens and/or carcinogens.

The probability of risk to health from chemical toxicants in domestic wastewater is very much lower than that from microbial infection. (Mara and Cairncross 1989). The presence of harmful chemicals in municipal wastewater is most likely to arise from industrial wastes. Even in the absence of industrial waste, urban wastewater carries a significant load of micro-pollutants of domestic origin.

To maintain public health and confidence and avoid undesirable impacts on reuse schemes, use of reclaimed water must be complemented by a comprehensive and enforced trade (industrial) waste policy. Certain types of wastes should be excluded, such as those containing:

- radioactive materials with a half-life of more than a few days;
- pharmacologically active compounds;
- non-biodegradable toxic organic materials;
- elevated levels of total dissolved solids (TDS);
- high concentrations of metals; and
- petrochemical and mining industries output.

For more details on this subject refer to NWQMS *Guidelines for Sewerage Systems - Acceptance of Trade Waste (Industrial Waste)* (Appendix 1).

While most organic material in wastewater is degraded by the normal processes of treatment, some organic compounds of concern are sourced from industrial processes or proprietary products used domestically or industrially. These compounds may be very stable and degrade only slowly in the aquatic environment. Some are potentially carcinogenic or mutagenic, or may be pharmacologically active.

In treatment systems, most organic compounds of concern tend to concentrate in the sludge stream rather than the effluent stream. Metals also tend to be separated into the sludge stream. Organics of higher molecular weight tend to be sparingly water-soluble, while organics with low molecular weight, which have higher vapour pressure, tend to be volatile.

It is not possible to monitor for all the chemical compounds that may be found in reclaimed water. Assurance of chemical safety is provided by:

- knowledge of industrial discharges;
- prescribed process trains for wastewater treatment; and
- monitoring of treatment efficiency by surrogates - eg. biochemical oxygen demand (BOD), suspended solids (SS).

Where it is known or suspected that chemical compounds are present at concentrations that may cause problems, specific monitoring to determine the concentration and source should be undertaken. Subsequent routine monitoring may also be necessary to provide quality assurance.

The USEPA 1993 Toxic Release Inventory (1995) is one possible source of information on the range of compounds to be considered. A list of toxicants together with guideline levels for protection of aquatic ecosystems is also given in the NWQMS *Australian Water Quality Guidelines for Fresh and Marine Waters* (Appendix 1).

There are specific requirements for reclaimed water used for irrigation. Long term application of reclaimed water at excessive levels could contaminate soil and groundwater. Soil properties including infiltration characteristics can be adversely affected.

Other factors influencing the suitability for irrigation are discussed in the literature on irrigation practice. Specific schemes may be subject to local environmental regulation. Local and state guidelines for irrigation water quality and practice may also apply.

Radioactive substances may originate from medical or extractive industry sources. The *Australian Water Quality Guidelines for Fresh and Marine Waters* recommend limits of 0.1 Becquerel per litre gross alpha and 0.1 becquerel per litre gross beta activity in water used for irrigation.

3.2 Linkage with other Guidelines

It is relevant to note that international guidelines such as those developed by the WHO are not intended for absolute and direct application in every country. Rather, they are intended to serve as a common background against which national or regional standards can be developed. In the context of reuse, there is evidence that "no-risk" or "zero-exposure" standards are over conservative, and that a "threshold" approach to standard-setting is more rational and incorporates a balancing of risks and benefits (Hespanhol and Prost, 1994).

Risk assessment methodologies use indirect measures of pathogen risk by modelling human exposure and disease response. Such methods have come into prominence because of the insenstivities of epidemiological methods in providing empirical data on health risks. Procedures are under development for determining health risks for waterborne pathogens (Crook, 1997; Neumann and Foran, 1997). These techniques cannot at present be relied on, and are no substitute for monitoring of bacteria, helminths, protozoa or viruses. However, risk assessment can be useful in planning and managing reclaimed water projects, and may assist in refinement of guidelines in future (Bastian, 1996; Crohn and Yates, 1997; Crook *et al*, 1998).

Guidelines for reclaimed water generally concentrate on public health issues and are mainly concerned with the microbiological aspects. Within this context they vary widely in their content and complexity. There are two guidelines that have formed models for those currently in place throughout the world:

1. Californian guidelines specify a high level of treatment with required process trains and low-level faecal coliforms: less than 23 per 100 millilitres or less than 2.2 per 100 millilitres, depending on application. The more recently developed United States Environment Protection Agency (USEPA) guidelines (USEPA 1992) are based on the Californian model and the accumulated experience of other states.

2. World Health Organisation (WHO) guidelines (WHO 1989), based on an epidemiological approach, specify levels of intestinal nematodes, faecal coliforms and a minimum level of treatment based on detention time in ponds. The WHO specifies faecal

coliforms less than 1000 per 100 millilitres, and absence of the helminths *Ascaris* and *Trichuris*.

To achieve USEPA guidelines, complex treatment processes are necessary involving large capital and operating expenses for plant and equipment. The WHO guidelines can be achieved by cheaper, simpler technology.

The USEPA approach has been to specify both treatment processes and water quality parameters for a particular application. The arguments for such an approach are that:

- surrogate parameters may not adequately characterise reclaimed water quality;
- specifying treatment trains and surrogate parameters removes the need to monitor for large numbers of chemicals or pathogenic microorganisms;
- the need to monitor specific pathogens such as viruses is eliminated reducing costs and time; and
- treatment reliability is enhanced.

Virus limits are not recommended because:

- there is a body of evidence demonstrating viral removal following filtration and disinfection;
- virus monitoring is slow, expensive and imprecise;
- up to 28 days are needed for virus identification;
- there is no consensus on the health significance of low levels of viruses in reclaimed wastewater; and
- there are insufficient studies available to define appropriate benchmark levels for setting viral guidelines.

The WHO and USEPA models along with the information used in developing the *NSW Guidelines for Urban and Residential Use of Reclaimed Water* have been considered in the development of these guidelines.

The USEPA philosophy of setting guidelines based on a combination of treatment requirements and levels for surrogate parameters has been followed with adaptation to local conditions.

3.3 Treatment

Treatment requirements for protection of human health for reclaimed water differ from environmental requirements where effluent is discharged to surface waters, groundwater or the land.

In limited circumstances in Australia direct application of raw sewage to land is allowable only as part of a well operated treatment process with well defined boundaries, monitoring, safeguards and controls. Reclaimed water to be used for irrigation should undergo further treatment. For many applications, secondary treatment with disinfection will suffice. For the higher contact applications, tertiary treatment will be required.

The degree of removal of microorganisms by a treatment process is expressed here in terms of $\log_{10}$ units, eg. a reduction of four (4) logs is equivalent to 99.99% removal.

The commonly used disinfection processes have been extensively reviewed (White, 1999a,b,c,d,e,f,g) and are listed below. Other process trains such as physico - chemical treatment followed by membrane filtration may provide equivalent results. Alternative treatment methods might be acceptable when performance is proven to the satisfaction of regulatory authorities.

3.3.1 Secondary treatment
This is principally aimed at removal of dissolved and suspended organic material by biological oxidation and sedimentation. Biological or chemical methods may also be used to achieve:

- oxidation of ammonia (nitrification);
- removal of nitrogen (denitrification); and
- phosphorus removal.

Secondary treatment may be preceded by primary treatment with or without chemical addition, screening and grit removal.

Secondary treatment processes include:

- activated sludge with settling or clarification;
- trickling filters with settling or clarification;
- oxidation ditch with settling or clarification; and
- lagoons or oxidation ponds.

It is possible to achieve:

- removal of around two log units of excreted bacteria (Mara and Cairncross, 1989);
- 85 per cent removal of BOD and SS; and
- high removal of metals and organic trace contaminants.

Secondary effluent generally has BOD < 30 mg/l, SS < 30 mg/L but may rise to >100 mg/L due to algal solids in lagoon or pond systems.

3.3.2 Pathogen reduction
Levels of pathogenic organisms are reduced by normal wastewater treatment processes and by the use of disinfectant chemicals. Additional pathogen reduction by disinfection is normally required for the use of reclaimed water. Effectiveness is reduced by the presence of suspended material that shields microorganisms from the disinfectant. Chlorine is the most widely used agent.

Other agents include:

- chlorine dioxide;
- ozone (O_3); and
- ultraviolet (UV) irradiation via sunlight or UV lamps.

Stabilisation or maturation ponds are a very effective and simple means of providing treatment and pathogen reduction.

Bacteria are less resistant to chlorine than are viruses, which in turn are less resistant than parasite ova and cysts (Feachem et al. 1983). Chlorine is most effective in the range pH 7- 8. Ozone offers one of the best approaches for effectively killing *Cryptosporidium* oocysts in water (Rose, 1997).

Under favourable conditions, ponds can reduce helminth populations by up to six log units within five days' detention. Parasites such as *Ent. histolytica* cysts are completely removed by ponds with 20 days retention time. (Feachem et al 1983). Similar conditions reduce bacteria populations by up to six log units, and viruses by up to five log units (WPCF 1989). Pond design should ensure turbulence and short-circuiting are minimised. The use of ponds in series is effective in this regard.

3.3.3 Tertiary treatment

This includes treatment aimed at further improving effluent quality beyond secondary treatment and may be required to meet specific end uses by further removal of:

- suspended solids;
- pathogenic organisms;
- nutrients such as phosphorus and nitrogen; or
- other specific contaminants.

Tertiary treatment processes include:

- microstraining;
- detention in polishing lagoons;
- filtration via sand, dual media or membranes - may include coagulant dosing;
- grass filtration; and
- artificial wetland processes.

<u>Conventional filtration</u>

This uses a physical process to separate suspended and colloidal matter from the effluent by passage through a bed of granular media. It improves disinfection efficiency through removal of suspended matter and other interfering substances.

Principal types of filters are classified according to:

- direction of flow through the bed;
- type of filter bed: single, dual, tri-medium beds;
- type of filter media: sand, anthracite, garnet, activated carbon, resin beds;
- flowrate: rapid filters, slow filters;
- driving force: pressure, gravity; and
- filter depth: may be shallow or deep (preferred)

Conventional filtration may be accompanied by chemical treatment with coagulants such as lime, alum or iron salts and polyelectrolyte to further improve effluent quality. It removes up to three log units of bacteria and around 30 per cent of BOD. Pathogens are retained on the filter media and are present in backwash streams that require subsequent treatment. Deep-bed dual media sand and coal pressure filters have been shown to be particularly useful in removing enteroviruses, *Cryptosporidium* and *Giardia* (Crook *et al*, 1998).

<u>Activated carbon treatment</u>

This is the most practical method of removing refractory organics that produce colour and contribute to the chemical oxygen demand (COD) of wastewater and persist in effluent after secondary treatment.

Activated carbon removes organic and some inorganic materials by adsorption. The carbon is used in two forms:

- powdered activated carbon (PAC) usually dosed into the secondary effluent, and
- granular activated carbon (GAC) used as a filter medium in fixed or moving beds.

Membrane systems / microfiltration processes
These have been used as an additional treatment to produce a high quality effluent with demonstrated effective elimination of bacteria and viruses. Pathogens are retained on the membrane or filter media and are present in backwash streams that require subsequent treatment.

Artificial wetlands
These are being developed as a potential process for upgrading effluent. Wetland systems exhibit seasonal variability, but have the potential for removal of BOD, SS and nitrogen.

Periodic harvesting of material may be necessary to remove nutrients and pollutants from the system.

Pathogenic bacteria are removed via sedimentation, predation, and natural die-off. Pathogenic die-off due to natural UV radiation occurs in artificial wetlands containing open water sections. Significant die-off rates have also been demonstrated for viruses.

Biting or pest insects are a possible major hazard that may arise. Management planning and control measures should be adopted to address problems from mosquitos and other insects.

Natural wetlands are unsuitable for effluent treatment or disposal.

3.3.4 Level of treatment

The level of treatment required depends on the application. Where there is restricted access to the general public, controls and safeguards may be applied and lower levels of treatment may be used. Conversely, where there is contact by large numbers of people and safeguards are not strictly enforceable, higher levels of treatment will be needed. Under these circumstances, multiple independent treatment processes or barriers should be considered to ensure system reliability and safety (Haas and Trussell, 1998).

Application options suitable for various treatment process trains are summarised in **Table 2**. Particular circumstances may dictate higher levels of treatment for these applications. This table summarises the more detailed information in **Table 3**.

Table 2: Process trains suitable for particular applications

Level of Treatment	Options for Reclaimed Water Use
Secondary	• agriculture (non human food chain, eg. cotton silviculture, turf) • aquaculture (non-human food chain)
Secondary with pathogen reduction	• indirect potable (surface water) • municipal irrigation (controlled access) • agricultural (no direct contact of water with crops) • pasture and fodder • passive recreation (ornamental waterbodies) • industrial (open system)
Tertiary with pathogen reduction	• indirect potable groundwater recharge by spreading • indirect potable groundwater recharge by injection • urban residential • municipal irrigation (uncontrolled access) • agricultural (direct contact of water with crops consumed raw)

3.3.5 System reliability

It is essential that reclamation facilities reliably and consistently produce and distribute reclaimed water of adequate quality and quantity. Careful attention must be given to reliability during the facility's design, construction and operation. Fallible elements include:

- the power supply;
- individual treatment units;
- mechanical equipment;
- the maintenance program;
- the operating personnel; and
- illegal trade waste discharge.

The following factors should be considered:

- independence of multiple treatment processes or barriers (Hass and Trussel, 1998);
- check of engineering design;
- duplicate and/or standby facilities for power, treatment units, pumps and pathogen reduction;
- automatic controls and alarms;
- flexible operating modes;
- engineering support;
- qualified personnel;
- effective monitoring program;
- effective maintenance and process control program;
- quality assurance; and
- provision for emergency storage and disposal.

3.4 Safeguards and controls

Protection of public health is paramount in the management of wastewater reuse projects. Protection is provided by barriers that control human exposure to pathogens and contaminants. Such barriers include:

- multiple independent treatment processes or barriers, where higher quality reclaimed water is required (eg. sedimentation and filtration are not independent if the success or failure of both barriers depends on efficient coagulation prior to sedimentation) (Haas and Trussell, 1998)
- industrial waste controls;
- reliable and resilient treatment processes and trained operators;
- reliable disinfection systems;
- secure effluent transfer systems;
- application controls (spray systems); and
- crop restrictions.

Monitoring of processes and indicators is necessary to ensure maintenance of these barriers. Some safeguards commonly used are outlined below.

3.4.1 Effluent disposal

Where reclaimed water may be unsuitable for use due to treatment failure or the normal reclaimed water application is not available, there is a need for the system operator to have available alternative storage and/or disposal options which will ensure protection of human health and the environment.

3.4.2 Plumbing

Where reclaimed water is piped to the site where it is to be used, there is a risk that the reclaimed water pipe could be mistaken for a potable water supply and cross connection could occur. Cross connection control and backflow prevention require the following measures:

- maintenance of complete pipeline plans;
- appropriate pipeline identification;
- education of owner, operator(s), plumbers and the wider community; and
- surveillance of operation and inspection of modifications to the reclaimed water system.

If potable water is supplied into the reclaimed water system as make-up water, an approved air gap meeting the requirements of AS 3500 or other appropriate standard must be installed in the potable supply at the point where it enters the system.

To protect the potable supply from backflow in the event of a cross connection, the reclaimed water system should be installed below the depth of the potable water supply and operated at a lower pressure than the potable system if practicable. Pressure tappings should also be provided to permit in situ testing for correct operation.

All pressure piping used for the reclaimed water system must be readily identifiable and distinguishable from potable water piping on the same site. All above ground and buried facilities and water hose tap outlets located in areas of public access must be distinctively colour coded and/or marked with the words ***Reclaimed Water - NOT FOR DRINKING***.

International Diagram Signs for Non-English speakers may be necessary. Childproof taps should be used to prevent children from drinking non-potable water.

For above ground installations, non-potable water services should not be installed within 100 millimetres of parallel potable water supply. Below ground installations of non-potable water services should not be installed within 300 millimetres of any parallel potable water supply.

Where reclaimed water is provided to residential areas as a piped non-potable supply, the minimum inspection frequency of the reclaimed water system should be:

- all new services at installation;
- all services on change of ownership;
- all services following completion of property extensions or plumbing modifications; and
- each service at least every five years by the authority responsible for the supply or by the owner/operator.

3.4.3 Access

Public access may be controlled, ie limited to times when irrigation with reclaimed water is not taking place or limited to areas outside irrigation spray drift. Alternatively where lower quality water is used eg in tree growing, public access may be restricted to prevent direct contact with irrigated areas. In cases where irrigation is to sites accessible to the public, signs should be visible at the main points of access advising the type of reuse and any restrictions relevant to the public consistent with Table 3.

3.4.4 Spray irrigation

Drift of reclaimed water spray into areas of public access should be minimised through the use of buffer zones, selection of large droplet design sprays and choice of spray height unless parasites and other pathogens are virtually absent.

Spray irrigation of agricultural crops which gives rise to aerosols should not take place within 50 metres of houses or roads. This is a minimum distance. The size of the buffer zone is dependent on factors such as proximity of the public, wind speed and direction, height and droplet size and type of irrigation system used. Buffer zones may need to be increased or decreased where high-pressure systems or low pressure, low rise sprays are used. Local authorities should be consulted when determining the size of the buffer zone. Anemometers may be used to determine wind speed and predict the direction and extent of spray drift. They may be used to cut off irrigation systems under high wind conditions. Cut off wind speed may be determined from a consideration of the factors listed above. The addition of vegetative barriers eg shrubs or small trees, within buffer zones could minimise spray drift.

3.4.5 Crop restrictions

Rigorous treatment may be avoided by appropriate crop selection. Use of reclaimed water to irrigate non-food crops such as cotton or timber effectively prevents pathogens from reaching the human food chain.

3.5 Monitoring and Reporting

The monitoring parameters and suggested frequencies here are additional to and separate from those for treatment plant environmental compliance and process control. They provide a minimum basis for assessment of reclaimed water quality. The health and environmental regulators will generally require reporting of reclaimed water quality data on a regular basis. Also any changes or abnormalities in treatment plant performance resulting in changes in reclaimed water quality would generally be reported to the regulator together with details of remedial action.

The aim of monitoring programs is to demonstrate reclaimed water quality at the point of entry to the reclaimed water reticulation system (point of supply) rather than at the treatment plant. In most cases monitoring will be at the point of entry to the reclaimed water reticulation system. For larger and more complex supply systems, one or more appropriately located sampling points may be used where there is good correlation with reclaimed water quality at the point of supply.

Assessment of reclaimed water quality must be based on a statistically valid sampling program. Monitoring requirements may be tailored in accordance with a statistically sound justification based on the scale and nature of the reclaimed water scheme and with the approval of the appropriate regulators. Sampling frequency may be reduced based on a satisfactory historical record and subject to approval by the health regulator. Where guideline values are exceeded, sampling frequencies should be increased eg. from monthly to weekly. A more rigorous monitoring program is required during the commissioning of a reclaimed water scheme. It may be relaxed later based on satisfactory compliance. A comprehensive account of reclaimed water monitoring, sampling and analysis procedures is given by Rowe and Abdel-Magid (1995b). NSW has specific requirements for bacteria, virus and parasite monitoring for dual systems for urban and residential use (NSW Recycled Water Co-ordination Committee, 1993).

For small, rural and/or remote communities where it is not feasible to apply normal microbiological monitoring the recommended frequencies may be reduced. In such cases greater reliance may be placed on surrogate parameters such as lagoon detention time or disinfectant residual. For assessment of the variation in quality over time a minimum five minute interval between samples is recommended.

Over time, a body of water quality data relating to a particular scheme will become available. When 20 per cent of results are greater than four times the median guideline level, there is cause for further investigation for underlying reasons.

Water quality guidelines together with monitoring control charts enable ongoing performance assessment and early detection of changes.

For weekly sampling consideration should be given to a six day rotating sampling frequency in order to monitor variations through the days of the week. Monitoring frequencies are given in **Table 3.**

3.5.1 Statistical treatment of data

The numbers of indicator organisms observed in a large number of 100 mL samples are not evenly distributed around any of the usual measures of central tendency such as the arithmetic mean, average or mode.

Where a large range of counts is observed, their logarithms are usually evenly distributed around such measures of central tendency. This is because the counts themselves tend to vary in what is called a logarithmically normal (log normal) distribution. Under these circumstances, the summary indices commonly used to characterise the distribution are the measures of central tendency known as the median and the geometric mean.

The choice between the median and the geometric mean as the summary index of log normal distributions is not clear cut. Examples of both measures can be found among criteria and guidelines in use overseas. In general for health related characteristics, a maximum or 95th percentile value is specified. However in the case of reclaimed water, the variation in the distribution makes this approach unsuitable.

In this document, the median is used for all bacterial guidelines for the following reasons:

- it is easily understood as a measure of central tendency, being in fact the central observation, with an equal number of observations on either side of it;
- it is easily ascertained by ordering the observed numbers from lowest to highest without performing any arithmetical operations on them;
- it is robust, not being influenced by extreme values such as zero on the one side or very large numbers on the other;
- it is distribution free, this means its interpretation does not depend on assuming any underlying statistical distribution of the observed numbers;
- it works well with low numbers as well as high, unlike the geometric mean, which must artificially assign to zero readings a value of one, thus having a distorting effect for distributions involving very low numbers; and
- it has produced reliable monitoring data in practice thus permitting satisfactory public health controls to be achieved.

4. Specific reclaimed water applications

The use of reclaimed water is classified in **Table 3** into a number of specific applications, each with its own requirements for:

- type of reuse;
- level of treatment;
- reclaimed water quality;
- reclaimed water monitoring; and
- controls

The order in which the specific applications are presented in **Table 3** is from highest to least contact and does not represent any prioritisation or order of preference for reclaimed water use.

For irrigation schemes the water quality guidelines provided here relate to spray application.

Reclaimed water of a lesser quality may be used under certain conditions. Such conditions would include well-constructed schemes using surface irrigation, eg by trickle or micro-irrigation systems, and demonstration of safety of the practice to the satisfaction of the regulators. The intensity and depth of irrigation should be adapted to soil and vegetation type to minimise leaching of lower quality water beneath the root zone.

For almost all applications control of nutrients, toxicants, salinity and sodicity of reclaimed water will be required to prevent unwanted effects such as damage to plant growth, eutrophication of surface waters or contamination of groundwater.

4.1 Direct potable

This involves the treatment of wastewater to such an extent that it can be fed into a potable treatment or supply system. It is not possible at present to provide any guidelines for this practice.

4.2 Indirect potable

This involves the augmentation of groundwater and surface waters with reclaimed water. Water may then be extracted from these sources and subsequently treated for potable purposes.

Ideally the water supply should be taken from the best quality sources available. Contamination of a water source should be prevented or controlled by the maintenance of the barriers. Where pristine sources are not available indirect potable water may be used. Reclaimed water used for augmentation should be of equal or better quality than the receiving water.

This practice of augmentation of surface waters using reclaimed water occurs in many parts of Australia. High dilution and extended storage of raw water normally takes place prior to abstraction and subsequent treatment to ensure that potable water meets NWQMS (1996) *Australian Drinking Water Guidelines* (Appendix 1). In the future this type of indirect potable reuse may in some cases be the best planning option for management of the water cycle particularly where water resources are limited.

Groundwater recharge and surface water augmentation using reclaimed water should be approved on a site-specific basis by the health and environment protection authorities.

A minimum of secondary treatment is needed in order to provide a raw water quality for subsequent treatment to potable quality. Additional pathogen reduction by means of disinfection may be necessary for some indirect potable uses.

Hydrological and geological characteristics along with soil type determine the suitability of specific sites for recharge.

By providing a retention period of 12 months prior to groundwater abstraction for potable use, virus numbers are reduced through die-off and adsorption.

Nitrogen content of surface and groundwaters supplemented by reclaimed water should be closely monitored. Total oxidised nitrogen levels should be less than 10 mg/L as N when diluted and abstracted for drinking purposes.

4.3 Urban non-potable residential

This category includes all uses of reclaimed water in urban situations such as irrigation of open spaces, cleaning and dust suppression. As there is potential for a high level of contact, high quality is required.

Thermotolerant coliforms must be at low levels. Treatment processes should remove particulate matter to enable destruction of pathogens by disinfection. Turbidity, suspended solids and chlorine residual are surrogates for pathogen removal and should be <2 NTU, <5 mg/L and >1 mg/L respectively.

For toilet flushing in closed systems, such as office or factory systems with no direct human contact with reclaimed water, guideline values for thermotolerant coliforms, turbidity, and suspended solids are not proposed. However, conventional filtration and pathogen reduction are required. Specific requirements for urban dual reticulation systems have been prescribed by authorities in NSW (NSW Recycled Water Co-ordinating Committee, 1993).

4.4 Urban non potable municipal

This is similar to the above practice but with some safeguards and controls possible. The level of treatment and water quality for this application depends on the extent of controls on public access. The urban residential guideline above applies for a high level of contact.

Where a withholding period can be applied between irrigation and public access, a lesser degree of treatment and water quality may be used. The withholding period should be until any ponding of water is no longer apparent. Ideally the surface and grass or foliage should be dry, normally four hours under temperate conditions, but this requirement may be increased where dew fall conditions prevent complete drying of foliage. Lesser withholding periods may be used where safety of the practice can be demonstrated.

4.5 Agricultural Food Production

There are a number of situations where it is appropriate to use reclaimed water in agricultural production systems including horticultural, pastoral and silvicultural applications. Prospective users of reclaimed water should seek advice on the acceptability of reclaimed water use from relevant food regulatory bodies, industry associations and product buyers.

Agencies responsible for the distribution of reclaimed water should appreciate that these guidelines have been drafted on the basis that only input from permitted industrial and human wastewaters has been taken into account. Where wastewater from animal enterprises like saleyards, abattoirs, animal refuges, knackeries and dairies is accepted into sewerage plants, the diseases of livestock endemic in an area need to be considered. Reclaimed water treatment, quality and controls should be set to ensure that animal diseases are not spread by reuse practices.

Australia is fortunate that *Taenia solium* has not established a life cycle in Australia and it must not be allowed to do so. To ensure this, the guidelines recommend that pigs are not exposed either to reclaimed water or to crops produced using reclaimed water.

As the survival of some human pathogens is not completely understood, a higher level of treatment incorporating safeguards and processes to control all types of pathogens including protozoa and viruses is required for crops consumed raw. Potential users of reclaimed water on these crops should seek advice from, and comply with any requirements of, appropriate state or territory authorities. In all such cases, the fundamental basis of assessment should be the quality of the water not its source.

Helminths should be absent from reclaimed water irrigation of crops destined for livestock uses or veterinary advice sought on alternative helminth controls such as cattle husbandry. In the case of dairy animals ie. cattle, sheep and goats, a withholding period from grazing access is required to allow for pasture drying. The withholding period is dependent on the reclaimed water quality.

No recommendations have been made on a guideline for protozoa in reclaimed water used in agriculture. Parasites such as cryptosporidia, giardia, toxoplasma, etc may be present in wastewater. No recommendations have been made because it is not known what guidelines should apply. To date, problems do not appear to have arisen in the absence of guidelines and the survival and epidemiology of these parasites in wastewater treatment and reuse systems is not well understood.

4.6 Agricultural Non Food Crops

Lower levels of treatment may be used in the production of non-food crops, eg silviculture. This is a low contact application. Public access should be excluded. The application rate will depend on several factors including soil type and topography. Runoff of excess irrigation water or stormwater contaminated with effluent should be avoided. Bunding may need to be constructed to control irrigation runoff and recover effluent runoff for reapplication.

4.7 Aquaculture

Reclaimed water may be a component of waters used in non-human food chain fish cultivation and to a lesser extent the cultivation of algae and zooplankton. Water quality requirements vary depending on the application. Aquaculture projects for human food chain purposes require approval by health regulators.

4.8 Recreational

There are no known examples of contact recreational use of impounded surface waters entirely supplied with reclaimed water in Australia. The main overseas example is in Santee, California, USA. Proposals for schemes of this kind would be regulated by state environmental and health authorities on a case by case basis.

Reclaimed water may be used in ornamental waterbodies where there is no human contact.

4.9 Environment

Environmental uses of reclaimed water covers examples of surface water augmentation other than in impoundments. Water quality requirements will be site specific and will be stipulated by the health and environmental regulators.

4.10 Industry

Reclaimed water may be used in industrial applications such as cooling or quenching and dust control. Applications using reclaimed water may have specific chemical quality requirements needing particular treatment trains.

Closed systems do not allow any contact and where these are used and water quality requirements permit, secondary treatment alone may suffice. Applications such as cooling waters will have highly specific chemical and microbiological requirements.

Open systems allow a degree of contact, and with correct system design and workforce education, the risk of accidental or deliberate ingestion or inhalation of aerosols can be minimised.

Where there is a possibility of contact with the effluent, issues related to the health of workers dictate secondary treatment followed by tertiary treatment such as filtration and pathogen reduction.

4.11 Aquifer Storage and Recovery

Aquifer Storage and Recovery (ASR) is the practice of injecting water into aquifers for storage and subsequent reuse. Reclaimed water may be used for this purpose. While the practice is in its infancy in Australia, there are several research and full-scale projects. ASR is likely to become more widespread as it offers a means of large-scale water storage at low cost. Guidelines are given for groundwater recharge for various environmental values. Possible uses of ASR include;

- augmentation of groundwater supplies eg. for irrigation;
- reduction of groundwater salinity (aquifer renewal); and
- prevention of seawater intrusion.

Water quality requirements for recharge purposes will be site specific and will be stipulated by the health and environmental regulators. NWQMS Guidelines for Groundwater Protection in Australia (Appendix 1) also apply.

Recent research has been conducted into fate of contaminants and changes in water quality in the aquifer matrix following ASR and guidelines have been developed. (P Dillon, P Pavelic 1996) Their subsequent research is facilitating further development of guidelines and Codes of Practice for ASR under Australian conditions.

Table 3: Guidelines for the Use of Reclaimed Water

Type of reuse	Level of treatment	Reclaimed water quality [1]	Reclaimed water monitoring [2]	Controls
DIRECT POTABLE	No guideline available			
INDIRECT POTABLE				
Surface water	Secondary		pH weekly	State Statutory requirements met. Surface water should comply with raw drinking water guidelines at abstraction point. (Appendix 1)
	And Pathogen reduction[5]	Thermotolerant coliforms [3] <1000 cfu /100ml[4]	Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Subsequent treatment to drinking water guidelines by filtration and additional treatment/ (Appendix 1)
Groundwater Recharge by spreading into potable aquifer	Secondary, possible need for Tertiary (nutrient reduction) (site specific)	Site specific, no deleterious effects on aquifer water quality or land resource	pH weekly	Minimum 3 m depth to groundwater. Groundwater quality meets pre-existing values. Groundwater should comply with raw drinking water guidelines after mixing. (Appendix 1)
	Possible need for pathogen reduction[5]	Thermotolerant coliforms[3] <1000 cfu/100ml		12 months minimum retention time of reclaimed water underground prior to withdrawal.
Groundwater Recharge by injection into potable aquifer	Secondary, possible need for Tertiary (nutrient reduction) (site specific) And	No deleterious effects on aquifer water quality or land resource	pH weekly	Irreversible clogging avoided. Groundwater quality meets pre-existing values. Groundwater should comply with raw drinking water guidelines after mixing. (Appendix 1)
	Pathogen reduction[5]	Thermotolerant coliforms[3] <10 cfu/100ml[4]	Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	12 months minimum retention time of reclaimed water underground prior to withdrawal.

Table 3: Guidelines for the Use of Reclaimed Water (continued)

Type of reuse	Level of treatment	Reclaimed water quality[1]	Reclaimed water monitoring [2]	Controls
URBAN (NON POTABLE)				
Residential Garden watering Toilet flushing Car washing Path/wall washing	Tertiary	pH 6.5 - 8.5[7] $\leq$2 NTU[9]	pH weekly BOD weekly Turbidity continuous	Plumbing controls.
	And Pathogen reduction[5]	1 mg/L Cl_2 residual[10] after 30 min, or equivalent indicator organism reduction to Thermotolerant coliforms[3] <10 cfu /100ml[4]	Disinfection systems daily[6] Thermotolerant coliforms[3] daily	
Toilet flushing closed systems (Office or factory systems with no direct human contact with reclaimed water)	Tertiary			Plumbing controls.
	And Pathogen reduction[5]	1 mg/L Cl_2 residual[10] or equivalent level of disinfection	Disinfection systems daily[6] Thermotolerant coliforms[3] weekly[6]	For non residential usage, legionella controls and biocide dosing may be required. Specific legionella control guidelines should be consulted.

Table 3: Guidelines for the Use of Reclaimed Water (continued)

Type of reuse	Level of treatment	Reclaimed water quality[1]	Reclaimed water monitoring [2]	Controls
URBAN (NON POTABLE)				
Municipal with uncontrolled public access Irrigation open spaces, parks, sportsgrounds, dust suppression, construction sites, ornamental waterbodies	Tertiary	pH 6.5 - 8.5[7] $\leq$2 NTU[9]	pH weekly BOD weekly Turbidity continuous	Colour reduction may be necessary for ornamental uses. Application rates limited to protect groundwater quality. Salinity should be considered for irrigation.
	And Pathogen reduction[5]	1 mg/L Cl_2 residual[10] or equivalent level of pathogen reduction	With disinfection system eg. Cl_2 Disinfection systems daily[6]	
		Thermotolerant coliforms[3] <10 cfu /100ml[4]	Thermotolerant coliforms[3] monthly[6]	
Municipal with controlled public access Irrigation open spaces, parks, sportsgrounds, dust suppression, construction sites, mines	Secondary		pH monthly SS monthly	Application rates limited to protect groundwater quality. Salinity should be considered for irrigation.
	Pathogen reduction[5]	Thermotolerant coliforms[3] <1000 cfu /100ml[4]	Disinfection systems daily[6] Thermotolerant coliforms[3] monthly	Irrigation during times of no public access. Withholding period nominally 4 hours or until irrigated area is dry.

Table 3: Guidelines for the Use of Reclaimed Water (continued)

Type of reuse	Level of treatment	Reclaimed water quality[1]	Reclaimed water monitoring [2]	Controls
AGRICULTURAL				
Food production Raw human food crops in direct contact with reclaimed water eg. via sprays, irrigation of salad vegetables	Tertiary	pH 6.5 - 8.5[7] ≤2 NTU[9]	pH weekly Turbidity continuous	Application rates limited to protect groundwater quality. Salinity should be considered.
	And			
	Pathogen reduction[5]	1 mg/L Cl_2 residual[10] or equivalent level of disinfection	Disinfection systems daily[6]	A minimum of 25 days ponding or equivalent treatment (eg. sand filtration) for helminth controls.
		Thermotolerant coliforms[3] <10 cfu /100ml[4]	Thermotolerant coliforms[3] weekly	
Food production Raw human food crops not in direct contact with reclaimed water (edible product separated from contact with effluent, eg. by peel, use of trickle irrigation).or crops sold to consumers cooked or processed	Secondary	pH 6.5 - 8.5[7]	pH weekly BOD weekly SS weekly	Application rates limited to protect groundwater quality. Salinity should be considered. Dropped crops not to be harvested from the ground.
	And			
	Pathogen reduction[5]	Thermotolerant coliforms[3] <1000 cfu /100ml[4]	Thermotolerant coliforms[3] weekly	Crops must be cooked (>70°C for 2 minutes), commercially processed or peeled before consumption.
Food production Pasture and fodder (for grazing animals except pigs and dairy animals, ie. cattle, sheep and goats)	Secondary	pH 6.5 - 8.5[7]	pH weekly SS weekly	Application rates limited to protect groundwater quality.
	And			
	Pathogen reduction[5]	Thermotolerant coliforms[3] <1000 cfu /100ml[4]	Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Withholding period of nominally 4 hours for irrigated pasture. Drying or ensiling of fodder Helminth controls[8].

Table 3: Guidelines for the Use of Reclaimed Water (continued)

Type of reuse	Level of treatment	Reclaimed water quality[1]	Reclaimed water monitoring [2]	Controls
AGRICULTURAL				
Food production Pasture and fodder for dairy animals (with withholding period).	Secondary And Pathogen reduction[5]	pH 6.5 - 8.5[7] Thermotolerant coliforms[3] <1000 cfu /100ml[4]	pH weekly SS weekly Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Application rates limited to protect groundwater quality. Withholding period of 5 days for grazing animals. Drying or ensiling of fodder Helminth controls[8].
Food production Pasture and fodder for dairy animals (without withholding period). Drinking water (all stock except pigs) Washdown water for dairies.	Secondary And Pathogen reduction[5]	pH 6.5 - 8.5[7] Thermotolerant coliforms[3] <100 cfu /100ml[4]	pH weekly SS weekly Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Application rates limited to protect groundwater quality. No withholding period Helminth controls[8].
Non food crops Silviculture, turf and cotton etc.	Secondary And Pathogen reduction[5]	pH 6.5 - 8.5[7] Thermotolerant coliforms[3] <10,000 cfu /100ml[4]	pH weekly BOD weekly SS weekly Thermotolerant coliforms[3] weekly	Application rates limited to protect groundwater quality. Restricted public access. Withholding period of nominally 4 hours or until irrigated area is dry.

Table 3: Guidelines for the Use of Reclaimed Water (continued)

Type of reuse	Level of treatment	Reclaimed water quality[1]	Reclaimed water monitoring [2]	Controls
AQUACULTURE				
Non-human food chain	Secondary		pH weekly SS weekly	Salinity Controls TDS <1000mg/L <10% change in turbidity (seasonal mean conc.) Dissolved oxygen controls may be required for fish, zooplankton.
	And			
	Pathogen reduction[5] [via]Maturation ponds (5 days retention time)	Thermotolerant coliforms[3] <10,000 cfu /100ml[4]	Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	

Table 3: Guidelines for the Use of Reclaimed Water (continued)

Type of reuse	Level of treatment	Reclaimed water quality[1]	Reclaimed water monitoring [2]	Controls
RECREATIONAL IMPOUNDMENTS				
Passive recreation Ornamental waterbodies with no contact	Secondary And Pathogen reduction[5]	 Thermotolerant coliforms[3] <1000 cfu /100ml[4]	pH weekly SS weekly Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Surface films absent. Consider nutrient status re. risk of eutrophication. Restrictions on access.
ENVIRONMENTAL				
Stream augmentation	Secondary (Site specific) And Pathogen reduction[5] (Site specific)	Site specific	Site specific depending on water quality requirement	Receiving water quality requirements to be considered. State Health and Environment regulations apply. Temperature controls. Consider nutrient status re. risk of eutrophication.
INDUSTRIAL				
Closed system Cooling water	Process specific	Site specific	Site specific depending on water quality requirement and end use	Additional treatment by user to prevent scaling, corrosion, biological growth, fouling and foaming.
Open system **Human contact possible** Mines, dust suppression	Secondary And Pathogen reduction[5]	Site specific Thermotolerant coliforms[3] <1000 cfu /100ml[4]	pH weekly, BOD weekly, SS weekly Thermotolerant coliforms[3] weekly Disinfection systems daily[6]	Additional treatment by user to prevent scaling, corrosion, biological growth, fouling and foaming. Windblown spray minimised.

NOTES TO TABLE 3

1. Reclaimed water quality refers to the quality of water following treatment appropriate for a particular application and prior to mixing with the receiving waters.

2. Monitoring demonstrates reclaimed water quality at the point of supply rather than at the treatment plant. In most cases this will be the point of entry to the reclaimed water reticulation system or other suitable representative sampling location.

3. Thermotolerant coliforms. Refer to Glossary.

4. Median value. Refer to Section 3.5.1 Statistical treatment of data.

5. Pathogen reduction beyond secondary treatment may be accomplished by disinfection eg. chlorine, or by detention eg. ponds or lagoons. Systems using detention only do not provide reduction of thermotolerant coliform counts to <10 per 100mL and are unsuitable as the sole means of pathogen reduction for high contact uses.

6. Disinfection systems refer to chlorination, ultraviolet irradiation or other disinfection systems. Monitoring requirements include such measures as checking chlorine residual or operational checking of UV equipment. Monitoring frequencies do not apply to pond or lagoon systems.

7. 90% compliance for samples.

8. Helminths controls include measures such as removal by treatment, veterinary inspection, cattle husbandry and/or a withholding period prior to grazing.

9. Limit met prior to disinfection. 24 hour mean value. 5 NTU maximum value not to be exceeded.

10. Total Chlorine Residual after a minimum contact time of 30 minutes.

5. Irrigation schemes

5.1 General

Because agricultural and municipal irrigation schemes comprise the most common use of reclaimed water, some broad principles of reclaimed water irrigation practice are included here.

Traditionally, the philosophy underpinning land application of reclaimed water has been to focus on disposal of large volumes with a minimum of adverse effects. Treated reclaimed water is now widely regarded as a resource available for use, rather than a waste requiring disposal. As a general principle, the beneficial uses should be encouraged where it is safe, practicable and economic to do so, and where they provide the best environmental outcome.

To achieve an ecologically sustainable agronomic system, best management practices must be adopted in the planning, design, construction, ongoing operation and management of reclaimed water irrigation schemes.

Schemes should comply with the objectives of ecological sustainability in an irrigation system - resource utilisation, protection of lands, protection of groundwaters, protection of surface waters, and community amenity. Ongoing monitoring and progressive modification should be integral components of any reclaimed water irrigation plan enabling:

- correction of any design flaws and deficiencies;
- system adjustments based on more complete site information as it becomes available;
- accommodation of appropriate new technologies; and
- change in operational parameters over time.

Subject to certain treatment, operation, management and pollution control requirements, secondary treated reclaimed water may be used productively for:

- municipal landscape watering;
- irrigation of pasture, turf, crops, gardens, orchards, vineyards and forests; and
- watering of golf courses, race courses, community recreation facilities and land rehabilitation areas.

Further information on the use of treated effluent and requirement for statuatory approvals, is available from relevant State and Territory authorities (ACT Government, 1999; DHS and EPA, 1999; EHPD, 1996; EPA Vic 1992; EPA NSW 1995; NSW Recycled Water Co-ordination Committee, 1993). Note that these guidelines do not necessarily assure protection of groundwater.

5.2 Planning issues

Some important environmental criteria in the evaluation of a site for a reclaimed water irrigation scheme are:

- consideration of low application rates, in proportion to total irrigation, for uses in near pristine environment (Hayes and deWalle, 1993)
- the availability of sufficient land to accommodate any necessary storage requirements;
- the quality of underlying water in any unconfined aquifer;

- the crop cultivation area to be irrigated; and
- any additional statutory land requirements.

Other important issues associated with the assessment of a proposed irrigation site are:

- climate;
- site topography;
- soil type, drainage, physico-chemical characteristics and depth;
- geologic formations;
- proximity to watercourses and groundwater wells;
- groundwater levels;
- flood potential;
- erosion control;
- land for storage;
- proximity to dwellings and public roads;
- reclaimed water quality;
- species of vegetation to be grown;
- cost; and
- public health considerations;
  - ◊ potential for human exposure;
  - ◊ potential for generation of aerosols and drift to more distant locations.

Reclaimed water should be applied to the site by methods other than flood or furrow irrigation as these techniques may result in over-application and resulting unintended environmental impacts. Use of 'spray irrigation' can take many forms. Spray irrigation systems range from high-pressure sprays with high aerosolisation and a broad sweep, to downward-pointing nozzle type sprays which generate minimal spray drift and aerosolisation. Protection (buffer) zones are required as indicated under 'Safeguards and Controls', and should be matched to the extent of likely spray drift (Eden, 1996).

For a reclaimed water irrigation scheme to be ecologically sustainable, it is important that the agronomic system does not become stressed by excessive hydraulic, organic or nutrient loading.

The characteristics of soils, groundwater and surface water should be clearly established at the beginning of the project as they will later serve as baseline data for assessing the scheme's performance.

A soil profile examination should be undertaken for features that can affect:

- water-storage capacity;
- soil drainage;
- nutrient uptake;
- aeration; and
- development of root systems.

Leaching of lower quality water to groundwater is a particular concern but in some cases can be controlled by careful design of effluent irrigation rates and attention to harvesting and removing vegetation from the site. Measures to protect groundwater quality will be more onerous where the ambient groundwater quality is capable of providing drinking water supplies or sustains ecosystems. Once contaminated, clean up of groundwater may not be possible or is very expensive.

In design of the system, reclaimed water requirements should be calculated on a monthly basis to ensure:

- the correct amount of reclaimed water is applied at the right time to prevent salt accumulation in the root zone, to prevent excessive leaching of nitrate and salt, and to meet crop requirements; and
- climatic variations within the year are taken into account.

The water balance equation requires design runoff to be zero, therefore the amount of reclaimed water applied plus precipitation should approximately equal the amount of water lost due to evapotranspiration. Irrespective of the maximum design application rate, it is essential that reclaimed water irrigation be done only under dry weather conditions and regular inspections be undertaken to ensure ponding or runoff does not occur. This obviously does not apply where runoff occurs into the normal discharge point. Runoff from an irrigated site may occur after rainfall. Schemes should be examined on a case by case basis to ensure that runoff does not degrade the local environment. Percolation of nitrogen and salt in irrigation waters below the root zone should be minimised to avoid groundwater contamination.

A limited amount of percolation is required to prevent salt accumulation in topsoil. Where this requirement is provided from rainfall, design percolation should be assumed to be zero but will inevitably occur. Where rainfall is insufficient to leach accumulated salts from the topsoil, design percolation below the root zone should be limited to the amount necessary to prevent salt accumulation. The amount of water and concentrations of salt and nitrate leached should be estimated at design stage and monitored during operation of the site.

Temporary storage of reclaimed water is necessary in almost all land application systems to prevent runoff and hydraulic overloading during periods when irrigation is not appropriate, such as extended periods of rain. Storage requirements may be determined from an analysis of water balances based on historical rainfall and evaporation data. System backup and flow equalisation should also be considered. It is important that excavated storage structures are adequately lined to prevent the seepage of reclaimed water and the consequent pollution of groundwaters.

When the system's design capacity is exceeded, overflows from the storage facility may be necessary. Overflows should be limited to times of high rainfall when flows in receiving waters are greatest. System overflows should be directed to the environment via a properly constructed and controlled licensed overflow point.

Organic matter contained within reclaimed water may increase soil fertility and improve site vegetative cover. The average maximum daily organic loading rate at an application site may be calculated from the hydraulic loading rate and the organic content (BOD) in the applied reclaimed water.

Over-application may lead to:

- detectable impacts on surface and groundwater (Hayes and deWalle, 1993)
- waterlogging;
- accumulation of unstabilised solids; and

- progressive changes in soil structure associated with increasingly anaerobic conditions.

The quantity of reclaimed water applied in a given area may also be limited by the loading rates of nutrients. To determine the nutrient balance at a site, compare the amount of the specific nutrient to be applied with that expected to be taken up by biological or physical processes within the crop/soil system used.

Consideration should be given to land use after irrigation with reclaimed water has ceased as the soil may be enriched with nutrients capable of mineralising and leaching, especially after tillage.

5.3 Water Quality

Although reclaimed water can supply most of the nutrients essential for healthy plant growth, imbalances can occur. Soil and crop analyses may be undertaken to diagnose nutritional disorders and to determine any corrective action needed. These analyses and calculations should be undertaken prior to irrigation.

Nutrients not removed from the site by harvest of vegetation or plant products may accumulate in the system, becoming a potential pollution source for surface and groundwaters. Physical and chemical soil reactions which constitute significant phosphorus removal pathways are not necessarily renewable. The useable lifetime of an irrigation site therefore depends on the soil's phosphorus absorption capacity.

The chemical quality of water used for irrigation is of importance. Crop damage may result from the presence of toxic ions taken up by roots and accumulated in leaves. Chloride, sodium and boron ions, sodicity (sodium adsorption ratio) and alkalinity can cause problems reducing crop yields. Infiltration characteristics of soils can be adversely affected.

Water quality should be compatible with the irrigation application envisaged. Crops are classified according to salt tolerance and will suffer a reduction in yield when irrigated with waters of salinity higher than the recommended range. See Table 4 for salinity guidelines.

Increasing salt loads into the sewerage system will limit reuse opportunities by degrading reclaimed water quality.

Some reclaimed water may contain contaminants, notably heavy metals and chlorinated organic compounds, which typically concentrate in soil. High concentrations of chemical contaminants in topsoil can cause toxicity and introduce unacceptably high residual concentrations in plants, animals and humans.

Solids which could block sprays should be removed by screening, straining, filtration or other appropriate treatment.

Organic content such as algae present in reclaimed water can decompose on prolonged detention in irrigation systems resulting in foul odours and negative perceptions. This can be overcome by periodically purging irrigation lines and minimising the time lag between disinfection and irrigation.

Table 4: General guidelines for salinity of irrigation water

Class	Comment	Electrical conductivity (µS/cm)	Total Dissolved Solids (mg/l)
1	Low-salinity water can be used with most crops on most soils and with all methods of water application with little likelihood that a salinity problem will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability	0-280	0-175
2	Medium-salinity water can be used if moderate leaching occurs. Plants with medium salt tolerance can be grown, usually without special measures for salinity control. Sprinkler irrigation with the more-saline waters in this group may cause leaf scorch on salt-sensitive crops, especially at high temperatures in the daytime and with low application rates	280-800	175-500
3	High-salinity water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and the salt tolerance of the plants to be irrigated must be considered.	800-2,300	500-1,500
4	Very high-salinity water is not suitable for irrigation water under ordinary conditions. For use, soils must be permeable, drainage adequate, water must be applied in excess to provide considerable leaching and salt-tolerant crops should be selected.	2,300-5,500	1,500-3,500
5	Extremely high-salinity water may be used only on permeable, well-drained soils under good management, especially in relation to leaching and for salt-tolerant crops, or for occasional emergency use	>5,500	>3,500

(NWQMS *Australian Water Quality Guidelines for Fresh and Marine Waters* (Appendix 1))

The water-loading rate is dependent on the type of crop. Where the reclaimed water contains a high concentration of nitrogen that the crop cannot absorb, the nutrient loading rate may become limiting. Design equations can be used to determine which area to irrigate.

5.4 Operational issues

Irrigation systems should be functional, reliable and straightforward to operate and maintain. They should be designed to allow system adjustments in response to variations in reclaimed water and vegetation characteristics, soil and weather conditions, and other parameters.

The operation of a reclaimed water irrigation facility should be clearly defined in a procedures manual that addresses:

- prevention of surface water and groundwater pollution;
- maintenance of soil quality with respect to organic, nutrient and contaminant loading; and
- maintenance of community amenity.

A key control in any reclaimed water irrigation proposal is that stormwater runoff which has passed over the irrigation site be prevented from polluting surface waters. Runoff control measures should prevent:

- uncontaminated runoff from entering the irrigation area, by the use of diversion measures; and
- contaminated runoff from the irrigation site from entering surface waters, by the use of collection and storage systems.

In most projects, an ongoing monitoring program will be needed to measure the various reclaimed water components, their uptake in crops and subsequent removal at harvest, and their accumulation in the soil and groundwater beneath the site and downgradient.

Where applicable, it may be necessary to monitor groundwater and surface waters upstream and downstream of the irrigation site and to periodically determine the total load of reclaimed water constituents introduced to the irrigated area.

The monitoring program should provide the operator with early warning of soil deterioration and pollution of groundwaters or surface waters. This should include monitoring of leachate below the root zone and will enable introduction of appropriate control measures to arrest the situation and prevent further deterioration of land and water quality.

A site management plan should provide a comprehensive guide to the entire facility and include:

- site selection;
- reclaimed water transport;
- storage arrangements;
- maximum loading rates;
- the irrigation system and its management, including operation and maintenance;
- soil erosion control;
- stormwater control arrangements;
- cropping practices for nutrient utilisation;
- irrigation scheduling;
- monitoring and control systems; and
- statutory requirements relating to the protection of the environment and public health.

A comprehensive schematic diagram of system controls, together with a clear description of all control systems should be included in an operation and maintenance manual. State and Territory authorities may require additional warning signs wherever reclaimed water is used, restrictions of use or of public access, limits on irrigation times, wider buffer zones, longer withholding periods, specific irrigation controls for each use, or additional requirements for irrigation management plans (ACT Government, 1999; DHS and EPA, 1999; EHPD, 1996).

A management plan and monitoring program should be introduced for reservoir storage of reclaimed water, when permanent storage is an integral part of any irrigation scheme. The monitoring program should include measurements from different locations around reservoirs, analyses of stratification, use of destratification techniques for reducing algae and other problems (Hayes and deWalle, 1993). Water impoundments, reservoirs and ponding can be sources of water-based diseases and insect vectors that can have a significant health impact. These diseases and organisms are controlled by appropriate management plans, and include

Schistosomiasis which could become important in Australia's north in the future, hookworm, intestinal roundworm, and mosquitoes (agents of arbovirus and other diseases) (Rowe and Abdel-Magid, 1995a, EHPD, 1996).

Appendix 1: National Water Quality Management Strategy Documents

Policies and Process for Water Quality Management

1	Water Quality Management - An Outline of the Policies
2	Policies and Principles - A Reference Document
3	Implementation Guidelines

Water Quality Benchmarks

4	Australian Water Quality Guidelines for Fresh and Marine Waters
5	Australian Drinking Water Guidelines - Summary
6	Australian Drinking Water Guidelines
7	Guidelines for Water Quality Monitoring & Reporting

Groundwater Management

8	Guidelines for Groundwater Protection

Guidelines for Diffuse and Point Sources

9	Rural Land Uses and Water Quality
10	Guidelines for Urban Stormwater Management
11	Guidelines for Sewerage Systems - Effluent Management
12	Guidelines for Sewerage Systems - Acceptance of Trade Waste (Industrial Waste)
13	Guidelines for Sewerage Systems - Sludge (Biosolids) Management
14	Guidelines for Sewerage Systems - Reclaimed Water
15	Guidelines for Sewerage Systems - Sewerage System Overflows
16a	Effluent Management Guidelines for Dairies Sheds
16b	Effluent Management Guidelines for Dairy Processing Plants
17	Effluent Management Guidelines for Intensive Piggeries
18	Effluent Management Guidelines for Aqueous Wool Scouring and carbonising
19	Effluent Management Guidelines for Tanning and Related Industries in Australia
20	Effluent Management Guidelines for Australian Wineries and Distilleries

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8. Glossary of terms

abstraction point	Point in a river or water storage where water is withdrawn for subsequent treatment for potable use.
activated carbon (AC)	Adsorptive carbon particles or granules which possess a high capacity to remove trace and soluble components from solution.
activated sludge	A sludge made by continuous recirculation of the solids from the secondary sedimentation tank to the aeration tank, thus acquiring many useful aerobic bacteria.
adsorption	The adherence of gas, liquid or solute to the surface of a solid.
becquerel (Bq)	Unit of radioactivity ($1Bq = 2.7 \times 10^{-11}$ Ci) .
beneficial use	A use of the environment or any element or segment of the environment that is conducive to public benefit, welfare, safety, health or aesthetic enjoyment.
biochemical oxygen demand (BOD)	A measure of the amount of oxygen used in the biochemical oxidation of organic matter, over a given time and at a given temperature; it is determined entirely by the availability of the material as a biological food and by the amount of oxygen used by the micro-organisms during oxidation.
BOD_5	BOD determined by standard test (5 days at 20^oC).
chemical oxygen demand (COD)	A measure of the amount of oxygen used in the chemical oxidation of carbonaceous organic matter in wastewater using dichromate or permanganate salts as oxidants in a two hour test.
chlorination	The application of chlorine or chlorine compounds to water or wastewater, usually for the purpose of pathogen reduction, but often to provide chemical oxidation and odour control.
cfu	colony forming unit
coagulation	The aggregation of very small suspended particles (<0.1mm) into small visible particles (0.1-1 mm) by adding a chemical coagulant.
controlled access	The limitation of public access to sites so as to minimise the likelihood of direct physical contact with reclaimed water.
conventional filtration	The process of passing wastewater through a bed of granular media eg. sand and anthracite to remove particulate matter.
denitrification	The anaerobic biological reduction of nitrate nitrogen to nitrogen gas.

direct potable reclamation	The derivation of drinking water directly from wastewater without an intermediate stage of storage or mixing with surface or groundwater.
domestic wastewater	Wastewater derived principally from dwellings, business buildings, institutions and the like. It may or may not contain groundwater, surface water or stormwater.
drinking water	See potable water.
electrical conductivity (EC)	Measure of electrical transmission. Measured in siemens per metre (S/m), μS/cm or ohm^{-1} per metre (SI units). Formerly measured in mhos per metre (mhos/m).
effluent	Treated or untreated wastewater flowing out of a treatment plant or transfer system.
ensiling	Process for preservation of animal fodder crops by storage in silos, pits or trenches with exclusion of air.
filter	A device or structure for removing solid or colloidal material from water, wastewater or other liquid.
furrow irrigation	A method of irrigation whereby water is applied via small ditches or furrows which lead from the supply channel, thus wetting only part of the ground surface.
geometric mean	Of *n* positive numbers, the *n*th root of their product (the root, to the total number of observations of the product obtained by multiplying them all together).
greywater	Domestic wastewater excluding toilet wastes.
groundwater	Sub-surface water from which wells or springs are fed; strictly, the term applies only to water below the water table.
groundwater recharge	Replenishing of groundwater naturally by precipitation or runoff, or artificially by spreading or injection.
guideline	Numerical concentration or narrative statement recommended to support or maintain a designated water use.
helminth	A worm; the helminths discussed in this document are parasitic worms.
high contact	Activities which provide a high likelihood of direct public contact with reclaimed water eg. urban residential garden watering.
indirect potable reclamation	The derivation of drinking water from surface or groundwater containing some proportion of treated wastewater.

industrial wastewater Wastewater derived from industrial sources or processes.

lagoon Any large pond or holding used to contain wastewater while sedimentation and biological oxidation occur.

low contact Activities which provide minimal opportunities for direct public contact with reclaimed water eg. irrigation of open spaces with controlled public access.

mean The arithmetic average obtained by adding quantities and dividing the sum by the number of quantities.

median In a set of observations ordered by value, the central or middle value obtained by dividing the set into two equal parts.

membrane filtration Techniques such as microfiltration (see below), nanofiltration and reverse osmosis are tertiary treatment processes used to produce high grade effluent for specific purposes.

microfiltration The process of passing wastewater through porous membranes in the form of sheets or tubes to remove suspended and particulate material. Pore sizes can be very small and particles down to 0.2 microns can be retained.

mode Most frequently occurring number.

nematode A roundworm of the class Nematoda, e.g. *Ascaris.*

nitrification The oxidation of ammonia nitrogen to nitrate nitrogen in wastewater by biological means.

NTU Nephelometric Turbidity Units. See turbidity.

oxidation ditch A secondary wastewater treatment facility that uses an oval channel with a rotor placed across it to provide aeration and circulation. The screened wastewater in the ditch is aerated by the rotor and circulated at around 0.5 metres per second.

pH A measure of the hydrogen-ion concentration in a solution. On the pH scale of 0-14, a value of 7 represents a neutral condition; decreasing values, below 7, indicate increasing hydrogen-ion concentration (acidity); and increasing values, above 7, indicate decreasing hydrogen-ion concentration (alkalinity).

ponds In the context of wastewater, ponds are bodies of water which are usually connected in series, used for the treatment of wastewater.

potable water Water suitable on the basis of both health and aesthetic considerations for drinking or culinary purposes.

primary sedimentation (primary treatment) — Initial treatment of wastewater involving screening and sedimentation to remove solids.

raw water — Surface water or groundwater that is available as a source for drinking water but has not yet received any treatment.

reclaimed water — Water derived from wastewater and treated to a level appropriate for its intended application.

recycle — To return water for further use after some type of treatment.

refractory — A stable material difficult to convert or to remove entirely from wastewater.

reverse osmosis — An advanced method of wastewater treatment which relies on a semipermeable membrane to separate water from its impurities.

reuse — The utilisation of appropriately treated wastewater for some further beneficial purpose.

risk, actual — Probability that an individual will develop a particular disease over a specified period.

risk, potential — The chance that an infection or disease might occur which does not occur at present.

secondary effluent — The liquid portion of wastewater leaving secondary treatment.

secondary treatment — Generally, a level of treatment that removes 85 per cent of BOD and suspended solids, generally by biological or chemical treatment processes. Secondary effluent generally has BOD < 30 mg/L, SS < 30 mg/L but may rise to >100 due to algal solids in lagoon or pond systems.

sewage — See wastewater.

sodium absorption ratio — An expression of the relative activity of sodium ions in exchange reactions with soil, indicating the sodium or alkali hazard to the soil. It is calculated from the expression $SAR = Na^{+}/[1/2(Ca^{2+} + Mg^{2+})]^{½}$. Here concentrations are in meq/l.

spray irrigation — Water is applied to the plants and soil by spraying, usually from pipes with fixed or moving spray nozzles.

SS — Suspended solids.

standard — An objective that is recognised in enforceable environmental control laws of a level of government.

tertiary treatment — Includes treatment processes beyond secondary or biological processes which further improve effluent quality. Tertiary treatment processes include detention in lagoons, conventional filtration via sand, dual media or membrane filters which may include coagulant dosing and land based or wetland processes.

thermotolerant coliforms Also known as faecal coliforms. A subset of coliforms found in the intestinal tract of humans and other warm blooded animals which can ferment lactose at 44° to 44.5°C to produce acid and gas. Consist chiefly of *E. coli* They are used as indicators of faecal pollution.

total coliforms Coliform organisms are used as indicators of faecal contamination of water. They are Gram-negative non-sporing rod-shaped bacteria capable of aerobic and facultatively anaerobic growth in the presence of bile salts and ferment lactose producing acid and gas within 48 hours at 35 - 37°C.

trematode Flatworms of the class Trematoda, including parasitic worms called flukes. Trematodes of importance medically have intermediate stages in snails, e.g. *Schistosoma.*

trickle irrigation A method of directly applying water at low rates of flow and pressure to soil around the plant roots.

turbidity A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light; any suspended solids imparting a visible haze or cloudiness to water, which can be removed by filtration; an analytical quantity usually reported in nephelometric turbidity units (NTU) determined by measurements of light scattering.

uncontrolled access Public access to sites so that direct physical contact with reclaimed water is possible.

waste stabilisation ponds A type of oxidation pond in which organic matter is biologically oxidised by natural or artificially accelerated transfer of oxygen to the water from air.

wastewater The used water of a community or industry, containing dissolved and suspended matter.