
GUIDELINES FOR ENVIRONMENTAL MANAGEMENT

DISINFECTION OF TREATED WASTEWATER

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DISINFECTION OF TREATED WASTEWATER

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FOREWORD

EPA Victoria is continually looking for improved ways to protect the environment, for the benefit of present and future generations of Victorians. Reclaimed water (that is, appropriately treated wastewater) is increasingly regarded as a valuable resource that can be utilised by agricultural, industrial and municipal sectors - rather than as a waste requiring disposal. While it should be viewed as a resource, reclaimed water still needs to be used in a safe and sustainable manner that is consistent with Victorian and national requirements.

With the above in mind, EPA Victoria undertook a review of the *Guidelines for Wastewater Reuse* (EPA Victoria, 1996, Publication 464). This took into account advances in technology and scientific knowledge, community expectations, stakeholder feedback on the 1996 guidelines, and the development of the national framework - the National Water Quality Management Strategy (NWQMS).

The review process has resulted in the release of two guidelines. The first guideline is the now retitled *Guideline for Environmental Management: Use of Reclaimed Water*, which largely adopts the approach described in the NWQMS *Guidelines for Sewerage Systems – Reclaimed Water* (ANZECC 2000). The second of the two guidelines (this publication) is a companion document that focuses on wastewater disinfection processes for both reuse and discharge to surface waters.

The two guidelines provide a framework for best practice management of wastewater and the exemption of reuse schemes from EPA Victoria's works approval and licensing provisions. The guidelines focus on desired performance objectives and outcomes through appropriate management practices, allowing scope for innovation. Suppliers and users of reclaimed water are able to consider and implement alternative measures to those suggested, provided they achieve an equivalent, or better, site-specific solution. At the same time, those seeking greater direction or certainty can simply apply the suggested measures.

In developing Guidelines for Environmental Management (GEM), EPA Victoria's underlying philosophy is to provide a forward-looking approach rather than simply reflecting current trends. By focusing on the elements that represent best practice and providing a systematic approach to achieving them, the GEM encourages suppliers and users of reclaimed water to strive for continued improvements in environmental



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GLOSSARY OF TERMS

Term	Definition
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ANZECC	Australian and New Zealand Environment and Conservation Council
BOD	Biochemical Oxygen Demand - a measure of the amount of oxygen used in the biochemical oxidation of organic matter. The BOD test is typically conducted in a period of 5 days under specified conditions and may then also be referenced as BOD ₅ .
Chlorination	The application of chlorine or chlorine compounds to water or wastewater, usually for the purpose of pathogen reduction. In some circumstances, chlorination may also provide chemical oxidation and odour control.
Coagulation	The addition of a chemical to a colloidal dispersion resulting in particle destabilisation by a reduction of the forces tending to keep the particles apart.
Disinfection	A process that destroys inactivates or removes micro-organisms.
<i>E.coli</i>	<i>Escherichia coli</i> . A bacterium found in the gut of warm-blooded animals that indicates faecal contamination.
Filter	A device or structure for removing solid or colloidal material from water, wastewater or other liquids by physically trapping the particles and removing them from the liquid.
Flocculation	The formation of settleable particles from destabilised colloidal-sized particles (refer coagulation).
GEM	Guideline for Environmental Management. Publication released by EPA Victoria to provide a best practice framework for managing environmental obligations.
Membrane filtration	Wastewater is passed through porous membranes, with differentiation between classes of membranes typically on the basis of the maximum molecular weight or size of compound capable of passing through the membranes. Membrane techniques such as microfiltration typically have pores from 50 to 10,000 nm, ultrafiltration typically involves pores from 1 to 100 nm, while nanofiltration and reverse osmosis typically have filtration equivalent to pores of 0.1 to 1 nm.
90th percentile	When expressed as a limit, ninety percent of the samples taken over a specified period must not exceed the prescribed value –that is, the 90 th percentile of the available data's statistical distribution.
NHMRC	National Health and Medical Research Council
NWQMS	National Water Quality Management Strategy
NTU	Nephelometric Turbidity Unit – unit of measure of the turbidity of water due to suspended, colloidal and particulate matter.
Pathogens	Organisms capable of causing disease. In untreated wastewater, the key potential pathogens include bacteria, viruses, protozoans and helminths.
Primary treatment	Wastewater treatment involving sedimentation (sometimes preceded by screening and grit removal) to remove gross and settleable solids. The remaining settled solids, referred to as sludge, are removed and treated separately.

Reclaimed water	Water that has been derived from sewerage systems or industry processes and treated to a standard that is appropriate for its intended use.
Residual	A chemical used or produced during the disinfection process , which is present at the completion of that process.
Reuse	The utilisation of appropriately treated reclaimed water for some further beneficial purpose.
Secondary treatment	Generally, a level of treatment that removes 85 percent of BOD and suspended solids via biological or chemical treatment processes. Secondary treated wastewater usually has a BOD of <20 mg/L and suspended solids of <30 mg/L but this may increase to >100 mg/L due to algal solids in lagoon systems.
SEPP	State Environment Protection Policy. These policies are adopted by Government, and gazetted pursuant to the <i>Environment Protection Act 1970</i> . SEPPs describe environmental objectives for defined environmental segments (for example, water and land). These objectives must not be exceeded through wastewater reuse or discharge to surface waters.
SS	Suspended Solids
Storage lagoon	A lagoon used to store treated wastewater prior to application, either to maintain adequate supplies, or to meet the SEPP (<i>Waters of Victoria</i>) requirement for on-site retention of all wastes up to a 90 th percentile wet year.
Tertiary treatment	The treatment of wastewater beyond the secondary biological stage. This normally implies the removal of a high percentage of suspended solids and/or nutrients, followed by disinfection. It may include processes such as filtration, coagulation and flocculation.
Thermotolerant coliforms (also known as faecal coliforms)	A subset of coliforms found in the intestinal tract of humans and other warm-blooded animals. They can produce acid and gas from lactose at 44.0-44.5°C; hence the test for them is more specific than for total coliforms and selects a narrower range of organisms. <i>E.coli</i> are typically the major proportion of thermotolerant coliforms.
Treatment lagoon	Any large pond or holding used to contain wastewater while treatment processes including sedimentation and biological oxidation occur. Stabilisation and maturation lagoons are examples of treatment lagoons.

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1. INTRODUCTION

These guidelines provide a framework of best practices for the disinfection of treated wastewater destined either for reuse or disposal to surface waters. They will also assist water businesses and private owners of package sewage treatment plants to meet their obligations for environmental protection as stated in the SEPP (*Waters of Victoria*).

The ultimate goal of wastewater treatment and disinfection is to produce an effluent of such quality (dependent upon final use) that minimal additional controls are needed to manage any human health, agricultural or environmental risks.

For wastewater reuse, the need for disinfection will depend on its intended uses. When reuse involves high-level risks of exposure for humans or livestock, that water will require disinfection processes to achieve the treatment levels set in the *Guidelines for Environmental Management: Use of Reclaimed Water* (EPA Victoria, 2002, Publication 464.1). Uses that involve a low risk of direct exposure will generally not require effluent to undergo a specific disinfection process.

Discharges of effluent to surface waters will generally need disinfection. This reduces potentially harmful micro-organisms in wastewater to a level consistent with achieving the water quality objectives set in the SEPP (*Waters of Victoria*), for the protection of human health.

1.1 Objectives

The purpose of these guidelines is to set environmental performance objectives for the disinfection of treated wastewater and suggest best practice measures to achieve these objectives.

The guidelines:

- define what constitutes best practice disinfection;
- set environmental performance objectives for the disinfection of treated wastewater; and
- suggest best practice measures to meet the performance objectives.

The guidelines target wastewater from sewage treatment plants (nominally greater than 5,000 litres per day), both public and privately owned. They are relevant to water businesses, private operators, users of treated wastewater and government agencies responsible for the protection of the environment and public health.

1.2 What Are Guidelines For Environmental Management?

The GEM series outlines key environmental objectives relevant to particular industries or activities, and provides suggested measures to achieve these objectives.

The *GEM: Disinfection of Treated Wastewater* provides the framework for best practices in the disinfection of treated wastewater.

The detail of disinfection methodologies largely reflects site-specific issues such as effluent quality, volumes and the management approach (reuse

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versus discharge to surface waters). Therefore, this guideline only describes a framework for disinfection, not prescriptive solutions for individual schemes.

Operators are encouraged to consider alternative ways to meet objectives and to apply site-specific measures equivalent to, or better than, the guidelines.

The GEMs are not driven by regulatory compliance, but by the recognition that this approach is synonymous with best practice business management and reduced environmental impact.

2. STATUTORY REQUIREMENTS

2.1 Legislation

Acts

Acts of particular significance to wastewater management and appropriate levels of disinfection include:

- *Environment Protection Act 1970*;
- *Health Act 1958*;
- *Food Act 1984*; and
- *Australian New Zealand Food Authority (ANZFA) Act 1991*.

Under the *Environment Protection Act 1970*, discharges to the environment must be managed so they do not adversely affect the receiving environment (that is, land, surface water or groundwater). This Act also includes provisions for EPA Victoria works approvals and licensing to ensure the appropriate control of discharges with significant potential to harm the environment.

The *Health Act 1958* makes provisions for the prevention and abatement of conditions and activities that are, or may be, offensive or dangerous to public health.

The *Food Act 1984* states that food is considered "adulterated" if it does not meet prescribed standards. Victoria complies with these national quality standards by enforcing the ANZFA *Food Standards Code*.

2.2 Policies

The SEPP (*Waters of Victoria*) applies to all surface waters within Victoria. It identifies beneficial uses that reflect the different surface waters across Victoria, and establishes ambient water quality objectives and wastewater discharge limits to protect these waters.

The SEPP (*Waters of Victoria*) lists water-based recreational activities as a beneficial use, and so the protection of people undertaking these activities needs to be a priority. This is particularly relevant to wastewater management because untreated wastewater can contain a range of pathogenic micro-organisms that pose potential health risks these people. As such, wastewater will generally require disinfection before discharge to surface waters. Effective disinfection needs to reduce potentially harmful micro-organisms in the wastewater to the ambient water quality objectives set in the SEPP (*Waters of Victoria*) for the protection of public health. Other beneficial uses listed in the SEPP include: maintenance of aquatic ecosystems; agricultural water supply; production of molluscs for human consumption; and industrial water use.

While an important step in the treatment process, wastewater disinfection can also result in the formation of by-products that may adversely impact upon the environment. To prevent this, SEPP (*Waters of Victoria*) states that: 'Waste disinfection methods which do not increase discharge toxicity ... shall be employed where practicable ... use of chlorine as a wastewater disinfectant shall be avoided where there is a practical alternative.'

Regulations

The *Environment Protection (Scheduled Premises and Exemptions) Regulations 1996* describe premises that are scheduled, and are thus required to comply with the licensing and works approval provisions of the *Environment Protection Act 1970*. The discharge of more than 5,000 litres per day of sewage from premises to surface waters or land is a scheduled activity and requires EPA Victoria works approval and licensing. This statutory process ensures that activities achieve the SEPP objectives.

Specific activities that are exempt from the licensing provisions and works approval are also listed in the regulations. As detailed below, effluent reuse is an activity that can be subject to an exemption from works approval and licensing.

Relationship To Exemption Of Reuse Schemes From Works Approvals And Licensing

The *Environment Protection (Scheduled Premises and Exemptions) Regulations 1996* includes the key provision that EPA Victoria works approval and licensing is not required for:

‘An effluent reuse scheme or activity which meets discharge, deposit and operating specifications acceptable to the Authority.’

The *GEM: Use of Reclaimed Water* (EPA Victoria, 2002, Publication 464.1) defines the acceptable discharge, deposit and operating specifications for reuse schemes and therefore forms the basis for an exemption from EPA Victoria works approval and licensing requirements. The *GEM: Use of Reclaimed Water* cross references this guideline for information on disinfection processes and therefore, where disinfection is required, adherence to both

guidelines is necessary to qualify for an exemption. It is important to note that treatment of wastewater (including disinfection) for reuse is not an exempt activity under the *Environment Protection (Scheduled Premises and Exemptions) Regulations 1996*. Wastewater treatment systems that exceed 5000 litres per day require works approval and may need a discharge licence depending on whether treatment results in a discharge of waste to the environment.

Typically, EPA Victoria considers on-farm winter storages, transfer pipes and the reuse site (for example, farm), to be exempt from works approval and licensing, provided the guideline requirements are achieved. However, all upstream treatment processes such as mechanical plants, oxidation lagoons and disinfection are subject to works approval and licensing.

3. INTRODUCTION TO DISINFECTION PROCESSES

3.1 Wastewater Pathogens

Untreated and secondary treated effluent contains a range of pathogenic micro-organisms that pose a potential risk to the health of humans and livestock (see Table 1).

The World Health Organisation (WHO) compiled a risk ranking of pathogens, reflecting the potential concentrations in wastewater, their resistance to treatment and infectious doses:

High risk: Helminths (for example, intestinal nematodes – *Ascaris*, *Taenia*)

Lower risk: Bacteria (for example, those causing cholera, typhoid and shigellosis); Protozoa (for example, *Giardia*, *Cryptosporidium*)

Least risk: Viruses (for example, enteric viruses)

Protozoa and helminths, often collectively referred to as intestinal parasites, are generally found in lower numbers in wastewater compared to other pathogen groups. However, traditional disinfection methods such as chlorination are not particularly effective in reducing helminths and some protozoan numbers to acceptable risk levels. This reflects the resistance of these pathogens to treatment and the extremely low levels that are needed in wastewater due to their small infectious dose.

Bacteria are the most common microbial pathogens found in wastewater. They are often used as an indicator of pathogen contamination and as a surrogate indicator to assess the efficacy of treatment and disinfection methods. However, as bacteria are generally the most sensitive group to

disinfection and have high infective doses, they present a relatively low health risk.

Although enteric viruses generally have a higher resistance to disinfection methods than bacteria, authors such as the WHO have suggested that enteric viruses generally pose the lowest pathogen risk. Transmission of enteric viruses in the home gives early exposure, and immunity to the virus lasts for long periods compared with short to medium immunity for bacteria and little immunity for parasites.

However, this view is not shared by all regulatory agencies – US EPA controls on reclaimed water focus on the management of viral risks (US EPA, 1992).

3.2 Performance Objectives

The following environmental performance objectives have been created for the disinfection of treated wastewater. Disinfection should:

- reduce microbial pathogens to below the minimum criteria in the *GEM: Use of Reclaimed Water* (EPA Victoria 2002, Publication 464.1) and levels consistent with meeting the receiving water objectives in the SEPP (*Waters of Victoria*);
- not result in an increase in the discharge toxicity of the wastewater;
- be reliable and cost effective; and
- not result in incremental risks to human health or the environment due to the transport, storage, or handling of disinfection chemicals or by-products.

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3.3. Disinfection Methods

Disinfection of wastewater is achieved using a variety of methods in Victoria, including:

- chemical (for example, chlorination, ozonation);
- physical (for example, ultraviolet radiation, microfiltration); and
- biological (for example, detention lagoons).

Chemical

Chlorination

Chlorine is used to disinfect wastewater in either gaseous form (Cl_2), or as hypochlorite salts. All forms of chlorine react with water to produce hypochlorous acid (HOCl), which rapidly dissociates to form the hypochlorite ion according to the following reaction:

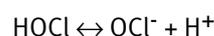


Table 1. Indicative levels of pathogens commonly found in secondary treated wastewater. Actual numbers will vary depending on the treatment process. (Sources: US EPA 1992; Rose 1995; Toze 1997)

Pathogen	Disease or Type of infection	Indicative levels of pathogens	Infectious dose
Bacteria	<i>Shigella</i> spp. <i>Salmonella</i> sp. <i>Escherichia coli</i> (enteropathogenic) <i>Campylobacter</i> spp. <i>Vibrio</i> spp. <i>Mycobacterium</i> spp.	Dysentery Typhoid and gastroenteritis Gastroenteritis Gastroenteritis Cholera Johne's disease (cattle, sheep, goats)	$10^4 - 10^6$ organisms/100mL $10^4 - 10^6$ $10^6 - 10^{10}$ $10^3 - 10^7$
Viruses	Enteroviruses: • Poliovirus • Echovirus • Coxsackievirus Hepatitis A Adenovirus Calicivirus: • Norwalk virus Rotavirus	Paralysis Gastroenteritis Meningitis Hepatitis Respiratory disease Gastroenteritis Gastroenteritis	$10^1 - 10^4$ viruses/L 1 - 10
Protozoa	<i>Giardia</i> spp. <i>Cryptosporidium</i> spp. <i>Entamoeba</i> spp.	Giardiasis Crypto-sporidiosis Amoebic dysentery	$10^1 - 10^4$ oocysts/L < 10
Helminths	<i>Ascaris</i> spp. <i>Ancylostoma</i> spp. <i>Trichuris</i> spp. <i>Strongiloides</i> spp. <i>Taenia</i> spp.	Roundworm Hookworm Whipworm Threadworm Tapeworm in humans (causes "Cysticercosis" infections in cattle (that is, "beef measles") & pigs)	$10^1 - 10^3$ eggs/L 1 - 10

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In addition to HOCl and the hypochlorite ion (OCl⁻), chlorine may also be found in the form, monochloramine (NH₂Cl) and dichloramine (NHCl₂).

The dominant form of chlorine depends upon the combination of parameters such as temperature, pH and ammonia concentrations. As pH increases, so does the proportion of hypochlorite ion relative to hypochlorous acid, while higher ammonia concentrations tends to increase monochloramine.

Knowledge of the dominant form of chlorine in a particular disinfection process is important. With the differing forms come varying oxidising strengths and thus biocidal efficiencies. The chlorine disinfection process occurs primarily through oxidation of cell walls leading to cell lysis (bacterial) or inactivation of functional sites on the cell surface. Hypochlorous acid (HOCl) is the most potent of the four main oxidising forms.

In addition to differences in oxidising strengths between forms of chlorine, the disinfection effectiveness varies across the range of micro-organisms. Protozoans, helminths and viruses are the most resistant, followed by bacterial pathogens, with each species varying in resistance.

Chlorine is very effective against enteric bacteria, such as *E.coli*, but less effective against other bacterial species (Queensland Department of Environment and Heritage, 1993). Therefore, the use of *E.coli* to estimate disinfection efficiency needs to consider the relative sensitivities of the different pathogen groups. Effective chlorine disinfection depends on the correct combination of pH, chlorine concentration and contact time as well as the levels of ammonia and suspended solids. The presence of

reducing agents will act to decrease chlorination efficiency.

One disadvantage with chlorine disinfection is that of free and combined chlorine residues being toxic to aquatic organisms. There is also potential for the formation of organo-chlorinated derivatives. These derivatives are of particular concern, as they tend to be relatively toxic, persistent and bioaccumulative.. However, in spite of the apparent ability to form such compounds, the operational results from major sewage treatment plants show that the actual levels of these compounds in the treated wastewater are very low (Arbanou & Miosecc, 1992; Asano, 1993).

It has been demonstrated that dechlorination techniques will remove all or part of the total combined chlorine residual left from chlorination. This is achieved using either chemical or natural processes (such as detention lagoons). However, dechlorination has no effect on the quantities of toxic chlorinated organic compounds present in the final discharge (Ernst & McDonald, 1986).

Ozonation

Disinfection by ozonation is achieved using the formation of free radicals as oxidising agents. Ozonation is more effective against viruses and bacteria than chlorination, yet problems with effective bactericidal action occur when conditions are not ideal.

The low solubility of ozone in water is the main factor that greatly reduces its disinfection capacity, and any ozone residual produced rapidly dissipates as a consequence of its reactive nature. The absence of a lasting residual may also be seen as a disadvantage as this may allow possible microbial

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re-growth and make it difficult to measure the efficiency of the disinfection process.

Physical

Ultraviolet radiation

The disinfection of treated wastewater via ultraviolet (UV) radiation is a physical process that principally involves passing a film of wastewater within close proximity of a UV source (lamp). The efficiency of UV disinfection depends on the physical and chemical water quality characteristics of the wastewater prior to disinfection. With a better quality of wastewater comes a more efficient UV disinfection process.

The advantage of the UV disinfection process is that it is rapid and does not add to the toxicity of the wastewater. There have been no reports of by-products produced from UV disinfection that adversely impact on the receiving environment.

UV disinfection does not result in a lasting residual in the wastewater. This is a disadvantage when wastewater must be piped or stored over significant distances and time (particularly relevant to reuse schemes) as re-growth of the microbial population is considered a risk.

Membrane filtration

Membrane technologies disinfect treated wastewater by physically filtering out micro-organisms. This disinfection process does not require the addition of reactive chemicals and as such, no toxic disinfection by-products are produced.

Key membrane technologies include:

- reverse osmosis;
- ultrafiltration;

- nanofiltration; and
- microfiltration.

Microfiltration is the most commercially viable technology for the disinfection of treated wastewater. The wastewater passes through membrane fibres, hollow cylinders permeated with millions of microscopic pores. These pores allow wastewater to flow through the same fibres that act as a physical barrier to particles and micro-organisms.

Microfiltration efficiently reduces particulates, bacteria, and a range of viruses, algae and protozoans. Protozoa are generally larger than 0.2 micron and are removed effectively by microfiltration, giving this method an advantage over other technologies. Viruses larger than 0.2 micron (which includes most enteric viruses) are also reduced effectively.

The main disadvantages associated with microfiltration include the potentially high capital costs, the resultant concentrated backwash with significant microbial contamination, and the handling and management of contaminated chemicals produced by periodic cleaning of the membranes.

Biological

Lagoons

The storage of secondary treated wastewater in pondage systems (nominally 30 days) allows natural disinfection to take place before discharging or re-using the treated wastewater. Natural disinfection can occur via sunlight and/or natural microbial die-off. Natural disinfection processes can be affected by a number of factors such as the:

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- turbidity of the wastewater, as it affects sunlight penetration;
- amount of suspended matter in the water, as viruses and bacteria may be shielded from the rays of the sun by being absorbed into surface pores; and
- ineffectiveness of sunlight in seawater compared with freshwater.

Temperature, pH, adsorption and sedimentation further influence the natural disinfection and inactivation processes occurring in wastewater stored in lagoons. The ability of ponds to remove or reduce the number of pathogens depends on such factors as the load of incoming solids and micro-organisms, temperature, sunlight and pond design related to detention time.

Re-infection of ponds by bird populations can also pose a problem for operators. Algal blooms in the ponds over summer will also reduce the efficiency of the natural disinfection process.

Systems using only detention do not typically result in a Class A effluent and are unsuitable as the sole means of pathogen reduction for high contact uses.

3.4. Current Practices

The majority of municipal wastewater plants in Victoria currently use detention lagoons for disinfection. Approximately 10 percent of plants use UV as the preferred method of disinfection. A smaller percentage of plants chlorinate; however, a number of these operations disinfect large volumes of wastewater. A small number of municipal plants do not disinfect their wastewater before discharging it to surface waters.

Of the smaller, privately owned wastewater package plants (of which there are more than 200 licensed by EPA Victoria), chlorination is the main form of disinfection, followed by detention lagoons. A smaller percentage of these plants disinfect wastewater using UV.

UV disinfection is, however, being increasingly used as an alternative to chlorination in most states, particularly for small to medium plants. Complexity and associated capital costs have tended to limit the use of ozone and microfiltration disinfection techniques in Victoria.

There is an increasing emphasis on both promoting ecological sustainability and concern over introducing potentially toxic substances to surface waters. Therefore, the design and approval of the disinfection process is now leaning toward technologies that destroy pathogens while balancing the effects of the disinfected wastewater on the receiving ecosystem. This has prompted renewed scrutiny of the practice of using chlorine as a disinfectant for wastewater treatment plant discharges.

4. PRETREATMENT AND DISINFECTION STANDARDS

There are two key control steps for producing an effluent, that depending on the enduses, will be of sufficient quality that it poses no unacceptable risk to the environment, livestock or human health.

The first control step is the adequate pre-treatment of effluent to ensure that selected disinfection processes work efficiently. Table 2 provides indicative wastewater quality criteria required to ensure effective pathogen reduction for each disinfection method. These values may vary depending on other wastewater qualities and as such are only a guide.

The second control step is to ensure that the actual disinfection produces an effluent meeting the required quality standards. The primary indicator used to assess the efficacy of the disinfection process is the concentration of *E.coli* bacteria.

It is important that the use of *E.coli* is not taken out of context, as it has been well documented that there can be poor correlations between *E.coli* levels and the concentrations of pathogenic organisms.

E.coli is used as an indicator of the treatment/disinfection efficiency. When coupled with other treatment process indicators (BOD for example), specific treatment methods, and direct verification of pathogen removal (for Class A reuse schemes) *the result is* an integrated measure of effluent quality.

Thermotolerant coliforms (of which *E.coli* are a major component) are also used as a treatment process indicator. However, *E.coli* is the EPA Victoria preferred indicator. Where thermotolerant coliforms are used, the *E.coli* criterion is applied directly as the thermotolerant coliform limit.

Part 1 of Table 3 outlines the receiving surface water quality objectives specified in the SEPP (*Waters of Victoria*) that must not be exceeded as a result of a wastewater discharge. Part 2 of the table specifies wastewater quality objectives and treatment requirements set to protect public, stock and environmental health from the reuse of treated wastewater as specified in the *GEM: Use of Reclaimed Water* (EPA Victoria, 2002, Publication 464.1).

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Table 2. Recommended wastewater quality (median) pre-disinfection (adapted from UWRAA, 1996)

Disinfection method	SS (mg/L)	BOD (mg/L)	Turbidity (NTU) ¹	Nitrate (mg/L)	Ammonia (mg/L) ²	pH
Chlorination	< 20	< 20	< 10	NA	See note 2	6.0 - 9.0
Ozone	< 10 - 15	< 20	< 5	maximised	< 1	6.0 - 9.0
UV³	< 10	< 20	< 5	maximised	NA	NA
Microfiltration	NA	NA	< 10	NA	NA	Neutral
Detention lagoons	NA	NA	NA	NA	NA	Neutral

Notes to Table 2

1. If a significant reduction in the number of pathogens is required (that is, less than ten *E.coli* organisms per 100 millilitres), the turbidity of the pre-disinfected wastewater should be less than two NTU (median) for any method.
2. Presence of ammonia with chlorine causes chloramination, which is a less effective disinfection method than chlorine; however, formation of toxic by-products is minimised. The required level of ammonia, therefore, depends on whether chloramination or chlorination is the disinfection process.
3. The transmission capacity of the wastewater is the most important parameter affecting the disinfection efficiency of UV and should be greater than six.

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Table 3. Receiving water and reclaimed water quality criteria for the protection of the environment, livestock and human health.

Beneficial uses or reclaimed water class	Bacteriological criteria <i>E.coli</i> org./100ml	Helminth and other pathogens
1. Receiving waters: discharges of treated wastewater should not cause bacteriological criteria to be exceeded in receiving waters		
SEPP (<i>Waters of Victoria</i>) Beneficial uses:		
• Shellfish harvesting areas recognised by EPA Victoria	< 14 org./100mL (geometric mean)	NS
• Where primary contact recreational activities occur in receiving surface waters	< 200 org./100mL (geometric mean)	NS
• Other uses; eg wading, boating	< 1000 org./100mL (geometric mean)	NS
2. Reclaimed water: Treated wastewater (that is, reclaimed water) quality should not exceed the criteria in <i>Environmental Guidelines for the Use of Reclaimed Water</i> (EPA Victoria, 2002, Publication 464.1).		
Class A (required where there is high risk of direct human contact with reclaimed water)	< 10 org./100mL (median)	< 1 enteric virus / 50 L ¹ < 1 viable helminth egg / L ¹ < 1 protozoa / 50 L
Class B ³ (required for irrigation of dairy pasture)	< 100 org./100mL (median)	Adoption of helminth reduction for cattle grazing ² .
Class C ³ (required where there is a low to insignificant risk of human contact with reclaimed water) or livestock access	< 1000 org./100mL (median)	Adoption of helminth reduction for cattle grazing ²
Class D ³ (required where there is insignificant risk of human or livestock contact with reclaimed water)	< 10,000 org./100mL (median)	NS

Notes to Table 3

NS Not specified

1. *GEM: Use of Reclaimed Water* (EPA Victoria, 2002, Publication 464.1) provides more detailed guidance on the objectives for pathogen removal for Class A reclaimed water and the required monitoring programs.
2. Helminth reduction is either detention in a pondage system for ≥ 30 days, or by a DHRE (Chief Veterinary Officer) and EPA Victoria approved disinfection system (for example, sand filtration).
3. In addition to achieving reclaimed water grades, there will also be management controls that apply for specified uses for example, agricultural withholding periods. Refer to the *GEM: Use of Reclaimed Water*.

5. SELECTING THE DISINFECTION PROCESS

Some degree of disinfection will generally be required to meet the performance objectives outlined in Chapter 4. This chapter outlines the suggested best practice disinfection measures for scenarios involving discharges to surface waters (Section 5.1) and land based reuse (Section 5.2). However, the optimal disinfection process for a specific site will depend on a variety of issues including:

- the beneficial uses protected at the location, when discharging to surface waters;
- the uses of the effluent and associated risks, when reused on land;
- the existing treatment processes and effluent quality;
- the available land, effluent volumes and funding regime; and
- the extent to which risk minimisation and maximisation of future options is required (through disinfection beyond the minimum needed for planned uses).

If alternative measures to those specified in the following sections are proposed, the proponent should undertake a site-specific assessment to determine if these measures meet the performance objectives outlined in Chapter 4.

In some circumstances, disinfection may not be needed to achieve the required objectives. The efficacy of any approach not involving disinfection will need to be supported by a detailed site-specific

risk assessment, particularly addressing public health.

5.1 Disinfection For Wastewater Discharges To Surface Waters

All wastewater discharged to surface waters, including inland and coastal waters, should be treated to at least a secondary standard. This treatment level will generally ensure that the wastewater meets a pre-disinfection quality that allows a medium to high disinfection efficacy using any of the suggested disinfection methods. Where a higher disinfection efficacy is required for discharges to surface waters (for example, less than 14 organisms per 100 millilitres to protect aquaculture areas), tertiary treatment will be needed.

Table 4 outlines the suggested best practice measures for the disinfection of treated wastewater discharged to surface waters.

Microfiltration is generally considered the most effective disinfection method in terms of biocidal efficiency, for treated wastewater discharged to surface waters. EPA Victoria encourages the use of microfiltration, where the cost of the system is not prohibitive, as the most effective disinfection method irrespective of the microbiological quality required..

While microfiltration is the most effective method, the costs of implementation can be prohibitive. Therefore, UV disinfection is the suggested best practice when discharging treated wastewater to surface waters. This is due to the UV disinfection biocidal effectiveness, minimum impact on the environment and cost effectiveness relative to

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chlorination, ozonation and lagoons. However, UV disinfection may not provide adequate parasite removal of helminths for example, and therefore processes prior to UV disinfection may need to incorporate parasite removal.

UV disinfection will generally not be cost effective for significant discharges to marine surface waters. The current minimum wastewater quality requirements specified on EPA Victoria marine discharge licences for BOD/SS are 20/30 milligrams per litre. In contrast, optimal UV disinfection efficiency requires that the quality of wastewater should be less than 10 milligrams per litre of SS. The pre-treatment costs associated with reducing SS to less than 10 milligrams per litre for effective UV disinfection may not be cost effective for marine discharges.

Table 4 specifies that lagoon-based disinfection is an acceptable practice for discharges to general surface water areas (that is, those with no primary contact activities or aquaculture-based industry). However, a median of less than 1000 *E.coli* per 100 millilitres must be consistently achieved and an algal management plan must be implemented for lagoons subject to algal blooms.

Natural disinfection via detention lagoons alone will not be considered best practice where a microbiological quality of less than 100 *E.coli* per 100 millilitres is required for the protection of public health.

Ozonation is currently a less attractive alternative to chlorine than UV disinfection for small to medium discharges. This is because ozone is more expensive to produce, must be generated on-site and used immediately, and has associated high

operational and maintenance costs (partially due to inherent inefficiencies with current technology).

Chlorination alone is not considered best practice disinfection for wastewater discharged to surface waters. It has the potential to increase the toxicity of the discharge and form disinfection by-products that may adversely impact upon the natural ecosystems of the receiving environment.

However, if disinfection by UV or detention lagoons is impractical (due to cost, reliability or land requirements), chlorination will generally be considered an acceptable practice for the disinfection of wastewater discharged to surface waters. This is provided that the wastewater is dechlorinated in order to achieve a chlorine residual of less than 0.1 milligram per litre to reduce its potential toxicity.

Dechlorination in terms of these guidelines may be achieved via chemical or natural (for example, detention/storage) processes. As dechlorination does not remove chlorinated organic compounds produced during the chlorination process, toxicity monitoring may be required when chlorination/dechlorination is used.

5.2 Disinfection For Reclaimed Water Use

For reuse on land, the selection of suggested best practice measures for the disinfection of wastewater is different to those where effluent is discharged to surface waters.

The required level of pathogen reduction in reclaimed water use is determined by the nature of the reuse application and potential for human or stock exposure to this water. The suggested best

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practice measures for the treatment and disinfection of reclaimed water are outlined in Table 5.

Tertiary treatment is required to achieve the pre-disinfected wastewater quality needed for ensuring high disinfection efficacy (less than 10 *E.coli* per 100 millilitres). This level of treatment is required for reuse applications where there is a high risk of human exposure to reclaimed water (refer to the *GEM: Use of Reclaimed Water* (EPA Victoria, 2002, Publication 464.1). Suggested best practice disinfection measures for such high quality applications include microfiltration, UV or chlorination. Chlorination, in conjunction with UV, ozonation or microfiltration, is considered best practice where bacterial re-growth is a significant risk due to both the piping of treated wastewater over large distances and its storage for long periods.

For reuse applications where secondary treated wastewater with less than 100 *E.coli* per 100 millilitres is required to protect public and/or stock health, suggested best practice disinfection measures include UV, chlorination or ozonation. Disinfection via detention lagoons alone is not considered a best practice measure to reliably obtain a wastewater quality of less than 100 *E.coli* per 100 millilitres.

Detention lagoons are considered best practice for the disinfection of secondary treated wastewater when the required microbiological level is greater than 100 but less than 10,000 *E.coli* per 100 millilitres (use scenarios with low risk human exposure to treated wastewater). However, where detention lagoons subject to algal blooms are the sole method used for disinfection, an algal management plan should be developed to reduce

the incidence of poorly disinfected wastewater due to high SS and turbidity.

Where secondary treated wastewater is used to irrigate pasture or fodder grazed by cattle, appropriate helminth treatment measures must be employed to reduce helminth levels. Conventional primary and secondary treatment processes, including disinfection by chlorination, do not ensure the adequate removal of helminths and some protozoans. The suggested best practice treatment measures to reduce helminths to acceptable levels in reclaimed water include ensuring an overall period of 30 days detention in treatment lagoons and/or storage facilities, or by implementing a Chief Veterinary Officer and EPA Victoria approved method of filtration, such as sand filtration.

Alternative best practice measures to reduce the risk posed by helminths may be considered if it can be demonstrated to EPA Victoria and other relevant agencies that helminths will be reliably reduced to levels which will result in negligible risk to stock and human health.

5.3. Assessment Criteria For Disinfection Methods

The following performance criteria are used to determine the most appropriate disinfection method for reused or discharged wastewater:

- biocidal efficiency;
- practicality;
- reliability;
- cost effectiveness;
- environmental impact; and

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- occupational health and safety (OH&S) risks.

Table 6 compares disinfection methods using these criteria.

Biocidal efficiency and reliability

In terms of effectiveness and reliability, microfiltration is generally the preferred method of disinfection where there is a high risk of exposure to treated wastewater by humans and/or stock. This is due to its ability to reliably reduce numbers of all four pathogen groups to very low levels relative to other methods. However, the high cost associated with microfiltration reduces its practicability where there is a low risk of reclaimed water exposure to humans and/or stock.

Occupational health and safety risks

In terms of OH&S risks, chlorination of wastewater poses inherent risks due to the generation,

transportation, storage and handling of chemicals. However, regulations exist for the storage and handling of chlorine chemicals that have resulted in a satisfactory safety record for chlorine plants in Australia.

Ozonation poses OH&S risks to operators due to the toxicity of the gas used and the hazards associated with exposure to the high electrical voltages required for the generation of ozone. Use of UV poses the risk of exposure to UV radiation and potentially to mercury during the disposal of lamps. However, these risks are very small and continue to decrease as UV technology improves.

The handling and disposal of caustic chemicals required to clean microfiltration equipment and contaminated backwash can pose a minimal OH&S risk. Detention lagoons also have low OH&S risks associated with their use, the most significant being the transfer of pathogens to on-site workers.

Table 4. Disinfection methods for wastewater discharges to receiving water.

Receiving water criteria (<i>E.coli</i> /100mL)	Suggested best practice treatment	Suggested best practice disinfection	Acceptable disinfection following site-specific assessment ¹
< 14 (shellfish harvesting areas)	Tertiary treatment	UV, microfiltration or ozone ²	Chlorination/dechlorinat. ³
< 200 (primary contact)	Secondary treatment	UV, microfiltration or ozone ²	Chlorination/dechlorinat. ³
< 1000 (general requirements)	Secondary treatment	UV, ozone ² or detention lagoons ⁴ with algal management plan	Chlorination/dechlorinat. ³

Notes to Table 4

1. A site assessment needs to demonstrate the performance objectives are being achieved.
2. Microfiltration is generally the most effective disinfection method, however, unless less than 14 orgs per 100 millilitres is required, ozone and microfiltration may be relatively costly.
3. Dechlorination may be achieved by chemical methods or natural methods (for example, storage lagoon). Dechlorination may not be necessary if no increase in discharge toxicity can be demonstrated.
4. Where a discharge from detention lagoons to surface waters occurs, an algal management plan will generally be required if suspended solids exceeds an annual median of 30 milligrams per litre.

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Table 5. Suggested disinfection methods for reclaimed water use.

Reclaimed water use ¹	<i>E.coli</i> org./100mL (median)	Suggested best practice treatment train	Suggested best practice disinfection
Class A (Involves high risk of human contact)	< 10 org./100mL (median) (and verified pathogen removal)	Tertiary treatment + disinfection	UV, microfiltration, chlorination ² or ozonation (and helminth reduction ³)
Class B (Involves medium risk of human or specified livestock contact)	< 100 org./100mL (median)	Secondary treatment + disinfection	UV, chlorination ² or ozonation (and helminth reduction ³)
Class C (Involves low risk of human contact or livestock access)	< 1000 org./100mL (median)	Secondary treatment + disinfection	UV, chlorination ² , ozonation or detention lagoons ³ (and helminth reduction for cattle grazing)
Class D (Involves insignificant risk of human or livestock contact).	< 10,000 org./100mL (median)	Secondary treatment	Detention lagoons

Notes to Table 5

1. Details of additional indicators of treatment process performance, reclaimed water uses and management controls (for example, withholding periods) are listed in *GEM: Use of Reclaimed Water* (EPA Victoria, 2002, Publication 464.1).
2. Chlorination is the preferred method if a residual is required due to the risk of microbial re-growth.
3. Helminth reduction is either detention in a pondage system for greater than or equal to 30 days, or by a NRE and EPA Victoria approved disinfection system (for example, sand or membrane filtration).

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Table 6. Comparison of disinfection methods (Source: modified from US EPA, 1992).

Consideration	Chlorine	Ozone	UV	Micro-filtration	Detention Lagoons
Effectiveness against					
Bacteria	high	high	high	high	medium-high
Viruses	low to medium	high	high	medium to high ¹	high if detention >14 days
Parasites	low	high	not fully assessed	high	high if detention >30 days
Practicality					
Process control	well developed	developing	developing	developing	well developed
Complexity	simple to moderate	complex	simple to moderate	simple to moderate	simple
Maintenance and cleaning	low to moderate	moderate to intensive	intensive	intensive	low to moderate
Reliability					
	high	high	medium	medium	medium to high
Costs (dependent on size of the plant)					
Operation Capital, (small to medium plant)	medium ²	medium ²	medium ²	high	low
Capital, (medium to large plant)	medium	high	low to medium	high	low to medium (reflects land value)
	low to medium	high	medium to high	high	medium to high (reflects land value)
Adverse Effects					
Safety risks: transportation	yes	no	no	no	no
Safety risks: on-site	substantial	moderate	minimal	minimal (high noise)	minimal
Fish and macro-invertebrate toxicity	toxic ³	unlikely	no	no	potential toxicity from algae
Formation of toxic by-products	potential	unknown	unknown	none	potential toxic algal by-products
Disposal of cleaning products	no	no	yes	yes	no
High energy consumption	no	yes	yes	yes	no

Notes to Table 6

1. Depends if viruses are attached to particles, and on the integrity of the membrane film.
2. The ranking of the three methods varies with the size of the system design.
3. The toxic chlorine residual can be reduced by dechlorination.

Environmental impacts

When undertaking an assessment of the real cost of employing any given method of wastewater disinfection, it is necessary to consider both human and environmental risks, which may be tangible and/or intangible.

Literature clearly reports the potential adverse toxicological impacts of chlorine chemicals and by-products of chlorination on the aquatic environment (Queensland Department of Environment and Heritage, 1993). High total residual chlorine in discharges to water may lead to an acute response of aquatic organisms, ranging from avoidance to death. The threshold tolerance limit of some aquatic species to chlorine is 0.002 milligrams per litre in freshwater and 0.01 milligrams per litre in saline water (Department of Environment and Heritage Report QLD, 1991). Disinfection by-products also have the potential to bioaccumulate in the aquatic environment. Dechlorination eliminates the toxicity of the free or combined chlorine residual, but does not effectively reduce other disinfection by-products. In summary, the beneficial use of aquatic ecosystem protection may be compromised when chlorinated wastewater is discharged to receiving surface waters.

Chlorination should not pose a significant risk to the environment if the treated wastewater is beneficially reused rather than discharged to receiving surface waters. This is an acceptable disinfection method for wastewater reuse. It should also be noted that chlorination is considered best practice for reuse applications where a residual is required to prevent microbial re-growth and hence re-contamination of distribution and storage systems. However, there is

a limit of one milligram per litre of chlorine at the point of application of reclaimed water. This limit corresponds to the aesthetic threshold and will not usually cause adverse effects on plants. However, some sensitive crops may be damaged at chlorine levels below one milligram per litre and users should consider the sensitivity of any crops that may be irrigated with chlorine disinfected reclaimed water.

Although the direct use of chlorine for disinfection of reclaimed water should pose little environmental risk, the manufacture, storage and transportation of chlorine products still poses a risk to the environment.

The risk that ozone poses to aquatic organism health requires further research. It has been suggested that the strong oxidation potential of ozone may cause the formation of toxic by-products, but this is yet to be proven. Ozone gas, however, may adversely impact on surrounding vegetation due to its corrosive and toxic nature.

Microfiltration only poses a risk to the environment if there is a spill of cleaning agents or the contaminated backwash waste is disposed of incorrectly.

The potential environmental risks associated with UV are less compared to other methods, but may include photo-reactivation and mutation of the microbial population present in the discharge. There is presently no reuse option for spent UV lamps.

Control over biological disinfection methods, such as detention lagoons, is more difficult as they are natural systems. A significant environmental risk associated with lagoon-based disinfection, is the potential for the excessive growth of undesirable

organisms, such as blue-green algae. Blue-green algal blooms may pose a risk to stock and human health through the production of toxins and to the environment via an increase in SS and BOD levels.

In terms of potential environmental cost, it would appear UV, lagoons and microfiltration have the least potential to impact adversely upon the environment, followed by ozonation then chlorination. This ranking is based on the potential production of disinfection by-products and the potential toxicity of the discharge to the receiving environment.

Capital and operating costs (cost effectiveness)

In terms of capital and operating costs, detention lagoons appear to be the least expensive long-term disinfection option for small to medium sized plants, followed by chlorination and UV.

Microfiltration and ozonation are generally the most expensive disinfection options based on capital and operating costs. These generalisations in terms of cost will vary depending on the size of the plant.

6. ENVIRONMENTAL MANAGEMENT

A wastewater treatment plant operation must be well managed if it is to achieve consistently sound environmental performance. This is best done by implementation of an environmental management system (EMS).

An EMS can be part of a wider quality management system. The EMS and (if applicable) the quality management system may use the International or Australian/New Zealand Standards ISO14001 and ISO9001 respectively, as guides to good management systems.

The key elements of an EMS are outlined below.

Management commitment

It is essential that senior management demonstrates its commitment to an environmental policy and that it is communicated to all staff. The policy should contain clear objectives and must be evaluated and reviewed regularly.

Environmental review and improvement plan

A thorough review of the plant's environmental impacts should be carried out. A plan including specific objectives and targets to reduce impacts can then be prepared.

Mechanisms to implement improvements

The management system should address responsibilities, communication processes, document control and operational procedures.

A manager at the plant should have the skills, authority and accountability to deal with environmental issues.

Maintenance and monitoring

Systems should be established to regularly maintain operations, and to monitor and review environmental performance.

System reviews

The EMS should be regularly reviewed to verify performance and identify areas for improvement.

Commitment to continuous improvement

The principle of continuous improvement is an integral part of good environmental management.

The development and implementation of an EMS is an essential part of best practice. Larger authorities that operate a number of sites can develop an authority-wide EMS that applies to all plants.

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Additional guidance or technical addendums to this guideline will be available from the EPA Victoria website (www.epa.vic.gov.au).

EPA Victoria will be pleased to receive comments on these guidelines. Comments will, where appropriate, be incorporated in future editions. Comments on these guidelines should be sent to:

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