

Pool operators' handbook



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Disclaimer

The *Pool operators' handbook* is a guide to operating public swimming pools. This information is advisory and is not intended to replace or override legislation.

Pool operators must adhere to and consult all relevant acts, regulations, codes of practice, standards and guidelines. Every pool operator is responsible for keeping abreast of and following relevant legislation and regulations. These are described in the Introduction and listed in the Bibliography, but be aware that some may be under review at the time of printing.

Published by Environmental Health Unit
Rural and Regional Health and Aged Care Services Division
Victorian Government Department of Human Services
Melbourne Victoria Australia

February 2008

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ISBN 0 7311 62 88 9

Also published on www.health.vic.gov.au/environment/water/swimming.htm

Authorised by the Victorian Government, 50 Lonsdale Street, Melbourne.

Printed on sustainable paper by Sovereign Press, 6 Traminer Crt, Wendouree 3355.

Acknowledgements

The handbook was first published in 2000, following the generous contributions of Victorian aquatic industry experts through a committee chaired by the Victorian Aquatic Industry Council. The contributors were:

Geoff Bell James Nightingale	Leisure Management and Marketing
Joe Calello Greg Leayr	Roejen Services Pty Ltd
Nicky Crawshaw	Australian Physiotherapy Association
Kerry Crossley Darryn McKenzie	Aqua Science Consultants Pty Ltd
Laurence Duggan	MRW Australia Pty Ltd
Norman Farmer Warwick Waters	Royal Life Saving Society Australia—Victorian Branch (RLSSAV)
Derek Lightbody	Department of Human Services, Environmental Health Unit
Colin Long	Local Government Professional Association
Jenni Maclean	Victorian Aquatic Industry Council (VICSWIM)

The first edition drew extensively on the Pool Water Treatment Advisory Group's (PWTAG) 1995 publication, *Pool Water Guide*. Where appropriate, text was extracted from this publication and the Development Committee acknowledges permission granted by the PWTAG for this use.

This edition was the result of contributions from the following people as representatives of the Victorian aquatic industry:

Colin Long John Coppock	Roejen Services Pty Ltd
Darryn McKenzie	Smart Connection
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Alistair Thom	Royal Life Saving Society Australia—Victorian Branch (RLSSAV)
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Preface

What is a healthy swimming pool? Obviously, one free from disease causing organisms and bacteria, with clear sparkling water and well maintained surrounds. Well managed swimming pools are healthy environments, where the risk of infection or illness is low.

Swimming pools are deeply connected with Australian culture—our dreams of having a backyard pool, a poolside holiday, achieving personal fitness or being an Olympic champion. For many communities, the public pool is the place to meet friends and keep cool on hot summer days.

Holidaymakers often choose a particular caravan park or motel because it has a swimming pool or spa and they expect these facilities to be in pristine condition. The operations of tourism accommodation businesses are often judged by the way their pools are managed. Pool operation and pool management entrusts staff with important responsibilities:

- maintaining healthy water and an inviting environment
- maintaining the pool's structure
- ensuring plant and equipment works reliably and efficiently.

This is a revised edition of the original *Pool operators' handbook*, first published in 2000 as a joint project of the Department of Human Services and the Victorian Aquatic Industry Council. A diverse committee of professionals with pool operations, pool management, public health, pool user and pool service backgrounds collaborated on the original Handbook. I believe it has served the industry very well, but it is time to update the publication and reflect changes to acts, regulations and codes of practice. You will also find new information on pool hygiene.

I hope that this revised edition provides clear guidance on water treatment and associated pool management issues for operators, owners, proprietors, body corporate managers, local government authorities and industry service providers.

Finally, I thank the contributing authors and their respective organisations for creating this valuable resource.



Dr John Carnie
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Introduction



Aims and objectives

Overview

The Handbook can be downloaded from <http://www.health.vic.gov.au/environment/water/swimming.htm>. It is recommended that you visit this site regularly for current information.

A clear, safe, sparkling swimming pool is the right of every user. It should also be the objective of every manager. In practice, this is sometimes difficult to achieve. Changes to the water's physical, chemical and microbiological conditions occur constantly in a busy pool—some in seconds; others in hours or days. Only a trained pool operator can identify and manage these changes.

This Handbook recognises the unique needs of Victorian pool operators and has considered the types of equipment and treatment used, the local regulatory environment and the experience and expertise of Aquatics and Recreation Victoria. It was prepared in association with a committee of industry professionals with backgrounds in pool management, water treatment, pool maintenance and service, pool user groups and public health.

This Handbook offers practical advice on pool operation and water treatment issues, encouraging pool operators to:

- follow safe working procedures
- maintain plant and equipment to achieve the desired service life
- achieve regulatory compliance
- provide the best swimming or bathing experience possible for the pool user.

Who should use this Handbook?

This Handbook is intended to provide advice and guidance on pool operation and water treatment for a range of managers and staff. According to the Health (Infectious Diseases) Regulations 2001, the proprietor is “the person who owns, manages or controls the spa pool or swimming pool.” These include:

- pool operators
- pool owners
- pool managers
- committees of management
- pool designers and consultants (including architects, builders and engineers)
- pool service companies and pool shops
- contract managers
- environmental health officers
- industry bodies.

What types of pools are covered in this Handbook?

This Handbook is intended for use at all pools where the public are admitted—as either a primary or additional service.

Much of this Handbook is based on the workings of a medium-sized community pool. However, the principles and practices of monitoring and control apply equally to all pools. The only difference may be that the size of the plant is scaled according to the size of the pool and treatment needs.

Pool locations

The following examples are situations where the information in this Handbook should be applied:

- apartments
- backpackers' hostels
- body corporates
- caravan and camping parks
- community and municipal pools
- exhibition pools
- gymnasiums, health and fitness studios
- hospitals and hydrotherapy centres
- prisons
- private clubs
- resorts, hotels and motels
- retirement villages
- schools and universities
- sports and leisure centres
- swim schools
- workplaces.

This is not an exhaustive list—if your specific situation does not appear above, contact the Department of Human Services for clarification on whether it is deemed a ‘public swimming pool’.

This Handbook is not aimed at domestic backyard pools of single dwelling properties used by the occupying family. Australian/New Zealand Standard 3633 should be referred to for the maintenance of a private swimming pool.

Staff and responsibilities

Overview

There are many factors critical to pool water quality and these are described in more detail later. They fall into three groups: human contamination, environment and design, construction and operation.

Human contamination

Skin, throat and faecal bacteria, body oils, cosmetics, ammonia and nitrogenous matter from sweat, urine, dirt, food, saliva and open infections.

Environment

Physical and chemical composition of pool water, algae and fungi, gases formed from chemical reactions, air and water quality and pollution, humidity, sunlight, evaporation.

Design, construction and operation

Pool bathing load, turnover, dilution, hydraulics, construction materials, chemical conditioning, disinfectants, dosing control, flocculants, filtration, testing and interpretation.

Given these factors—any of which can affect bathing conditions and become a hazard to health—a pool or spa requires proactive water quality management.

Management structure

Staff needs vary with pool size

The actual management structure will vary according to the type of facility. For example, a small hydrotherapy, community or hotel pool will require a small number of multi-skilled staff. A large community swimming pool complex will require a team of specialised staff.

All staff require training

Whatever its size, maintaining the pool requires that all staff be trained to understand and interpret pool operations and water conditions. Personnel should be trained in plant operation and water treatment measures required to maintain water quality. Where possible, a manager or other person responsible for water quality should be professionally qualified.

As the size and complexity of the pool increases, specialist staff are required. In a large multi-facility site, the services of qualified staff for day-to-day plant operations are indispensable. Their actions should be guided by documented plant operation manuals and maintenance inspection schedules.

Peripheral staff are also important

Understanding the pool water treatment process should not stop with the appointment of management staff. The actions of lifeguards and supervisors also have an effect on pool water quality. Relevant staff should have an appropriate understanding of basic water chemistry and the testing, water treatment, plant operation and the general procedures required to maintain good quality water.

As well as supervision, lifeguards may be required to conduct accurate water tests, provide a hygienic pool area, ensure pre-swim hygiene and respond to a soiling incident. The supervisor should be sufficiently familiar with water quality to be able to correct a condition that could lead to water quality deterioration. If the pool water begins to lose clarity or fall below the relevant standards set out in the Health (Infectious Diseases) Regulations 2001, the on-site supervisor must be able to decide if bathing should cease.

Management responsibility

Managers responsible for large, multi-purpose facilities may delegate day-to-day pool operation to team members with appropriate skills. Nevertheless, the manager still carries the ultimate responsibility. Whether or not the managers have hands-on skills, they must have a sound understanding of pool operations and be able to spot problems and institute remedies. For instance, a swimming pool with poorly maintained water is a perfect breeding ground for disease. Even a well maintained pool can provide a vehicle of transmission to patrons. Also, careless management of flocculants, filtration, disinfection and chemical balances can cause turbidity (cloudiness) that obscures swimmers' and lifeguards' vision of the pool floor, even in shallow water. See the chapter 'Health and hygiene'.

Operating the pool environment

Cost pressures

With increasing demands on public and private expenditure, competitive tendering of public services and greater awareness of water and energy conservation issues, there is pressure to find more cost-effective ways to operate swimming pools. Water, energy, water treatment and waste water disposal costs are very real concerns for managers; but where the consequences of alterations and adaptations to limit these costs are not fully understood, disaster can follow.

Poor training and techniques can increase costs

In terms of capital expenditure, energy, maintenance and day-to-day operation, a swimming pool is an expensive item. Managers and staff should be trained to obtain maximum life from their facilities and to operate them cost-effectively.

Lack of training and knowledge about energy conservation and water treatment systems can actually *increase* the cost of operations dramatically. Poor use of chemicals and methods may mean that major items of plant, equipment and buildings require early replacement. This can even lead to the closure of the facility.

Poor maintenance and operation can often be attributed to a lack of professional expertise or knowledge (or possibly resources). Either way, it represents a failure of management, and may require the owners of pools, local authorities, schools or private operators to spend large amounts of money on

pool refurbishment, sometimes within ten years of operation. This may include new filters, plumbing, pumps, tiling, grouting, calorifiers, steelwork in the pool hall, heating and ventilation plant, lighting and electrical work.

The pool operator

Responsibilities

A pool operator should be appointed at each facility. This person should take responsibility for the overall operation pool plant and equipment and ensure that appropriate operational and maintenance activities are carried out. The pool operator must have a comprehensive knowledge of relevant statutes, regulations, codes and other standards.

In pools that are open for long hours each week, responsibility for the daily operation of the plant may be shared. The pool operator should ensure that those left in charge have a working knowledge of the Regulations and can ensure that the treatment plant continues to provide pool water that meets these requirements. They should also be able to identify problems and know how to obtain corrective advice. Additional training may be required, to ensure adequate understanding of the statutory requirements.

Pool managers and owners should ensure that appropriate staff involved in water quality and plant operation all have relevant training and are competent to carry out the required responsibilities.

Acts, regulations, codes of practice and guidelines

Overview

Information in this Handbook is advisory, not mandatory. In the future, however, pool operators may be required by law to adhere to 'all relevant guidelines and standards'. In this case, the Handbook would qualify as a 'relevant guideline'. Failure to meet reasonable standards in providing a safe public environment already carries heavy penalties. Therefore, it is sound practice to closely follow the guidelines in this Handbook.

Much of this guidance is intended to assist compliance with the requirements of the Health (Infectious Diseases) Regulations 2001, the *Occupational Health and Safety Act 2004* (including the Occupational Health and Safety (Plant) Regulations 1995), and the *Dangerous Goods Act 1985*. In the event of an accident, the extent to which pool operators have adhered to accepted guidelines would determine their level of vulnerability to legal action for negligence/public liability.

All legislation relating to using and operating a public swimming or spa pool must be followed. These guidelines do not replace the requirements of the legislation.

Pool operators are advised to consult all appropriate acts, regulations, codes of practice, standards and guidelines, as well as industry publications. Many of these are listed in the Bibliography, but operators should be aware that some may be under review at the time of printing. It is the pool operator's responsibility to keep abreast of changes to legislation and regulations.

Relevant acts, regulations and codes of practice

Please note that some of these statutes and regulations are under review. They may in fact have their names or titles changed. It is the responsibility of the pool manager/owner to keep up to date with:

- Health (Infectious Diseases) Regulations 2001
- *Occupational Health and Safety Act 2004*
- Occupational Health and Safety Regulations 2007
- *Dangerous Goods Act 1985*
- Dangerous Goods (Storage and Handling) Regulations 2000
- Chemical Notifiers Self Assessment Tool
- Australian Standards
- codes of practice
- compliance codes.

These are discussed in detail later in this chapter.

Safe work practices

Apart from adhering to relevant acts and regulations, employers also need to establish their own safety policies and written safe work practices. Develop these in consultation with employees and include an assessment of all operational hazards and the precautions taken to control these risks.

Hazards common to public pool operations include:

- chemicals used in disinfection causing irritated skin or eyes; greater flammability of materials because disinfectants are strong oxidising agents; leaks of toxic gases; explosions¹
- murky water harbouring disease-causing microbiological contaminants and obscuring pool users in difficulty
- miscellaneous risks to employees, including work in confined spaces and use of electrical equipment.

Training employees

Adequate training on safety measures and hazards should be provided to all employees, with records kept of content and attendance at courses or in-services:

- Training should be specific to the particular pool and plant, its associated hazards and substances used. Manufacturers' instructions should be readily available (for example, affixed to the plant itself).
- Provide for enough employees to ensure that plant need never be operated by untrained staff.
- Train employees in the use, care and maintenance of personal protective equipment (PPE).
- Require that employees demonstrate that they can operate and maintain the plant safely.

¹ The most serious risk is uncontrolled escape of chlorine gas, following incorrect fitting of chlorine gas lines or the inadvertent mixing of chlorine-based disinfectant with acid.

Health (Infectious Diseases) Regulations 2001

Sets out parameters within which public pools and spas must be maintained, to ensure safe water conditions for pool users. This includes chemical and microbiological levels, as well as testing and recording requirements. The Regulations also prescribe minimum levels of water clarity.

Pool managers should ensure that all staff involved in water quality and plant operation are familiar with and have access to current health regulations. A copy should be kept on-site.

Figure 1 Location of safety showers and eye wash facilities



Safety Showers and eyewash facilities should be located immediately adjacent to the hazardous area, but not within the hazard.

Occupational Health and Safety Act 2004

The Act's objectives are to:

- Secure the health, safety and welfare of employees and other persons at work.
- Eliminate at the source any risks to the health, safety or welfare of employees and other persons at work.
- Ensure that public health and safety is not placed at risk by the conduct of employers and self-employed persons.
- Involve employees, employers and their representative organisations in forming and implementing health, safety and welfare standards.

The pool manager should have the authority to ensure that the premises are safe and that all plant and substances are operated, stored and used without risks to staff or pool users. Identifying hazards and taking precautions to control risks will help managers to reduce their liability. Training, certification and record keeping are fundamental to providing a safe, healthy environment—they are the manager's key to safeguarding legal requirements and producing a successful operation.

It is also important for employers to be aware of the Occupational Health and Safety (Plant) Regulations 1995.

There are specific requirements outlined in the *Occupational Health and Safety Act 2004* for particular roles in aquatic facilities and plants.

Obligations and duties of employers

The *Occupational Health and Safety Act 2004* sets out a number of specific duties for employers. These include providing:

- safe plant and systems of work (for example, regulating the pace and frequency of work)
- safe systems of work in connection with the plant and substances (for example, toxic chemicals)
- a safe working environment (for example, by controlling noise levels)
- adequate staff welfare facilities (for example, washrooms, lockers, dining areas)
- adequate information on hazards, as well as instruction, training and supervision to employees, to enable them to work safely.

Proprietors, including pool managers, should ensure that all staff, including those involved in water quality and plant operation, have an appropriate knowledge of the requirements of the Occupational Health and Safety Act 2004.

Obligations and duties of employees

Employees are required to:

- take reasonable care of their personal health and safety
- take reasonable care of the health and safety of anyone else who may be affected by their acts or omissions in the workplace
- cooperate with any action taken by the employer to comply with any requirements imposed by or under the Act.

Dangerous Goods Act 1985

The *Dangerous Goods Act 1985*, and in particular the Dangerous Goods (Storage and Handling) Regulations 2000, apply to employers whose business involves substances hazardous to health.

Dangerous goods and hazardous substances are classified according to different criteria. Dangerous goods are classified on the basis of immediate physical or chemical effects—such as fire, explosion, corrosion and poisoning—on property, the environment or people. Many chemicals are both hazardous substances and dangerous goods, and in these cases, both sets of laws apply. Pool operators should therefore specifically consider bacteria and viruses, other pollutants and disinfection by-products, when planning to store and use dangerous goods. This includes many disinfectants and other chemicals used in and around a pool.

Dangerous goods include microorganisms, by-products and any substances creating the sort of hazard that might come from a classified chemical. Pool operators should specifically consider bacteria and viruses, other pollutants and disinfection by-products when deciding how best to store and use dangerous goods. This includes many disinfectants and other chemicals used in and around a pool.

Employers and employees should have easy access to copies of the relevant legislation on-site, as well as Material Safety Data Sheets (MSDS). Conduct a formal assessment of all dangerous goods held, then assess health risks to employees and anybody using the premises. This must be regularly reviewed and updated whenever circumstances change—for example, a change in the type of disinfectant used, or its application method.

Pool and contract managers should ensure that all staff, including those involved in water quality and plant operation, have an appropriate knowledge of the requirements of the *Dangerous Goods Act 1985* and the Dangerous Goods (Storage and Handling) Regulations 2000.

Dangerous Goods (Storage and Handling) Regulations 2000

The Dangerous Goods (Storage and Handling) Regulations and the Hazchem legislation made under the *Occupational Health and Safety Act 2004* have certain signage requirements. These types of acts and regulations are under constant review and may have changed since this Handbook was printed.

The purpose of the placarding part of the Regulations (Hazchem) is to ensure that emergency services are prepared and equipped to combat fires or spillages involving dangerous goods. The Regulations require that notices are displayed at all workplaces where the quantities of various classes of dangerous goods kept exceed a prescribed aggregate amount.

Managers should ensure that an assessment of their signage has been conducted, so that they are confident it meets current requirements. This will depend on the quantity and type of chemicals stored on the site.

Notices required

Entrance Notice

If the prescribed aggregate quantity of ANY one class of dangerous goods at a workplace is exceeded, then the workplace must be provided with an outer warning notice (HAZCHEM) at every road and rail entrance to the workplace.

There are a number of exceptions:

1. In the case of a farm, or primary or secondary school, the notice is required only at the main road entrance.
2. If the only dangerous goods which exceed the prescribed aggregate quantity is Liquefied Petroleum Gas (LP Gas), *in cylinders* and kept outside a building and connected to consuming appliances within the building.
3. If the only dangerous goods which exceed the prescribed aggregate quantities are substances stored in or within the vicinity of a dwelling at the workplace and are for use in or on the dwelling.

Placarding

If a workplace requires notices under the above definition, then a Composite Warning Notice is required for all storage of dangerous goods:

1. In the case of *packaged* dangerous goods, a Hazchem notice (Figure 2) must be displayed:
 - a) at the entrance to any building or room in which dangerous goods are kept
 - b) adjacent to any storage of dangerous goods kept in the open.

Figure 2 Hazchem signage for packaged dangerous goods



Class labels should be displayed at the entrance of any building or room in which dangerous goods are kept in the open.

2. In the case of *bulk* dangerous goods (storage tank or bulk container), a notice (Figure 3) must be displayed on or adjacent to the tank or bulk container.

Figure 3 Hazchem signage for bulk dangerous goods



Hazchem codes must be displayed on or adjacent to the tank or bulk container.

Hazchem codes

The Hazchem code provides advisory information to emergency services personnel, enabling them to take appropriate action to combat the incident. For example, the code for chlorine gas is 2XE.

The Dangerous Goods Class Labels are an international system for identifying the primary hazard of various substances—whether the substance is a gas, a flammable liquid, a poison or a corrosive substance. They are shown in the diamond on the right hand side of any composite labels.

Chemical storage quantities (Schedule 2)

Schedule 2 of the Dangerous Goods (Storage and Handling) Regulations 2000 describes the quantities of chemicals stored that trigger enforcement of placarding and manifest requirements. The prescribed quantities may depend on the packaging class.

Separation distances for chemicals

Many chemicals can be dangerous if stored too close to other dangerous goods, or near public places. There may be interactions and hazards involved. For information on appropriate separation distances, refer to the Dangerous Goods (Storage and Handling) Regulations 2000 and the Victorian WorkCover Authority.

SafetyMAP (previously “chemical notifiers”)

The Victorian WorkCover Authority has developed an auditing tool to help organisations of all sizes improve their management of health and safety. The audit criteria enable an organisation to:

- measure the performance of its health and safety program
- implement a cycle of continuous improvement
- benchmark its health and safety performance
- gain recognition for the standards achieved by its health and safety management system.

Table 1 Interpreting Hazchem codes

Hazchem Code	Meaning
2XE	Chlorine gas
2	Indicates that emergency services should use fog to combat the spill
X	Indicates that emergency services should use full protective equipment, including breathing apparatus. They should contain the dangerous goods on-site, and seek to avoid spillage into drains and waterways.
E	Indicates that the officer in charge of the emergency should consider evacuating the site.

Table 2 Classes of common dangerous goods kept at pools

Class	Description	Common chemical
Class 2.2	Non flammable, non toxic gas	Carbon dioxide gas
Class 2.3	Toxic gas	Chlorine gas
Class 3	Flammable liquids	Petrol
Class 5.1	Oxidising substances	Calcium hypochlorite Trichloroisocyanuric acid
Class 8	Corrosive substances	Hydrochloric acid Sodium hypochlorite

Material Safety Data Sheets (MSDS)

Material Safety Data Sheets (MSDS) are a key to working safely with chemicals. MSDS are prepared by manufacturers and importers for the chemicals they produce or supply and help protect the health and safety of employees working with hazardous chemicals.

An MSDS describes the chemical and any health hazards and precautions for safe handling and use. If the chemical is also a dangerous good, an MSDS provides information about its classification, United Nations numbers, packaging group, chemical and physical properties, storage, incompatible substances and procedures for handling leaks or spills.

Worksafe Australia's National Code of Practice for the Preparation of Material Safety Data Sheets explains the required format and content.

Are MSDS compulsory?

Occupational Health and Safety (Hazardous Substances) Regulations 1999 require that manufacturers and importers of hazardous substances ensure that an MSDS is prepared for the substance, *before* it is first supplied for use at a workplace. Suppliers and manufacturers are also required to supply an MSDS on request.

Employers must obtain an MSDS for each hazardous substance they use. The MSDS can be used to develop ways of minimising exposure when using the substance in a workplace.

Sections of the MSDS

Generally, an MSDS has four main sections. These are described in Table 3.

Codes of practice

Pool managers should be familiar with a range of existing codes of practice. These include a number of Codes published by Health and Safety Victoria, on:

- first aid in the workplace
- manual handling
- noise
- plant
- storage and handling of dangerous goods.

Information contained in these Codes may affect pools, so management and owners of facilities should be familiar with them and follow them if applicable.

Guidelines for Safe Pool Operation (GSPO)

The Royal Life Saving Society Australia's *Guidelines for Safe Pool Operation* (GSPO) was first published in 1991, with a second edition released in 1996. As 'guidelines', the GSPO are secondary to any act, regulation or code of practice. However, they should be used as the industry guide to supervising aquatic facilities. Topics include:

- first aid
- facility design
- supervision
- learn-to-swim programs
- general operations.

Table 3 Main components of the MSDS

Section	Content	Example
Identification	This section describes the product, its ingredients and physical and chemical properties	Flashpoint The lowest temperature at which there is enough vapour to ignite. Petrol has a flashpoint of about minus 40°C. Therefore, in all normal situations there will be enough vapour released from liquid petrol to ignite.
Health Hazard Information	This section describes known health effects from acute (immediate) and chronic (long-term) exposures to the substance. First aid information is also given for acute exposures.	Acute exposure Inhaling mists may produce respiratory irritation and coughing. Inhaling high concentrations may cause fatal respiratory collapse.
Precautions for use	Any exposure standards, engineering controls, such as mechanical ventilation isolation, and suitable protective equipment for use with a substance is given here.	Personal Protective Equipment PVC gloves should be used when or handling this substance. Engineering and other controls Capture the substance at the source for safe disposal using local exhaust ventilation.
Safe handling information	This section details how the substance should be stored and transported, how to clean up spills and what may happen to the substance in a fire or when mixed with incompatible substances.	Response to a fire Some substances release toxic vapours when they burn; others may explode. In these cases, staff and others should know how to evacuate the area and not attempt to put out a fire involving the substance, without assistance from authorities.

Australian Standards

Pool operators may find further valuable information relating to the aquatic industry in a number of key publications from Standards Australia. Table 4 Australian Standards lists some that may be useful.

Environment Protection Authority

The Environment Protection Authority (EPA) is responsible for protecting Victoria's environment from pollution, by minimising and controlling waste and noise. It does this through a range of statutory and non-statutory processes and programs.

State Environmental Protection Policies (SEPPs)

The *Environment Protection Act 1970* provides for the formulation of State Environmental Protection Policies (SEPPs). Of most interest to pool operators is the SEPP—Waterways of Victoria, 2003.

This policy applies to all government organisations, private and individuals in Victoria. It identifies beneficial uses of Victorian surface waters to be protected,

specifies indicators to measure and define environmental quality, sets environmental quality objectives and details a program to attain and maintain these objectives.

Discharge of waste from pools

In the SEPP—Waterways of Victoria, minimum requirements for discharge from municipal and commercial swimming pools are given. Discharge of waste from municipal and commercial swimming pools must conform to several requirements relating to filter backwash and pool content.

Filter backwash

According to the SEPP, filter backwash may be discharged to land, sewer, treated via a solids settling tank, with the supernatant recycled back into the pool, or treated and discharged to surface waters. When filter backwash or pool contents are discharged to surface waters, the water must have total residual chlorine less than 0.1 ppm (parts per million) and suspended solids less than 10 ppm. When re-used in the pool, total dissolved solids and combined chlorine levels will rapidly accumulate in pool water.

Figure 4 Backwash tank



The backwash tank should be appropriately sized to retain the entire contents of the backwash.

Discharge water

Discharge water should be analysed by an accredited laboratory, to ensure it conforms with the SEPP—Waterways of Victoria. Results must be submitted to the EPA within 28 days of the samples being taken and the volume of the discharge must be recorded.

waterMAPS

Under the *Water Act 1989* and *Water Industry Act 1993*, major water users are required to improve their water efficiency through the implementation of their own water Management Action Plan (waterMAP). A waterMAP requires eligible non-residential water customers to assess their current water use, identify inefficiencies and opportunities for water savings, prepare an action plan to implement water conservation activities and annually report on the implementation of such activities. The waterMAP must be submitted to the relevant local water corporation.

Table 4 Australian Standards

AS1470–1986	Health and safety at work—principles and practices.
AS1668.2–2002	The use of mechanical ventilation and air-conditioning in buildings: ventilation design for indoor air contaminant control.
AS1885.1–1990	Code of practice for recording and measuring work injury experience.
AS2610.1–2007	Spa pools—public spas.
AS/NZS2865–2001	Safe working in a confined space.
AS/NZS2927–2001	Storage and handling of liquefied chlorine gas.
AS/NZS3633–1989	Private swimming pools—water quality.
AS3780–1994	The storage and handling of corrosive substances.
AS3979–2006	Hydrotherapy pools.

Infrastructure



Swimming pool design

Overview

Pools are complicated structures and make serious demands on design, construction, operation and maintenance. The Pool operators' handbook is principally concerned with operation; however, design and construction are critical to successful operation. Design is the first issue to be considered for new and existing structures and should be addressed in collaboration with all parties responsible for design, construction and operation. It is important to ensure the design and end usage take into consideration the *Occupational Health and Safety Act 2004*.

Water treatment systems are an integral part of the architectural, structural and mechanical design, and should be addressed from the very start of the project. Water treatment plant design must, initially and crucially, take into account potential bathing load, circulation rate, turnover and dilution, choice of treatment system, filtration, circulation hydraulics, plant room and operation. Overall, the design must conform to the appropriate standards or guidelines for maintaining safety and the chemical and microbiological quality of the water.

At all stages of design and construction, the Occupational Health and Safety (Plant) Regulations 1995 should be considered to ensure compliance.

Although the Handbook cannot advise on the details of design, it does indicate the areas that need to be covered in a design brief. Finally, there is advice on obtaining specialist design and contracting help.

Design brief

Water treatment is just one factor within the design of what may be a multi-use leisure complex. The starting point for design is a full assessment of community needs and potential demands, taking existing facilities into account. Depending on the particular project, there may have been a strategy prepared, a multi-discipline project team appointed, a feasibility study commissioned, and decisions made on location and finance.

The end of this stage should result in the appointment of a pool manager and an architect qualified in pool design. The pool manager and architect should work together to produce a design brief that will consider the type of facility proposed. The design brief should consider:

- the type and amount of use envisaged, for example: swimming, therapy, education or leisure
- structural features, such as moveable floors or booms to convert competition or diving pools into teaching or leisure pools
- joint-use arrangements
- possible shared treatment plant for different pools
- changing rooms and their accessibility
- street access to the facility
- fire and emergency evacuation
- capital cost
- operational cost
- ease of use
- lifespan.

It is uncommon for one person—consultant, architect, manager, pool operator or other staff—to be familiar with or have expertise in *all* these technical issues. However, persons responsible for a new building or alteration do need to be aware of the following important areas, and take them into account when working on the design of a pool complex.

Bathing load, circulation rate and turnover

Bathing load dictates the rate of circulation or turnover period required. Bathing load and pool volume should be considered together to determine the size of filtration plant and the choice of water treatment system. These issues are central to good water quality.

Water treatment

From a design perspective, the following factors should be considered:

- pool type (recreation, hydrotherapy, toddlers, spa and so on)
- pool temperature
- method of removing suspended and colloidal matter
- oxidising agents
- disinfection system
- coagulants
- ph adjustment
- water balance
- fresh water dilution
- effects on air quality
- plant size and operation
- plant personnel; training
- water testing and recording
- plant monitoring and control
- energy and operation costs
- chemical storage and handling.

Hydraulics

The design of water movement demands attention to:

- pool size and shape (including profile)
- size, number and location (including safety considerations) of pool water inlets and outlets
- design and correct sizing of the filtration plant, including filters and filtration rates (see the chapter 'Monitoring systems')
- size and routing of circulatory pipework
- size and location of balance tank
- water circulation within the balance tank
- transfer channels
- pumping and location of sump pump
- integration of water features
- moving floors and booms
- effect of evaporation (normal and induced by water features) on relative humidity in the pool complex
- effect of water movement on noise levels
- pool location.

Plant room

Many issues need to be considered at the design stage:

- size and location of plant room, taking into account filter specifications, the scale of other water treatment plant, flooded pump conditions and short suction pipework lines
- location of other plant items and ductwork
- plant layout for ease of operation and maintenance
- interfaces and coordination with other building elements, including ventilation intakes (well away from plant room and chemical stores)

- access for plant replacement/refurbishment
- access for chemical deliveries
- special bunded storage areas for chemicals
- waste water and drainage requirements
- health and safety requirements
- plant room environment relating to temperature, humidity, ventilation and noise
- builders' work requirements
- electrical requirements.

Specialist help

Successfully building or substantially refurbishing a swimming pool demands a clear understanding of the distinction between design and installation. It is also important that the *responsibility* for issues of design and installation is clearly identified.

Who designs the pool?

Water treatment design requires specialist engineering knowledge, which needs to be recruited together with the architect and structural and environmental service engineers. This knowledge, which is critical to producing a satisfactory design, is available from two sources:

- **consultants**—can provide independent specialist advice and who are appointed as full members of the design team
- **contractors**—can work to the consultants' brief and specifications, to their own schedule or to a client's.

Bathing load and circulation rate

Bathing load is a difficult issue in pool water management. There may be pressure to maximise income by overloading the pool. For a new pool, at least, there is no excuse for not planning and maintaining a realistic relationship between bathing numbers and pool and treatment plant capacity. The turnover rate must be sufficient to cope with maximum bather load at all times, to maintain water quality in accordance with the Health (Infectious Diseases) Regulations 2001.

The pool capacity should be determined at the design stage. Unlike some other countries, Australia does not have set formulas relating to water turnover or square metres per pool area to regulate bather loads. Australian Standards (AS3979) recommend a two-hour turnover for hydrotherapy pools, and every 20 minutes for spa pools (AS2610.1).

Choice of treatment system

When choosing a water treatment system, these aspects should be considered:

- the quality of the water supply
- the type of pool
- likely bathing loads
- desired water quality
- the pool hall atmosphere
- the skills required to operate the system.

Those responsible for deciding on a treatment system should call on the experience of other managers and operators of similar facilities.

When a system is chosen, assess the types and amounts of chemicals required and how they are stored, to ensure adherence to regulations and guidelines. The testing chemicals may also need to be assessed.

Filtration

Filters should operate for 24 hours a day to deal with the pollution arising from pool users. If water quality can be maintained, it may be possible to reduce the flow rate overnight. If the filters are not effective, turbidity (generally meaning 'suspended solids') will not be adequately reduced, whatever the turnover period. In some circumstances, an inefficient filter yielding an effluent containing suspended matter may in fact increase turbidity, not improve clarity. Effective filtration, well-maintained filter media and a short turnover period will ensure that suspended solids are removed. (More information about filtration is provided in the chapter 'Physical management of water'.)

Circulation hydraulics

A well-designed circulation system within the pool will ensure that treated water reaches all parts of the pool and

contaminated water is removed from areas most used by bathers. If effective circulation is not achieved, water treatment may not necessarily provide good water quality. Conversely, first-rate circulation hydraulics may allow an over-stretched water treatment system to produce decent pool water.

Inlets, outlets and surface water withdrawal are crucial. A wet deck system (where pool water level is with the surrounds) with a balance tank and pool surround collecting channels, is particularly efficient. In this way, 50 to 100 per cent of the total circulation volume can be removed from the surface, where pollution is greatest. Leisure pools, particularly if they are to have a freeboard area for water features such as waves, may allow only a partial wet deck system. (For more information on circulation, see the chapter on 'Monitoring systems'.)

Plant room

Plant room design should take into consideration four key issues: location, size, access and segregation.

Location

The location of the filtration and water treatment system, in relation to the pool, critically affects hydraulic design. Circulation pumps should, ideally, operate under flooded suction conditions and be situated near the balance tank and near extraction points from the pool. If the pumps have to be some distance from the balance tank, increasing the suction pipe size may improve pump performance. If the plant room has to be at pool surround level, the pump can be installed in a well, to provide flooded suction conditions. If there is no balance tank, the connection between pool water and pumps must be designed to keep air out of the circulation.



Size and access

The size of the plant room (water treatment plant only) will typically be between 15 and 30 per cent of the pool water area. It should be sized to ensure good access, both to the plant room itself and for plant room equipment operation, maintenance and replacement. When designing a plant room, maintenance and replacement of major plant components should be considered. Filter media will need to be replaced periodically.

Segregation

Certain equipment needs to be segregated. For example, chemical storage and dosing units should ideally be housed in separate, secure storage rooms. Electrical control panels, chemical control units and ozone generators should be in clean, dry areas away from chemical stores.

Operation

The water treatment contractor should provide training for the plant operator, during commissioning of the plant and also once it is operating. The management and operator should be present for the critical process of commissioning. Commissioning should incorporate system checking for health and safety requirements, including plant room and the safety of any water features, and comply with all design specifications.

The water treatment design brief should require the provision of operation and maintenance manuals (including plant and pipe layout drawings and electrical circuits). It should also detail how the system is to be operated. These briefs should list the necessary daily, weekly, monthly and annual checks.

Choosing water treatment specialists

The Consultant

A water treatment consultant should develop the brief, produce a competent design, detailed drawings and specifications, and monitor the installation work on-site. When competitive tenders are needed, the consultant will be particularly valuable in ensuring that they are based on an equivalent level of specification and scope of work.

It is important that the consultant has appropriate qualifications and experience for the project being undertaken and does not limit specifications to any one particular manufacturer's equipment. Purchasers of consultancy services and owners of the facility should pursue references, and verify skills and experience by interview.

The Contractor

A water treatment contractor can be appointed to design as well as install the plant, if the client has a good design brief/specification. The choice of contractor then becomes particularly important.

In any case, the contractor should be responsible for the supply, installation and commissioning of the system, and for installing equipment from reputable manufacturers. There is no single method for finding the right contractor; however, the following guidelines may be useful for selecting contractors and manufacturers:

- Consider members of trade and professional associations first.

- Contractors may offer some form of quality assurance—see ISO9000. Where contractors provide a design warranty, they should be qualified to Part 1 of this standard. This should imply a quality system, though not necessarily a quality product.
- Check previous work, by visiting installations and viewing references from clients, architects and engineers. References should comment on design ability, performance during contract, reliability of equipment recommended and used, commissioning and staff training record, standard of operating and maintenance manuals and after-sales service.
- A long and successful record of quality work is a positive indication.
- Good contractors, like good consultants and good suppliers, will be familiar with this Handbook.

Types of pools

Overview

The Pool operators' handbook has been compiled to provide advice to all non-domestic pool operators. Most pools are rectangular swimming pools without extra water features and are used by people of all ages. The following describes a range of conventional pools in specific applications, as well as a number of non-conventional pools. Please note this is not an exhaustive list of pool types. Other names may be commonly used, but must still meet the requirements of the Health (Infectious Diseases) Regulations 2001.

Competition pools

For short-courses (championships) the pool should be 25 m long, ideally with eight lanes at least 2.0 m wide, with two spaces of at least 0.2 m outside the first and last lanes. The minimum required depth is 1.0 m.

Olympic and World Championship pools should be 50 m long by 25 m wide, with a minimum depth of 2.0 m, with at least eight lanes 2.5 m wide, with two spaces of 2.5 m outside of lanes one and eight.

Diving pools

For steep-entry dives from springboards and fixed platforms, a specially designed pool is needed. The depth and area of water for a diving pool or pit is determined by FINA regulations. A one-metre springboard requires minimum water depth of 3.4 m and a ten-metre platform requires a depth of 5 m.

Further information regarding specifications for competition pools are described in the *FINA (International Swimming Federation) Handbook*.

Adjustable (flexible) pools

These pools incorporate a moveable floor and/or bulkhead (boom). The moveable floor gives variable depth. The semi-submerged bulkhead divides the pool into two, in any proportion. Perforated panels allow water flow between pools. It is important that the turnover period should cope with the largest bathing load possible.

Dual use pools/school pools

Two or more different types of customers use these pools at different times. The term is usually applied to a school pool that is also opened to the public for some sessions. If a new pool is planned for dual use, the design (circulation, filtration, disinfection and so on) should accommodate the demands of a higher bather load.

If an existing school pool is to be opened to the public, care should be taken to ascertain its bathing load and not to exceed it. In either case, serious consideration should be given to the training and qualifications of those responsible for the operation and management.

Adequately trained non-specialist staff using simple disinfection and filtration systems may manage school pools that are only ever used by pupils in controlled swimming sessions quite successfully. But if the public uses them, or if there is a real possibility that this will happen in the future, then the guidance above for dual use pools should be followed. In any case it is better, if practicable, to follow the guidelines given in this Handbook for conventional pools.

Hydrotherapy/warm water exercise pools

These are generally smaller pools specifically designed for physiotherapy and gentle exercise. Operating temperatures of over 32°C are recommended. Specific design and construction requirements are outlined in AS3979. Pool users and staff use these types of pools for long periods. As a result, they are more demanding to manage than conventional pools—or at least, the consequences of basic mistakes can be more immediate and dramatic.

Lazy and rapid rivers

Lazy and rapid rivers are sometimes referred to as 'moving water'. In rapid rivers, pumps and jets under the water surface create a rapid water flow. Because the water flow is rapid, circulation hydraulics is not a problem. However, lazy rivers with large volumes of water that are not continually flowing may cause some water contamination problems. Pool operators will need to monitor the water quality carefully in this type of application, or ensure that a constant flow is created.

Splash pools

These are specially designed areas of water in which a rider safely completes the descent of a water slide or water flume. If the splash pool shares its water circulation with that of a main pool, the turnover must be able to cope with the highest bathing load possible. Bather pollution will tend to be high for the amount of water involved, so hydraulics is important.

Salt water pools

Treatment of saline pools should be the same as for fresh water pools, except that the materials used in filters, pipes and pumps should be resistant to salt water corrosion.

Spa pools

There are many types of spa pools, but they all have their use in common: they are for sitting in, rather than swimming, and contain water usually between 32°C and 40°C, filtered and chemically treated. A pool with *untreated* water that is replaced after each user, and water agitation of some sort, is a spa *bath*.

Bathing loads may be high in spas. Combined with the high temperatures, this can make it difficult to maintain satisfactory disinfectant residuals, pH values and microbiological quality. In general, good water quality can be maintained by controlling both bathing loads and intervals between sessions (both of which can be specified in the design), turnover periods of less than 20 minutes, adequate filtration, and emptying at least once a week—even daily, when loading is high. Refer to Australian Standard for Public Spas AS2610.1.

Spas may have particular difficulties with the safety requirements for inlets and outlets. The main criterion for designers, manufacturers and operators is to take all reasonable precautions to prevent a bather, or part of a bather's body, becoming trapped.

Teaching pools/learn to swim/program pools

These are separate pools with a depth of less than 1.0 m, that is, they have a large surface-area-to-volume ratio. Pollution is likely to be high when young children use them, so bathing load control is particularly important. Turnover periods should be short and filtration standards as effective for conventional pools.

Particular attention should be paid to design where a teaching pool is to share filtration plant with other pools—separate the disinfectant monitoring, controls and heating.

Leisure pools

There are many different types of 'leisure pools', and many conventional pools are becoming 'leisurised'. They tend to have in common an irregular shape and more shallow areas than a conventional pool. This makes for less predictable hydraulics and disinfectant dynamics. Therefore, circulation patterns and inlet/outlet positions should be carefully designed. Bather loads and turnover periods need to be taken into account during the design phase. In general, turnover periods will have to be less than 90 minutes.

The unusual water volumes involved, and a tendency to high-localised concentrations of bathers, can also result in contamination problems.

Water features will tend to distort the dynamics of water treatment. Disinfection systems should be as sophisticated (in terms of automatic dosing and monitoring), as the pools are in terms of features. It is recommended that water features use water directly from the treatment plant.

Access to the pool from areas such as artificial beaches and lawn areas, and varied use of the pool, can all introduce novel forms of pollution. At the very least, it is wise to have a realistic regime of pre-swim hygiene. Good showers and toilets, well signposted, with encouragement to use them, will assist with water quality maintenance.

Outdoor pools

Outdoor pools inherit special problems, caused by changes in the weather. In summer, sudden sunshine may bring a large increase in bathers and a degradation of the chlorine disinfectant by ultraviolet light. Chlorine can be stabilised by adding cyanuric acid. The often large volumes of water in outdoor pools should help the pool cope with increases in bathing load, but if the turnover of the large volume is slow, it may be difficult to maintain the appropriate disinfectant residual throughout the pool.

Appropriate management and testing will accommodate pools that are sensitive to fluctuating demands.

Toddler pools

Toddler pools are likely to need the same sort of attention described for outdoor pools. They may be highly polluted relative to their volume, because children will tend to urinate in them and introduce other forms of pollution.

Disinfectant residuals should be maintained as for conventional pools. This may be more difficult if the pool is outdoors due to pollution for other sources, for example, birds and other foreign matter blown in. In this case, the water may need to be changed regularly—daily if practicable—but this depends on filtration efficiency and build-up of chloramine and total dissolved solids.

If circumstances make proper hygiene standards impossible to maintain, pool managers should consider closing the toddler pool altogether.

Plunge pools

These are used in association with saunas and spas to cool bathers by immersion in unheated water. They may be big enough for just one person, or large enough to swim in. The water should be disinfected and filtered like a conventional pool. Special consideration should be given to the introduction of body fats and other contaminants. Good surface water draw-off and regular water replacement are key considerations.

Wave pools

These are usually incorporated into a free-form leisure pool. Waves are generated at one end, which requires a high free board. The waves cross the pool to dissipate on a beach area. Surface water draw-off needs attention, as does water quality in the wave generation chambers.

Zero depth splash grounds

Although these facilities are not covered by the Health (Infectious Diseases) Regulations 2001, they could be a potential source of infection. The department recommends that these facilities have appropriate treatment and filtration to minimise the risks associated with them.

Health and hygiene



Sources of contamination

Overview

Pool users can be affected by disease-causing microorganisms (pathogens), transmitted by contaminated pool water, contaminated surfaces or person-to-person contact. Illnesses such as gastroenteritis and infections of the skin, eyes or respiratory system may result.

Swallowing pool water can increase the risk of disease. Even in well maintained pools, some pathogens such as *Cryptosporidium* can remain infectious. Patrons with diarrhoea and nappy-aged children pose the largest risk of contamination to pools and facilities.

Pool operators are encouraged to adopt a risk management approach to prevent disease transmission. Strategies include staff and patron education, encouraging hygienic practices, and maintaining optimal control of pool operations.

For more information about healthy swimming advice please visit <http://www.cdc.gov/healthyswimming/>.

Cryptosporidium resists normal levels of disinfectants and can survive for days in pool water.

Contamination is mainly introduced by pool users, but also via the environment. It can occur within the pool itself, on the pool deck, or in facilities such as changing rooms.

Environmental contamination is especially relevant to outdoor pools, where organic material such as dust, soil, sand, leaves and grass is constantly in and around the pool. Birds and other animals can also contaminate the pool with droppings, reducing the levels of available disinfectant in the pool.

Pool users may contaminate the pool with faecal material, body fluids, hair, skin, lotions and cosmetics. Small amounts of faecal material can come from the skin of bathers, particularly those with diarrhoea or children wearing nappies. Bathers may continue shedding infectious pathogens for days or weeks after their diarrhoea symptoms cease. Large amounts may arise from faecal accidents.

To prevent contamination, pool users who have had a diarrhoeal illness should not use any swimming pool until symptoms cease. If a person has a confirmed diagnosis of an infection with *Cryptosporidium* (cryptosporidiosis), they should not swim for two weeks after symptoms have ceased.

Staff or patrons with diarrhoea should not use the pool until after their symptoms cease.

The risk of pool contamination is increased by:

- high bather loads during peak periods
- swimmers with a diarrhoeal illness or faecal incontinence
- use by nappy-aged children
- insufficient disinfectant levels in the water, or inadequate filtration.

Infections and conditions associated with pool use

Although normal disinfectant levels will inactivate most pathogens, it takes time to work. Bacteria are usually inactivated quickly by disinfectants, but viruses and parasites may persist for much longer. Variations in disinfection time for a range of pathogenic organisms are shown in Table 5. Pool facilities and shared equipment can also transmit pathogens.

Table 5: Disinfection times for selected pathogens in pools

Contaminant	Disinfection time*
<i>E. coli</i> bacteria	< 1 minute
Hepatitis A virus	16 minutes
<i>Giardia</i> parasite	45 minutes
<i>Cryptosporidium</i> parasite	9600 minutes (6.7 days)

* 1 mg/L (1 ppm) chlorine at pH 7.5 and 25°C
Source: Centres for Disease Control
<http://www.cdc.gov/healthyswimming/fecalacc.htm> Accessed 04/12/2006

The risk of transmission increases if pool water disinfectant is not maintained at appropriate levels, or if pool facilities are not cleaned adequately.

Bacteria

Maintaining routine disinfection levels will normally inactivate bacteria in pool water, but if disinfectant levels drop, they can quickly proliferate.

Pseudomonas aeruginosa bacteria may cause eye, ear and skin infections and have been associated with disease outbreaks where the pool water was inadequately disinfected. Particular care should be taken with spa pools, as the water turbulence, temperature and heavy bather loads increase the risk of *Pseudomonas* growth.

Legionella bacteria are found in soil, rivers and creeks. Infection with *Legionella* can lead to Pontiac fever or Legionnaires' disease, a severe respiratory illness caused by inhaling contaminated aerosols. Legionnaires' disease has not been associated with transmission through swimming pools, but has been transmitted by poorly maintained and disinfected spa pools, fountains and showers.

Escherichia coli are bacteria which colonise human intestines and their presence in pool water indicates that there is likely to be faecal contamination in the pool. Some types of *E. coli* can cause serious disease in humans and transmission may occur through inadequately treated pool water.

Shigella, *Salmonella* and *Campylobacter* are other bacteria that can cause gastroenteritis and can be transmitted through untreated or inadequately treated water.

Mycobacterium marinum ("swimming pool granuloma") is a very uncommon infection causing skin ulceration or nodules which may be associated with inadequately chlorinated pools.

Viruses

Many viruses are highly infectious and can be transmitted through water. Although recommended disinfection concentrations effectively inactivate them in most circumstances, they are more resistant to chlorine than bacteria.

A range of viruses, including enteroviruses, adenoviruses and norovirus may be transmitted through swimming pools. Many of these will cause gastroenteritis. Some such as adenoviruses may cause eye and throat infections. Some types of enterovirus infections may result in meningitis.

Molluscum contagiosum is a viral disease that causes small round bumps (papules), on the skin. It has been associated with transmission through swimming pools, with direct contact between people or sharing towels likely ways of becoming infected.

Plantar warts grow on the bottom surface of the foot. They are caused by the human papillomavirus. Infection is more likely where the skin of the feet is damaged or constantly damp. Wet environments such as shower blocks and pool surrounds can facilitate spread of this virus.

Protozoal parasites

Cryptosporidium and *Giardia* are parasites that cause gastrointestinal disease. Infection occurs when they are shed in the faeces of an infected person, and are ingested by another, such as when swallowing contaminated water. Once a person has been infected, the parasite multiplies in the intestine and is passed in the stool. Because the parasite is protected by an outer shell, it can survive outside the body in the environment for a long time. Symptoms include diarrhoea, vomiting, nausea and abdominal pain. Sometimes there are no symptoms at all, but the parasites may still be excreted in large numbers by the infected person.

Pool water disinfectants at recommended residual levels have only a limited effect on *Giardia*, and are ineffective against *Cryptosporidium*. Normal filtration processes take time to remove these organisms, and testing for the parasites in water is difficult. If *Cryptosporidium* is suspected, the level of disinfectant may need to be increased (see the chapter 'Water treatment'). Adding coagulant to the water and frequent backwashing of filters is highly recommended. Advice from the Department of Human Services should be sought where a problem with *Cryptosporidium* is suspected.

The most effective way to control transmission of *Cryptosporidium* is to prevent it getting into pool water.

Cryptosporidium is very resistant to disinfectants at normal levels. Prevention is the best means of control.

For more information download the fact sheet from <http://www.health.vic.gov.au/environment/water/cryptosporidium.htm>.

Amoebae, such as *Naegleria fowleri* occur naturally in environments such as mineral springs and thermal bores. Although unlikely to be a problem in swimming pools in Victoria, operators of facilities that use natural water sources should be aware of the potential hazard. Amoebae thrive in shallow warm water and occasionally can infect a swimmer through the nose. Although rare, a fatal infection of the brain and membranes covering the brain can result. Maintaining the required level of disinfectant² in pool water will rapidly kill these organisms. Circulation systems, including balance tanks, should be designed to avoid prolonged periods of stagnation.

Fungi

Tinea pedis ('Athlete's Foot') is a fungal infection causing an itchy scaling between the toes. The fungi are spread by contact with damp floor surfaces, such as showers or around pools.

Chemical irritants

Swimming pool disinfectants may cause skin, eye and respiratory irritation. High levels of chloramines (free chlorine bound to ammonia compounds such as sweat and urine, give pools their 'chlorine smell' and can cause symptoms particularly in indoor pools. Manage this by increasing the air turnover in the pool area with fresh air, and ensuring that pools are regularly treated with raised levels of disinfectant to remove the chloramines, particularly after periods of high bather load.

Outbreaks and notification

The Department of Human Services conducts surveillance for a range of notifiable infectious diseases that may be transmitted in swimming pools. *Cryptosporidium* cases may be linked to a public swimming facility if two or more people with confirmed infection have used the same pool within two weeks of developing their illness. In this situation, pool operators may need to seek advice from the department and undertake additional procedures such as closing the affected swimming pool until it has been treated with increased levels of disinfectant. It is important to ensure that the total chlorine level in a treated pool is less than 8 mg/L before re-opening it to the public. If an outbreak is large or ongoing, the department may request additional steps be undertaken.

² See Health (Infectious Diseases) Regulations 2001—Part 7.

Risk management

The most effective way to prevent swimming pool contamination is prevention. This involves educating staff and patrons about the health issues, encouraging appropriate swimmer behaviour and undertaking optimal pool management processes. Signage should display key messages that are described in *Education and signage*.

Swimmer hygiene

All patrons should be encouraged by staff to shower with soap before entering the pool and after going to the toilet. Most people have small amounts of faecal material on their perianal region, which can transfer pathogens into the water. Appropriate signage in change rooms and toilets can encourage patrons to adopt more hygienic behaviours.

The pre-swim shower will wash contaminants down the drain, not into your pool, but is still not enough for patrons with diarrhoeal illness.

Pool operators should ensure that they have adequate hygiene facilities available for patrons. Hand washing facilities, including soap dispensers and hand-dryers or disposable hand towels, should be available at hand basins. Shower facilities should have warm water available and be stocked with soap. Provide sanitary and nappy changing facilities and nappy bins in the change rooms. Hygiene facilities should be sited close to the pool to allow easy access, and be well stocked and maintained. Regular inspections and cleaning should be part of routine management. Pool operators should plan to increase the frequency of these, according to swimmer numbers.

Swimmers with diarrhoea

People with diarrhoeal illness can experience liquid faecal accidents, often undetectable in swimming pool settings. These types of accidents may contain huge amounts of pathogens, which may then infect other bathers. After recovery from diarrhoeal illness, patrons can continue to shed pathogens for days, or even weeks. Pool users and staff who have a diarrhoeal illness should not enter the pool until after symptoms cease. In the case of confirmed diagnosis or outbreak of *Cryptosporidium* infections, users and staff should not enter the pool for two weeks after symptoms have ceased. All change rooms and toilet facilities should contain appropriate signs with this message.

Non-toilet trained infants

Infant 'aqua-nappies' and swim pants are commonly used, but may give parents and pool staff a false sense of security about faecal contamination. There is no scientific evidence to suggest that they can prevent faeces (particularly if liquid) from leaking into the pool.

Parents should be reminded of the importance of not swimming with diarrhoea and waiting for the symptoms stop before swimming again. Regular nappy changing and frequent trips to the toilet can further reduce the chance of a faecal accident. Prohibit nappy changing at poolside, as this may contaminate the surfaces of the pool deck.

Education and signage

Pool operators are encouraged to promote healthy swimming behaviours amongst staff and patrons, in accordance with their duty of care. Signage is an important aspect of public education, with key messages displayed in the entrance foyer and amenities areas. During outbreaks, the Department of Human Services may request additional signage be displayed, to further increase awareness.

Swimmers should be asked to assist in maintaining a healthy swimming environment through signage. Key messages to feature on signs include:

- Do not use this pool if you have diarrhoea.
- Do not swallow pool water.
- Practice good hygiene—shower before swimming and wash hands after using the toilets.
- Take children to the toilets regularly.
- Do not change nappies beside the pool.

Children's pool design and filtration

Children's pools are at high risk of faecal accidents and should ideally have a separate filtration system. If the children's pool's filtration system is linked to other pools, faecal contamination can disperse. Similarly, infant pool activities should be restricted to toddler pools, where possible. If the pools are not on separate systems, consider separating pool circulation systems when facilities are upgraded.

Pool staff

Pool staff need to have a good understanding of the range of illnesses and health conditions transmitted through pool water, particularly the fact that *Cryptosporidium* is a microscopic parasite which is resistant to normal levels of disinfectant, and that people with diarrhoea should not use the pool until their symptoms have ceased. All staff should be trained in the relevant operational procedures, particularly the faecal accident policy.



Operational control and management

Optimal control and management of swimming pools and spas is essential to maintaining the required water quality.

Bather load

The bather load generally introduces pollution to a pool. High bather loads can place additional demands on disinfectant levels and filters, so extra care should be taken during these times.

Filter maintenance

Filtration systems should be maintained to provide optimum efficiency and operate 24 hours a day.

Hot water systems

Systems serving showers and hand basins should deliver water at less than 43°C, to prevent scalding. The main boilers should be maintained at temperatures not below 60°C, to prevent colonisation by *Legionella* bacteria. The temperature reduction required can be achieved by mixing valves.

Tepid water systems (or modified tepid water systems that keep temperatures below 60°C) must be maintained in accordance with the Health (Legionella) Regulations 2001. Instantaneous hot water systems can be controlled to provide water at these ranges, without the need for storage or mixing valves.

Figure 5 Instantaneous hot water system



Instantaneous hot water systems can be set to provide warm water without mixing valves, or having to store hot or warm water.

Microbiological testing

Swimming pools should be tested in accordance with the Health (Infectious Diseases) Regulations 2001. Specific pathogens, such as *Cryptosporidium*, cannot be detected by these methods, so routine testing for these organisms is not recommended.

Faecal accident policies

Pool operators should develop a formal faecal accident policy that should be used to train staff and be available at all times. The treatment required will depend upon the condition of the faecal matter. Loose or liquid faecal matter (diarrhoea) requires greater treatment than a firm stool, as it tends to contain a large number of microorganisms, will spread rapidly over a large area and is not easily retrieved from the pool. Pool operators will need to assess each situation and make a judgment about the exact action to be taken. The following policies are recommendations by the department and can be downloaded from <http://www.health.vic.gov.au/environment/water/faecal.htm>.

Solid faeces

1. All pool users in the immediate area should be asked to exit the pool.
2. As much solid material as possible should be immediately removed from the pool, with a fine mesh scoop. If necessary, the immediate area should be vacuumed and the waste directed to the sewer or other approved waste disposal system. Vacuum equipment and scoop should be cleaned and disinfected before reuse.
3. If the pool is a low volume pool, such as a paddling pool, consider closing and draining the pool.
4. Spa pools must be closed, drained and cleaned, as the faecal matter will have dispersed.
5. Once the solid matter has been removed, check that chlorine levels and water clarity are within regulatory limits. The affected area may be reopened, after allowing ten minutes contact time with the disinfectant.
6. Log the incident and the action taken.

Liquid faeces

1. The pool should be immediately cleared of people.
2. If there are multiple pools connected to the same filter as the contaminated pool, all pools will have to be cleared of people.
3. Using a fine mesh scoop, immediately remove as much faecal material as possible from the pool. The area should also be vacuumed, with waste being directed to the sewer or other approved waste disposal system. Clean and disinfect vacuum equipment and scoop before reuse.
4. If a low volume pool, such as a paddling pool, consider closing, draining and cleaning the pool.
5. Spa pools should be closed, drained and cleaned.
6. Raise and maintain the free-chlorine level of the pool to 14 mg/L for 12 hours, or 20 mg/L for eight hours.
7. A coagulant should be added (if appropriate), to improve the removal of pathogens by the filtration system.
8. The final level of chlorine and pH should be checked, and if within limits of the Health (Infectious Diseases) Regulations 2001, the pool may be reopened.
9. Log the incident and the action taken.
10. If possible, identify the source to determine if the person has recently been ill.

The department's faecal accident policy can be downloaded from <http://www.health.vic.gov.au/environment/water/faecal.htm>.

Blood and vomit

Pool operators should develop a formal blood and vomit policy that should be used to train staff and be available at all times. The treatment required will depend upon the amount of blood or vomit. Pool operators will need to assess each situation and make a judgement about the exact action to be taken. The following policy is recommended by the department.

1. All pool users in the immediate area should be asked to exit the pool.
2. As much solid material as possible should be immediately removed from the pool, with a fine mesh scoop. If necessary, the immediate area should be vacuumed and the waste directed to the sewer or other approved waste disposal system. Vacuum equipment and scoop should be cleaned and disinfected before reuse.
3. If the pool is a low volume pool, such as a paddling pool, consider closing and draining the pool.
4. Spa pools must be closed, drained and cleaned, as the blood or vomit will have dispersed.
5. Once the solid matter has been removed, check that chlorine levels and water clarity are within regulatory limits. The affected area may be reopened, after allowing ten minutes contact time with the disinfectant.
6. Log the incident and the action taken.

Disinfecting contaminated surfaces

Contaminants on the pool deck should never be washed into the pool water circulation system.

Chlorine based disinfectants are commonly used for dealing with blood or body fluid spills. For example, a 1:10 dilution of sodium hypochlorite in water can be used. Dangerous Goods (Storage and Handling) Regulations 2000 should be consulted before preparing chemical dilutions.

1. Wear rubber gloves and remove excess contaminants, using disposable paper towels or similar.
2. Wipe non-porous surfaces with hot water and detergent, then flood with a chlorine based disinfectant and leave for ten minutes.
3. Porous surfaces, such as the pool deck, are more difficult to clean. Wash the area thoroughly with detergent and allow the run-off to go down the drain. Flood with a chlorine based disinfectant and leave for ten minutes.
4. Towels, gloves, excess contamination and other items should be placed in a bag and sealed. All contaminated items should be disposed of appropriately.

Pool cleaning

Around pool and changing rooms

To prevent transmission of infection, pool surrounds and change rooms need to be cleaned regularly. Frequency will again depend on bather load, but should be monitored as part of routine management. Minimising dirt from shoes can be achieved with good design. The use of cleaning agents needs to be strictly controlled and storage should comply with the Dangerous Goods (Storage and Handling) Regulations 2000.

Floors need to be hosed, mopped, washed or scrubbed at least once each day. Keeping cleaning products out of the pool water is almost impossible, particularly with wet-deck pools. Pool surrounds should therefore only be cleaned by washing and scrubbing with pool water, or with chemical cleaners specifically formulated for pool-side use. On the sides of the pool, deposits of dirt just above the water line can be cleaned off with a scourer, using sodium bicarbonate solution. Goggles and gloves should be worn. Tanks and channels should be inspected and cleaned frequently.

It is extremely important that commercial products used for cleaning in and around the pool are compatible with pool water and the chemicals used for disinfecting it. Care needs to be taken that cleaning chemicals do not affect residual levels, or interfere with monitoring. Chlorine and pool chemicals can also interact with other chemicals, in a way that can be hazardous. Care should be taken to avoid outright incompatibility between cleaning and pool chemicals, by always following manufacturers' instructions.

Bottom of pool

There should be some way of cleaning debris and algae from the pool floor. The simplest method is a long-handled, wide, weighted brush used to sweep the debris to the deepest outlet grating. Algae or staining requires suction to remove it. There are a number of suction vacuum units on the market, some requiring manual handling and others remote-controlled. Some will pump out through the pool's filtering system; some have built-in filters that need cleaning after each use. All electrical systems need to comply with Australian Standards (AS3000).

Emptying the pool

The pool should not normally be emptied, due to the potential for structural damage.

If emptied, the walls and floor can be assessed for cracked, broken or loose tiles or vinyl and these mended or replaced. The surfaces can then be cleaned with a chlorine-based disinfectant. Acid washing may be necessary to get the tiles clean—refer to the manufacturer's advice, as this may damage grouting. In either case, the solution needs to be neutralised then rinsed to waste, before the pool is refilled.

Cleaning spa pools and water features

Body oils are deposited on the insides of the piping system, restricting water flow and harbouring pathogens. Public spa pools should be drained and the surfaces and pipe work cleaned weekly. Commercially formulated degreasing solutions (specifically manufactured for spas) should be used to remove the pipe deposits.

Water treatment



Choosing a disinfectant

Overview

Disinfection is achieved when there is minimal transmission of infection between pool users, and growth of algae and other nuisance organisms is inhibited.

Chlorine and bromine based disinfectants

Disinfectants need to kill bacteria very quickly. Free chlorine or bromine are effective treatments and suitable for use in swimming pools, as their levels can be established on-site with relatively simple test kits. These disinfectants have another advantage—they oxidise bather wastes, such as sweat, skin particles, mucus and urine.

Chlorine and bromine based disinfectants are the only disinfectants suitable for use in public pools as their levels can be established on-site with relatively simple test kits.

Ozone or UV treatments

Disinfectants should be of a residual nature and be present in the main pool water body to encounter microorganisms as they are introduced to the water. Off-line treatment systems, such as ozone or UV, are not regarded as disinfection systems alone, as neither can prevent person-to-person transmission of disease, nor sanitise pool surfaces.

Ozone is excellent for oxidation and destruction of chemical pollutants or disinfection by-products within the circulation and filtration plant. UV is beneficial in the breakdown of chloramines.

Other disinfection treatments

There are other disinfectant systems marketed in Australia involving mechanical or other chemical methods. These systems generally have no application to public pools and should be avoided. If in doubt, contact the regulatory authority for advice.

Best Practice Model

- Design disinfectant dosing systems for every pool, to cope with a range of bather loads
- Use automatic monitoring and dosing of disinfectant and pH in all spa pools and any other pool subject to inconsistent chlorine demand.
- Maintain disinfectant residuals at the lowest end of the regulatory scale, where possible. Pools with poor circulation rates or dosing systems may need to maintain higher residual levels, to accommodate demand from the influx of pool users.
- Ensure that cyanuric acid is present in all outdoor pools, to minimise chlorine loss to sunlight.
- Superchlorinate at least weekly to disinfect filters, control algae and oxidise bather pollution.
- Maintain a stable pH when using automatically controlled disinfectant dosing, to avoid fluctuations in disinfectant levels.

Suitable disinfectants

Type of pool

The most suitable type of disinfectant will depend on these factors:

- indoor or outdoor situation
- swimming pool or spa pool
- chemical characteristics of the water supply
- likely bather loads
- circulation capacity and pool design
- chemical handling and safety issues
- supervision and maintenance issues
- pool water temperature.

Chlorine based chemicals

Chlorine based chemicals include:

- elemental chlorine gas
- liquid chlorine (sodium hypochlorite)
- granular chlorine (calcium and lithium hypochlorite)
- chlorine tablets (calcium hypochlorite)
- electrolytic generation of chlorine from saline salt (salt chlorination)
- stabilised chlorine granules/tablets (dichloroisocyanurate and trichloroisocyanurate).

Bromine based chemicals

Bromine based chemicals include:

- tablet (BCDMH)
- sodium bromide with an activator (hypochlorite or ozone).

Chlorine gas

Chlorine gas is used by professional pool operators to disinfect large community pools. It usually requires dosing with an alkali (such as sodium bicarbonate or soda ash) to maintain pH, as hydrochloric acid is formed when elemental chlorine gas is added to water.

The Dangerous Goods (Storage and Handling) Regulations 2000 limit the use of chlorine gas to pools with sufficient buffer distances from residences and public places to minimise the risk of injury in the event of a chlorine gas leak. For this reason, gas cylinders and injection points are located in external buildings and not within the pool hall or attached plant rooms. Refer to AS2927-2001.

Figure 6 Chlorine gas, weight scales and regulator



Hypochlorites

Sodium hypochlorite is easily dosed by metering pump and generally used in combination with acid or carbon dioxide dosing. Strongly alkaline, it tends to keep high pH levels. It is stabilised in a caustic solution, thereby having a shelf life of some weeks. It does pose chemical handling risks, however, particularly in a bulk handling and storage situation.

Calcium hypochlorite is widely available and suitable for manually dosing pools, following closure. It is useful for soft waters, maintaining hardness levels lost by dilution and backwashing. It is not generally used for metered dosing.

Lithium hypochlorite is shelf stable, non-scaling and highly soluble in water—ideal for spa pools.

In outdoor situations, cyanuric acid should be used with hypochlorites to reduce chlorine loss from sunlight.

Figure 7 Bulk sodium hypochlorite container in bund



Salt chlorination

Salt chlorinators use a low voltage electric current to convert chloride salt in pool water into free chlorine. Salt water pools involve minimal chemical handling and daily maintenance—ideal for hotels and motels, caravan parks and apartment blocks where professional pool operators are not usually employed. A timer or an automatic sensor and control system can control the operation of a salt chlorinator. A residual of between 2,000–8,000 ppm of salt is maintained in accordance with manufacturers' specifications, which require periodic topping up to maintain chlorine production rates.

Chlorinator output is related to the size or number of electrode plates. As this output is fixed, bather loads and chlorine consumption should be considered before installing this system.

Scaling of the electrode plates may occur if there is too much calcium hardness in the water; clean them with acid periodically, in accordance with manufacturer's directions.

Outdoors, cyanuric acid should be present in salt chlorinated pool water. Pools may require the addition of pH control chemicals.

Chlorinated isocyanurates

This type of disinfectant (for example, trichlor, dichlor) combines chlorine with cyanuric acid stabiliser and suits pools exposed to direct sunlight. Used outdoors, a start-up concentration of 25 ppm of cyanuric acid is recommended. When levels of cyanuric acid increase to 100 ppm, control levels by diluting the pool water more frequently.

Trichlor is used in many pools because it is easy to store and dispense (using erosion feeders). It is suitable for hard, alkaline water, as it does not contain calcium and helps keep pH down. It has been used in community pools, but is not as flexible as gas/hypochlorite systems. Take care that cyanuric acid does not reach excessive levels—correct by regularly backwashing or draining the pool. Pools containing cyanuric acid are often referred to as stabilised pools and require higher levels of free chlorine, in accordance with the Health (Infectious Diseases) Regulations 2001.

Chlorine dioxide

Chlorine dioxide is an effective disinfectant and oxidant and is not greatly affected by pH. Stabilised chlorinous oxide solutions that form chlorine dioxide when added to water are used at low levels (0.2–0.3 ppm) in swimming pools, to supplement chlorination.

Chlorine dioxide must be used in conjunction with free chlorine under tight supervision. The presence of chlorine dioxide may affect the operation of automatic chlorination equipment and specialist advice should be sought before use.

A potentially problematic by-product is chlorite formation or reconversion, which is controlled by continued free chlorine addition and periodic superchlorination. Chlorine dioxide may also be generated on-site, by mixing hydrochloric acid with sodium chlorite.

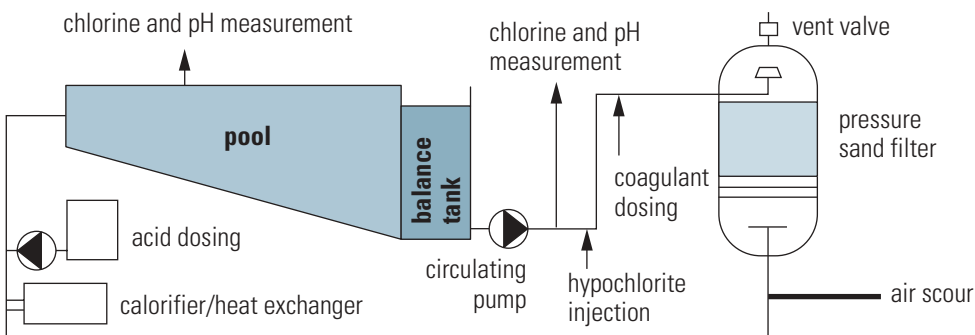
Bromine

Bromine has been commonly used for some years, particularly in warm water pools, but is losing popularity. Bromine has been associated with instances of skin irritation, and some pools have had difficulty remaining within regulatory limits for total bacteria count.

Bromochlorodimethylhydantoin (BCDMH) has been favoured in hydrotherapy pools, as it retains disinfectant better in heated situations and has no chlorine odour. Like trichlor, BCDMH is dispensed by erosion feeders and is acidic. Bicarbonate buffering is usually adequate to control pH, where BCDMH is used.

Bromide-oxidant activator systems use a reserve of sodium bromide in the body of the pool, with an activator. In this system, sufficient bromide ions are maintained in the pool water. Sodium hypochlorite (ozone) forms hypobromous acid when injected into the water. After reaction with contaminants, the hypobromous acid reverts back to bromide and the cycle recommences.

Figure 8 Pool water treatment with chlorine disinfectant



Bromine can be purchased as a pre-formed hypobromite/hypochlorite liquid. It can also be manufactured on-site by pre-mixing sodium bromide with sodium hypochlorite in line, prior to injection into the water stream. These solutions will form a chloramine build-up after continued use. Hence, the sodium bromide/sodium hypochlorite system relies on dilution with fresh water to reduce chloramines.

Problems with bromide/ozone pools

Bromide/ozone pools have had problems because the rate of bromine production is related strictly to the ozone production capacity. Reserve bromide ions react with ozone to form free bromine. As the system relies on the bromide reaction to prevent ozone getting into the pool, it may be unsafe to add chlorine to supplement bromine production while the ozone generator is on, because ozone could escape into the pool.

If the ozone system breaks down and it becomes necessary to add sodium hypochlorite to activate the bromide, problems with chloramines and other compounds may emerge. A minimum bromide level must be maintained within the system. The use of this type of system has been discontinued in some pools, because of these issues.

Chloramine removal

Chloramines are formed by a reaction between hypochlorous acid and nitrogen based products from pool users. Chloramines can be reduced by a number of processes. Superchlorination/shock dosing, ozonation and dilution are three conventional methods of chloramine reduction.

Continuous dilution is the best way to minimise the build-up of combined chlorine, particularly the stable organic-nitrogen complexes formed from nitrogen-based compounds present in sweat and urine. Continuously maintaining a free chlorine residual, at least 50 per cent (but preferably 75 per cent) of the total chlorine residual during normal pool operation, should control the accumulation of simple inorganic chloramines.

Superchlorination

Superchlorination is a periodic maintenance procedure where the free chlorine residual is raised two to four times the normal operating level, to prevent algae, remove colour and maintain clarity. Superchlorination reduces combined chlorine, in most circumstances. It also assists in keeping the pool water within bacteriological requirements during normal operation, by periodically removing biofilms (bacterial harbourages) that resist normal chlorine levels.

Best Practice Model

- Superchlorination should be conducted when the pool is closed to bathers (for example, overnight). This will prevent the introduction of pollution that may hinder the superchlorination process.
- Superchlorination must be carried out with the pH between 7.6 and 7.8. If the pH drops below 7.5, nitrogen trichloride may be formed. This stable compound causes chlorinous odours and irritates eyes.
- Under most circumstances, superchlorination is achieved at chlorine levels around 6–8 ppm. This level is sufficient to remove chloramine and will return to normal operating levels by the next morning.
- It is generally recommended that superchlorination is conducted at weekly intervals. Some pools may require more frequent treatment, depending on their pollution profile.

Chloramine concentrations may also be increased if make-up water supplies contain chloramines. Periodic superchlorination is the best method of removing inorganic chloramines.

In pools using chlorinated isocyanurates as their regular disinfectant, superchlorination may elevate cyanuric acid levels over time. Consider using a hypochlorite for superchlorination purposes, once cyanuric acid is at the preferred concentration.

Shock dosing

Shock dosing is an industry term for the process of superchlorination, when specifically used to solve issues such as destroying algae blooms and treating colour and clarity problems. The chlorine dose is usually higher than that used for preventative superchlorination.

Shock dosing to 10–15 ppm, or around five to seven times the normal free chlorine residual, may be used to help correct a serious problem, however dosing above this level would waste chlorine.

Shock dosing immediately after refilling an empty pool from a town water supply that is heavily chloraminated will remove the chloramine present. In this situation, the free chlorine should not be raised by more than ten times the combined chlorine residual.

Best Practice Model

- pH should be maintained between 7.6 and 7.8 when shock dosing, for the same reasons as for superchlorination.
- Shock dosing good quality pool water will not change the water quality, and is simply a waste of chemical.
- More serious problems, such as persistent combined chlorine, can be solved by dilution through backwashing and introducing fresh water.
- Always consider the Regulations and bather comfort, as well as the levels of chemical in the water, when the pool is open for use.
- If chlorine levels are too high to allow bathing, even after allowing sufficient time for the process to work (for example, overnight), then dechlorination may be required prior to reopening the pool.

Treating a system suspected of containing *Cryptosporidium*

You may be requested by the department or your local government authority to undertake precautionary action against *Cryptosporidium*. This entails raising the free chlorine within the pool and maintaining it over a specified period of time. Most commonly, this is raising the free chlorine to 14 ppm over a period of 12 hours. The free chlorine level must be monitored over this period, to ensure the level is maintained. Shorter contact times may be used, but there are issues that may arise from this. Should you wish to alter this, contact the department.

Dechlorination

Dechlorination is sometimes required when the pool has been accidentally overdosed, and is beyond the upper limit of the Health (Infectious Diseases) Regulations 2001. Corrective actions will require the pool to be closed until the chemical parameters are back within the regulated ranges.

Situations that require dechlorination should be avoided.

Prior to dechlorinating, ensure the accuracy of the free chlorine test, utilising the dilution method on page 51.

Dechlorination is achieved most commonly in two ways: dilution (usually by adding fresh water), or by adding sodium thiosulphate. When diluting, pool water is released from the plant to waste—often by a ‘long backwash’, thereby making some positive use of this water.

In some cases, an excessive application of sodium thiosulphate has been known to discolour swimming pool water. Any situation requiring free chlorine reduction of less than 10 ppm can be treated and the pool can realistically expect to be ready for use again within one hour. Conversely, an overdose situation requiring more than 10 ppm reduction should be recognised as a significant event that should take several hours to resolve.

When using sodium thiosulphate, it is important to avoid risking overdosing, thereby “bouncing” chlorine levels from too high to too low. It is difficult to accurately measure high chlorine levels, so the recommended approach is to add half the calculated quantity of sodium thiosulphate at a time, wait for it to circulate and then retest. Overdosing may result in a higher residual of sodium thiosulphate than required, which will remain in the water until additional chlorine is added. If this “staged” approach needs to be repeated a few times, it will usually ultimately result in a faster “fix” time by reducing the risk of “bounce” as well as the impact on pH and other parameters.

It is important to fully dissolve the crystals before adding them to the pool, as inadequate dissolution may prevent satisfactory chlorine neutralisation. Approximately 10 g of sodium thiosulphate per 10,000 litres (10m³) of pool water is required to lower chlorine by 1 ppm.

Ozone and UV

Ozone is an effective oxidant and ozonated pools have a reduced need for superchlorination. Superchlorination is still periodically required to sanitise pool surfaces and prevent algal colonisation. UV light from both natural and unnatural sources has a positive benefit in chloramine reduction. (See page 41 for a fuller description.)

Oxygen based oxidisers

Oxygen based oxidisers are available, but are difficult to control. Expert advice should be sought prior to application. They have no application in ozonated pools, as ozone works in a similar manner.

Cyanuric acid

Cyanuric acid is a granular compound which, when dissolved in pool water, shields a percentage of chlorine from sunlight, thereby significantly reducing chlorine loss. It is an essential in outdoor pools, but has reduced benefit for indoor pools.

A slightly higher level of disinfection residual should be maintained within the pool water body because some studies have suggested that the speed of disinfection is slower when cyanuric acid is present. Oxidation is also impaired by the use of cyanuric acid, as the oxidation-reduction potential is reduced, particularly in still water conditions. This can be demonstrated by measuring the oxidation potential of a chlorine solution of equal chlorine concentration and pH when cyanuric acid is absent or present.

At least 25 ppm of cyanuric acid is needed for it to work efficiently, but there is no advantage in increasing levels above 50 ppm (except to allow for a drop-off in levels), due to backwashing and water losses on the pool deck.

Disinfectants containing isocyanurate continue to add cyanuric acid through the swimming season, so there is no need to top up cyanuric acid levels. High levels of cyanuric acid may contribute to water cloudiness and are controlled by dilution with fresh make-up water. In these pools, a start up dose of 25 ppm is recommended after refilling.

Cyanuric acid is extremely difficult to dissolve; gradually adding chlorinated isocyanurate disinfectants may be the easiest method.

Oxidation-Reduction Potential (ORP)

Oxidation-Reduction Potential ('ORP' or 'redox') measurements are a reliable indicator of water condition, as they measure the relative oxidative properties that are immediately available.

Research has shown that in chlorinated water, ORP values in excess of 720 millivolts (mV) using a silver/silver chloride electrode, or 680 mV using a Calomel electrode, should guarantee water that is in good microbiological condition. Values in excess of 750 mV can be achieved in good pools, with excellent filtration and supplementary oxidation processes. However, the action of other chemicals, pH and temperature may affect ORP values. Therefore, desirable ORP control settings are somewhat site-specific.

If ORP is used as a water quality parameter in its own right, compare the sensor response using Light's solution³ before interpreting the reading. The desirable ORP values above are based on a Calomel sensor reading 435 mV, or a silver/silver chloride sensor reading 475 mV, when placed in Light's solution.

ORP measurements themselves do not guarantee the capacity of the system to disinfect or oxidise a minimum quantity of contaminants per litre of water, so minimum free disinfectant residuals need to be measured by other means.

Controlling algae

Algae are single-celled green plants that thrive in water and sunlight. Spores are introduced into water via raindrops, wind-borne dust and on the feet of water birds. High pH, low chlorine, sunlight, warm water and mineral content—particularly phosphates and nitrates—all encourage algae growth.

In a pool that is used and maintained in accordance with the Health (Infectious Diseases) Regulations 2001, algae problems should never occur. Regular superchlorination should be all that is required. If algacides are used, there may be significant impacts on public health and on the environment. Firstly, they should not be present in pool water during the swimming season, unless 'exceptional circumstances' permission has been obtained from the Department of Human Services.

Also, most algacides are toxic to plants and stream life. Those containing metal ions or residual herbicides have properties that last for many months and are harmful to the environment, even if discharged to sewer. EPA policies require all unnecessary chemicals be avoided and that commercial pool operators undertake waste minimisation practices.

³ Light's solution is available from scientific instrument suppliers.

Algicides actually increase the rate of chlorine consumption, as metallic compounds and other complexes are oxidised by chlorine. Metallic or other compounds may alter the oxidation profile of the pool water and inhibit chloramine destruction and disinfection. Algicidal compounds generated from ionising electrodes are basically the same as residual metal-based algicides obtained from liquid or powder.

Unsuitable disinfectants

Some commercial pool disinfectants are not suitable for public pool use, because the rate of disinfection (biocidal efficacy) cannot prevent infectious disease in public pool situations. Some of these include:

- hydrogen peroxide
- silver/copper ions
- polymeric biguanides
- quaternary ammonium compounds
- ionisers
- electromagnets
- energy polarisers.

There are other disinfectant systems marketed in Australia which involve the use of mechanical or other chemical methods. For example, oxygen based oxidisers are available, but are difficult to control. They have no application in ozonated pools, as ozone works in a similar manner. If in doubt, contact the regulatory authority for advice.



Table 6 Characteristics of pool water disinfectants

Chemical or process	Form	Shelf life	Typical concentration of active ingredient	pH when solution made into	Effect on total alkalinity	Effect on calcium hardness	Cyanuric Acid required for outdoor use	Suitable for in line dosing	Comments
Chlorine gas	Gaseous cylinder	Years	100%	2	Decreases	Nil	Yes	Yes	<ul style="list-style-type: none"> Mostly used in large pools with trained pool operators. Dangerous Goods (Storage and Handling) Regulations 2000 restrict the siting of gas plant. Usually requires alkali dosing. Low operational maintenance.
Sodium hypochlorite	Liquid	4–12 weeks	12.5%	11	Increases	Nil	Yes	Yes	<ul style="list-style-type: none"> General use in all pools. Usually requires acid dosing. Flexible in dosage requirements. High operational maintenance. Shelf life depends upon storage conditions.
Calcium hypochlorite	Granules Tablets	Years Years	65% 65–70%	9 9	Increase Increase	Increases Increases	Yes Yes	No Can be used in erosion feeders but solubility is poor	<ul style="list-style-type: none"> Used for shock dosing. Can be used in manual dosing for lightly loaded pools prior to pool opening. Good for soft water. Useful for winterising.
Lithium hypochlorite	Granules	Years	35%	10.5	Increases	Nil	Yes	No	<ul style="list-style-type: none"> Mostly used in indoor spa pools.
Sodium dichloroisocyanurate (dichlor)	Granules	Years	58–63%	6.8	Nil	Nil	No—contains stabiliser	No	<ul style="list-style-type: none"> Mostly used in outdoor spa pools. Has little effect on pH/alkalinity. Must monitor cyanuric acid levels.
Trichloroisocyanurate (trichlor)	Tablets	Years	85–90%	2.4	Decreases	Nil	No—contains stabiliser	Yes (erosion canister)	<ul style="list-style-type: none"> Small pools with low/medium bather load. Good for hard water areas. Not suitable for pools with variable bather loads or long operating seasons. Must monitor cyanuric acid levels.

Table 6 Characteristics of pool water disinfectants (continued)

Chemical or process	Form	Shelf life	Typical concentration of active ingredient	pH when made into solution	Effect on total alkalinity	Effect on calcium hardness	Cyanuric Acid required for outdoor use	Suitable for in line dosing	Comments
Salt chlorinator	Electrode plate using salt in saline pool.	Years	Depends on the size of electrodes, flow and operating time.	mildly alkaline	Increase	Decrease	Yes	Yes	<ul style="list-style-type: none"> Low maintenance system suitable for non-professional operators. Good where chemical handling and storage are issues of concern. Not suitable for pools that are subject to sudden large increases in bather load.
Bromine (BCDMH)	Tablets	Years	90%	4.5	Decrease	Nil	Not suitable	Yes (erosion canister)	<ul style="list-style-type: none"> Mostly used in indoor spa pools and hydrotherapy pools with elevated temperatures. Slow to respond to sudden large increases in bather loads.
Bromine (sodium bromide/sodium hypochlorite)	Liquid	4–12 weeks	Depends on formulation. 8–22% chlorine equivalent. Can be manufactured on-site.	11	Increase	Nil	Not suitable	Yes	<ul style="list-style-type: none"> Mostly used in indoor spa pools. Chloramine can form and be a problem and is not easily removed. The presence of bromide inhibits chlorine oxidation and superchlorination/shock dosing is not practical.
Sodium bromide/ozone	Liquid and corona discharge ozone generator.	Years	Limited by ozone output.	n/a	n/a	n/a	Not suitable	Yes	<ul style="list-style-type: none"> System has been demonstrated to be not practical in many working situations. Does not cope well with varied bather loads. Is not compatible with chlorination. Bromine residual difficult to control. If ozonator breaks down, pool has to be closed or chlorine substituted as activator.
Chlorine—chlorine dioxide	Stabilised liquid plus any form of chlorine.	See label directions also see chlorine.	Manufacturers' Specifications.	Variable	Variable	Nil	Yes	Yes	<ul style="list-style-type: none"> Must be used with chlorine. Regular superchlorination required to reduce chlorite build-up. Suitability currently under investigation by the Department of Human Services.

Ozone and ultraviolet radiation

Overview

Ozone and ultraviolet radiation water treatment systems are different from the other methods discussed, because they purify the pool water as it passes through the plant room. Both deal with water contaminants without providing a disinfectant residual, and allow the water in the pool itself to operate with a lower level of conventional residual disinfectant than it otherwise would.

Both ozone and ultraviolet radiation are potentially hazardous and attention should be paid to the safety of plant room operators, particularly during maintenance. Ozone plant rooms should be ventilated to Occupational Health and Safety Regulations 2007.

Ozone

Until recently, the prime objective of chemical treatment of a pool was to create a body of water that was clean and healthy in which one could swim with safety. An additional concern of pool operators and health authorities was to have a water and pool hall environment that looks appealing to the pool customer.

With the increasing demand for improved water quality, ozone is now being used with a measure of success and is being more widely used in public pools. Its use results in vastly improved water quality, both from health and aesthetic aspects where water quality problems exist.

Chemistry

Ozone is a bluish/purple gas that can appear naturally around electrical equipment, but for pool water disinfection, it is generated on-site.

As ozone is relatively unstable, it cannot be manufactured elsewhere and then transported to the pool in cylinders, like chlorine. Ozone is produced in a generator, when high voltage electricity is passed across a discharge gap. When dried air containing oxygen passes through this gap, the oxygen molecule is activated 'up to' an ozone molecule. Only a small percentage of the oxygen in air is converted to ozone.

It is toxic in significant atmospheric concentrations, so excess (unreacted) ozone must be removed within the treatment system.

Dealing with contaminants

The chemistry between ozone and pool contaminants is complex. Ozone interferes with the reactions that produce contaminants, more so than actually destroying urea, amino acids or trihalomethanes. There are also significant reactions that allow subsequent filtration of the organic molecules by a process of microfloculation. A slow reaction with chloramine to form chloride and nitrate also occurs, thus enhancing breakpoint chlorination and the removal of ammonia. The filters—especially granular activated carbon (GAC)—that remove ozone from the water before it returns to the pool, also remove some contaminants (activated carbon filters will also remove chlorine). The effect of ozonation and GAC filtration is to remove most of the chloramine, so the purity of the water is enhanced before it re-enters the pool.

As a result, the low dose of chlorine added to the water after filtration is completely available as a free chlorine residual for the pool. Well managed ozone pools are generally odour free.

Dosing with ozone

There are two different ways in which ozone can be used. In each case, the contact time between ozone and water should be two minutes or more; the O_3 concentration during this period 0.8–1 ppm.

With new installations, all the water to the pool should be dosed with O_3 at a concentration that depends on what specific system is used. Ozone acts best in contact with filtered water, so systems with separate filtration, ozonation and de-ozonation are best. All-in-one systems are an acceptable compromise.

On existing installations where, due to space restrictions, it is not possible to install equipment to ozonate the total flow rate of the system, treating a percentage of this flow rate may be considered. This so-called 'slipstream ozonation' should dose a minimum of 20 per cent of the flow rate. The benefits of slipstream ozonation will be proportional to the percentage of water ozonated; but installation costs will not be. Therefore, cost-effective benefits are likely to be difficult to achieve.

Figure 9 Pool water treatment with ozone and hypochlorite



De-ozonation

The de-ozonation stage immediately follows ozonation; all traces of ozone must be removed from the treated water before it enters the pool. Granular activated carbon (GAC), activated heat-treated anthracite and thermal destruction methods are commonly used for de-ozonation.

ORP probes (above) detect oxidation levels in pool water before de-ozonation and after de-ozonation. They check the effectiveness of the ozonation and de-ozonation processes.

Plant safety

Ozone in concentration is a dangerous gas and leakage into the plant room presents a serious occupational health risk. Ozone has a distinctive smell, but an ozone leak detector should still be installed within the plant room. Ozone carrier pipes need to be fully sealed and pressure tested periodically, to ensure that the installation can withstand the pressures involved. Where air containing ozone is bled off the top of filters (degassing), the air should be passed through a carbon destructor to destroy ozone gas prior to discharge outside the plant room.

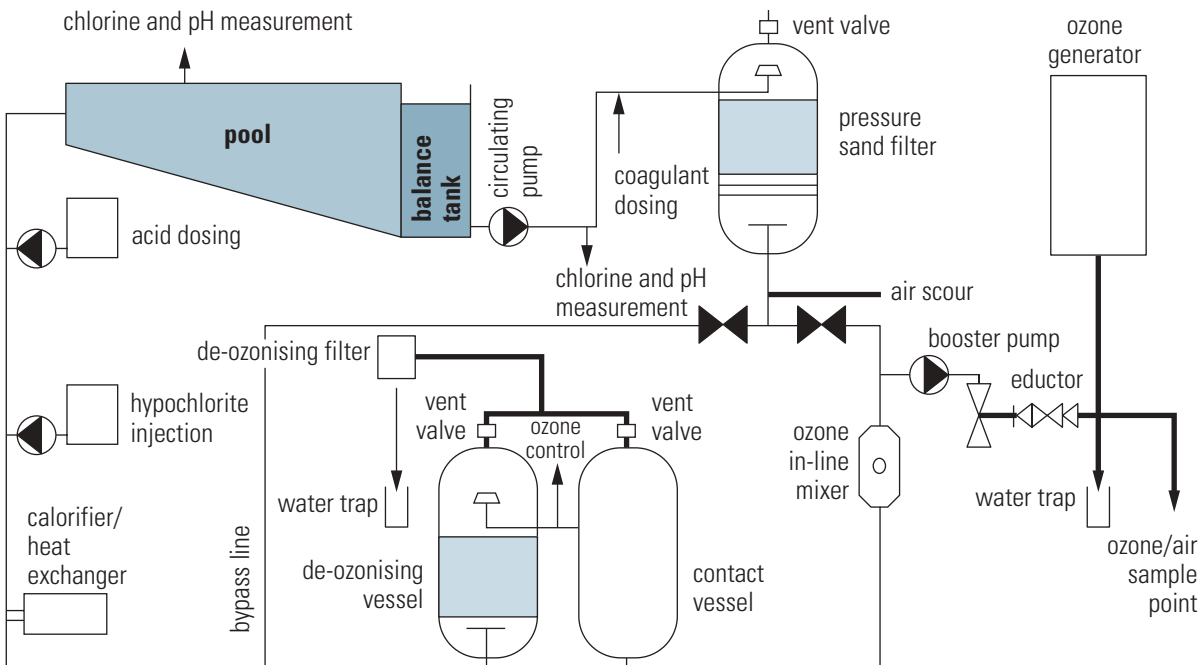
Figure 11 Ozone leak detector



Figure 12 Ozone off-gas destructor



Figure 10 ORP probes



Bacterial colonisation

Chlorine is removed with the ozone. If it is totally removed, there may be bacterial colonisation of the filter. Therefore, maintain some degree of residual disinfection throughout de-ozoneation. Bed depth and filter velocity appears to be critical here. Recent experience has indicated that colonisation is likely in the de-ozoneation media (particularly GAC) if the bed depth exceeds the levels recommended above, or if the velocity through the media is too low.

Residual dosing

After ozonation and de-ozoneation, the water should be essentially free from bacteria, and most organic matter oxidised. It will not contain enough residual disinfectant to prevent cross-infection within the pool itself. A disinfectant residual must therefore be provided, normally sodium hypochlorite.

pH Value

In all cases, the pH value should be maintained within the Health (Infectious Diseases) Regulations 2001. The agent for pH control should be selected according to the nature of the fresh water supply and disinfection type.

Ultraviolet radiation (UV)

The disinfectant ability of ultraviolet radiation is well established. UV treatment has long been used in drinking water, industrial and effluent applications.

UV kills bacteria, viruses, moulds and spores, which reduces the risk of transmission of stomach, skin and respiratory tract infections to pool users. An important secondary action is initiating photochemical and photo-oxidation reactions which destroy chloramines. This is particularly important in leisure pools, where features such as water slides and waves provide a greater surface area for the release of chloramines into the air. UV reduces the burden, making the atmosphere safer and more pleasant.

The limiting factor tends to be water clarity, as dissolved and suspended material inhibits UV penetration. Filtration will remove some of these solids from swimming pool water, but to optimise the effectiveness of the UV, it is important that the full flow of water returning to the pool is exposed to the ultraviolet radiation. This will ensure the pool water is treated on a regular and continuous basis. An automatic wiper removes solids that settle onto the quartz thimble around the UV arc tube.

To maintain a disinfectant residual in the pool, a chlorine or bromine based disinfectant must be used in conjunction with UV systems.

Water balance

Overview

Water balance describes the scale or corrosion activity of pool water. These aspects must be controlled while remaining within correct pH for disinfection efficacy and bather comfort. Water balance is affected by five factors:

- pH
- total alkalinity
- calcium hardness
- temperature
- total dissolved solids (TDS).

These factors are discussed individually below.

pH

pH is a measure of the relative acid/alkali strength of a solution. pH is measured on a scale from one to 14, with 7.0 being neutral. Correct pH is essential for three reasons:

- equipment protection
- bather comfort
- sanitiser (disinfection) efficiency.

When pH is too high (relative to the other water balance parameters), water is more likely to have scale-forming properties. When pH is too low, water will become corrosive to pool equipment and surfaces. The pH of the eye fluid is around 7.4, so good quality water within the prescribed pH range should not cause eye irritation.

As pH increases, free chlorine loses oxidative activity. At a pH of 8.0, only 20 per cent of free chlorine is immediately available as hypochlorous acid to kill germs. At a pH of 7.5, about 50 per cent is immediately available.

The pH change in pools is caused by adding disinfectants—which can be strongly acidic or alkaline—and the acids present on pool users' skin. Aeration in spa pools tends to drive the pH up, by removing acidic gases. Dilution (diluting) water may affect the pH, in extreme cases. See Table 6 for the pH effect of disinfectants.

Total alkalinity

Total alkalinity measures the amount of alkaline salts present in the water. Total alkalinity works as a 'shock absorber', reducing pH fluctuation when alkalinity is above regulatory limits. Conversely, total alkalinity above 200 ppm can make any necessary pH adjustment difficult.

Higher total alkalinity is appropriate when using acidic disinfectants, such as chlorine gas, trichlor or BCDMH. To increase total alkalinity, the number of dissolved alkaline substances should be increased.

Calcium hardness

Calcium hardness measures the amount of calcium salts present in the water. Relative to the other water balance parameters, if calcium hardness is too high, scaling of heaters and pool finishes may occur. If calcium hardness is too low, etching of cement and tiles and corrosion of heating and circulation components may occur.

Calcium behaves differently from most chemicals, in that it becomes less soluble as temperature rises.

In areas of high calcium source water, specialist advice should be sought before establishing recommended water balance parameters and choice of disinfectant and pH chemicals.

Temperature

The higher the temperature, the more likely scaling is to occur, because calcium solubility is lowered. At a lower temperature, the water can absorb more calcium. Concrete, marble sheen or tiled pool surfaces may become etched, particularly at low temperatures.

Total Dissolved Solids (TDS)

TDS measures all solids and salts dissolved in pool water. TDS is increased by the addition of chemicals and salts from pool users and concentrated further by the evaporation of water. Salt in salt chlorinated pools constitutes the bulk of TDS and must be accounted for when measuring TDS.

Adjusting water balance parameters

Increase total alkalinity

- Add 1 kg sodium bicarbonate per 10,000 L of pool water, to increase the total alkalinity by 50 ppm.

Decrease total alkalinity

- Diluting pool water will lower alkalinity in most situations. If consistently high total alkalinity is creating problems, expert advice should be sought on the choice of disinfectant and pH correction chemicals.

Decrease pH

- Before adjusting pH, ensure the total alkalinity is appropriate and stable.
- Add 100 mL of hydrochloric (muriatic) acid or 120 g of sodium bisulphate (dry acid) per 10,000 L of pool water for a decrease in pH by approximately 0.1–0.3. Always dilute the acid in fresh water before adding it to the pool.

- No more than 100 mL of hydrochloric acid or 120 g of sodium bisulphate per 10,000 L should be added at once. Otherwise, the pH may be lowered dramatically.
- The pH should be retested after a turnover period before adding further acid.
- Carbon dioxide gas can also be used to decrease pH and can be injected automatically.
- Hydrochloric acid and sodium bisulphate should be diluted according to the manufacturer's instructions when dispensed via automatic dosing equipment. Otherwise, a dilution of at least one in ten should be prepared before manually adding it to the pool water. Never add acid to the water body of the pool while it is in use.

Figure 13 Carbon dioxide tank



When lowering pH, carbon dioxide is often preferred to acid.

Increase pH

- Before adjusting pH, ensure the total alkalinity is appropriate and stable. If pH is not corrected by setting the total alkalinity level, it can be further raised by adding more sodium bicarbonate (pH 8.2). However, this will further increase the alkalinity.

In most pools, pH can be effectively controlled by using sodium bicarbonate, without increasing alkalinity excessively. Sodium carbonate, also known as soda ash (pH 12.1), is sometimes used, but is more dangerous to handle than sodium bicarbonate and contributes to scale formation. Adding sodium hydroxide, also known as caustic soda (pH 14), to correct pH will cause high pH problems and should not be used.

Figure 14 Hazards of poor labelling



Increase calcium hardness

- Add 110 g of calcium chloride, or 140 g of calcium sulphate, per 10,000 L of pool water to increase calcium hardness by 10 ppm.

If calcium hardness is consistently too low, consider using calcium based disinfectants.

Decrease calcium hardness

- Diluting pool water is the only practical way to lower calcium hardness. If calcium hardness is high, disinfectants containing calcium should be substituted for those containing sodium.

Lower Total Dissolved Solids (TDS)

Dilute pool water usually by backwashing and refilling with fresh water. Regular dilution according to bather loading and backwashing should eliminate high, unaccounted-for TDS from occurring.

Calculating water balance

Water balance can be calculated using a number of indexes or tables. The Saturation Index (SI), also called the Langelier Scale, is the most universally accepted method. SI is a formula used to determine whether water is balanced, according to the following factors:

- pH
- total alkalinity (TA)
- calcium hardness (CH)
- temperature (T)
- total dissolved solids (TDS Constant = 12.1).

If the balance of these factors is too low, water will be corrosive to fittings and finish. These corrosive conditions occur when SI is less than -0.5 (for heated water, SI should not be less than -0.2).

When the balance of these factors is too high, water will cause deposits to form on fittings and finish. These scale-forming conditions occur when SI is more than +0.5.

The formula for Saturation Index is:

$$SI = pH + TF + AF + CF - 12.1$$

Best Practice Model

- Pool water should be appropriately balanced to prevent scaling and corrosion of fixtures and fittings.
- Automatic monitoring and dosing of pH correction chemicals should be used in all spa pools and other pools subject to fluctuating pH.
- Maintain total alkalinity levels that are appropriate to the type of disinfectant used.
- Maintain pH within tight tolerances when using automatically controlled disinfectant dosing.
- Excess Total Dissolved Solids (TDS) should be diluted with fresh water.

Table 7 SI Index of Factors

Temp (°C)	TF	Total Alkalinity	AF	Calcium Hardness	CF
0	0.0	5	0.7	5	0.3
3	0.1	25	1.4	25	1.0
8	0.2	50	1.7	50	1.3
12	0.3	75	1.9	75	1.5
16	0.4	100	2.0	100	1.6
19	0.5	150	2.2	150	1.8
24	0.6	200	2.3	200	1.9
29	0.7	300	2.5	300	2.1
34	0.8	400	2.6	400	2.3
41	0.9	800	2.9	800	2.5
51	1.0	1,000	3.0	1,000	2.6

Dosing and control systems

Overview

All pool disinfection systems should be designed to match the expected rate of disinfectant consumption *under the worst conditions that may be expected*. For some pools, this may be bright sunshine at 40°C and standing room only.

The higher the pool turnover rate, the easier it is to circulate the disinfectant, measure it and respond to demand. Some systems, such as chlorine gas and liquid chlorine, are quite flexible in the amount that can be injected per hour. Others such as salt chlorinators and erosion feeders (BCDMH, trichlor) must be correctly sized on the basis of pool volume, flow rate and anticipated bather load and have a reserve capacity to cope with peak situations.

Design of dosing systems

Metering pumps dispense liquid systems at pressure into the circulation system. Usually, the stroke volume and frequency can be adjusted to change feed rates. These pumps require priming to ensure that air bubbles are not present in the lines, which may cause ineffective pumping.

Gas systems (chlorine and carbon dioxide) use valves and an injector into a circulation loop. The feed rate can be set using a sight glass valve on the cylinder.

Figure 15 Metering pump



Metering pump mounted on liquid container

Figure 16 Carbon dioxide controller



Tablets are dosed by installing a flow through an erosion canister (feeder), where the circulation flow passes through eroding the tablets within. This is usually done in-line or on a side-stream basis, where flow is controlled by a valve.

Figure 17 Erosion canister (erosion feeder)



Points of dosing

There are varying arguments about the merits of where chemicals should be dosed.

Disinfectants, when dosed before the filter, have the advantage of continuously disinfecting the filter media preventing colonisation of organisms, such as *Pseudomonas* and *Legionella*. The disadvantage is that more chloramines may be created and disinfectant consumption may increase. However, if disinfectant is injected after filtration, regular superchlorination will also control filter colonisation. Where ozonation is present, disinfection should take place after ozone is removed.

Control systems

Control systems analyse disinfectant and pH levels using a sensor and electronic meter, and when outside the set parameters, send a signal to the pump or solenoid valve to allow more chemical to be injected or released.

Controllers are divided into two types:

1. *Proportional controllers* that feed faster when the measured concentration is far away from the set point. Conversely, the addition rate slows when the pool condition is close to the set point.
2. *Feed wait control*, where chemical addition is performed at the same rate when away from the set point.

Figure 18 Pool control panel and chemical measuring station



Either type of controller should have facilities to minimise 'controller bounce' (dampening of signal variations). The pumps should be adjusted to deliver chemical at an appropriate rate per hour, to minimise overdosing.

Some control systems can also measure electrical conductivity and operate a dump valve to ensure dilution of pool water and control of TDS.

Safety issues

Relevant markings to Australian Standards or international standards prescribed by Standards Australia should be present on the controller. The units should be mounted in a safe area and not directly subject to accidental water splashes, such as may happen when cleaning electrodes. The mains power supply to the controller should have safety circuit breakers fitted, both for the pool operator safety and to provide some protection of the controller electronics.

Disinfectant and acid should not be added simultaneously. The controller system itself, or some other means, should prevent acid and disinfectant contact.

Pumps and other chemical delivery units should be constructed from materials rated for use with the pool chemicals being delivered. Close attention should be paid to tubing used for disinfectant and acid. Inspect this tubing at least weekly.

Sensors

pH sensors

pH is measured by a glass electrode that selectively measures the relative hydrogen (acid) activity and sends a reading in millivolts to a pH meter/controller. The meter/controller converts this into pH units.

Disinfection sensors

There are two commonly used methods of automatically analysing disinfection: Direct Chlorine Residual Measurement (Amperometric) and Oxidation-Reduction Potential Measurement (ORP, Redox, Rh).

Direct Chlorine Residual Measurement (Amperometric)

This method uses a chlorine sensor to estimate the actual concentration of free chlorine, by measuring the hypochlorous acid component. Because pH affects the ratio of hypochlorous acid/ion, keep it constant so that the free chlorine is measured accurately.

Oxidation-Reduction Potential Measurement (ORP, Redox, Rh)

This method uses a platinum electrode to measure the relative oxidative strength of the water. When the pH is kept constant, there is generally a close relationship between free chlorine and ORP readout. Because pH affects the ratio of hypochlorous acid/ion, it should be kept constant so that the free chlorine effect is measured accurately.

Calibrating sensors

Chlorine

Because it is difficult to obtain stable chlorine solutions, primary calibration of equipment is usually not done. Compare the readout with the result obtained from a DPD photometer or comparator, and realigning the readout to match the DPD test.

ORP

Calibration is not required for ORP sensors used to control disinfection, as the individual readings are electrode- and site-specific. Finding the correct minimum ORP setting for each pool requires monitoring of pool performance and correlation with measured water quality and disinfection parameters with ORP readings.

pH

Primary calibration of a pH sensor should be done with two standard solutions that cover the swimming pool pH range. These standard solutions can be obtained from scientific suppliers. Solutions commercially available as pH 7.01 and pH 9.01 are recommended, as this will produce an accurate response in the desired range. To make a secondary calibration of controllers, measure the pool water with a separate pH meter or phenol red indicator and adjust the controller accordingly.

Location of sensors

Sensors should be located at a point representative of the actual swimming conditions. Sensors can be inserted directly into the circulation loop, subject to manufacturer specifications on pressure and flow velocities.

Alternatively, a loop can be created which side-streams a small flow to a wall-mounted sensor installation.

Figure 19 Chemical sensors installed in a side-stream loop



Cleaning sensors

Sensors should be regularly inspected, cleaned and calibrated in accordance with manufacturer's directions, or when fouling or faulty operation is suspected.

Sensors that have not been cleaned for several months may be extremely inaccurate. Comparing the controller readout with pool test results will indicate the necessary cleaning frequency. After cleaning, recalibration is required.

Best Practice Model

- Disinfectant dosing systems for all pools should be designed to cope with a range of bather loads.
- Aim for continuous dosing that matches consumption rates.
- Automatic monitoring and dosing of disinfectant should be used in all spa pools and other pools that are subject to inconsistent chlorine demand.
- To ensure accurate results, regularly calibrate control systems.
- Dosing systems should be designed so that disinfectants do not come in contact with acids.

Monitoring systems



Chemical testing

Best Practice Model

- Photometers or comparators should be used for all manual chemical tests.
- Operators should prescribe their desired range of operating parameters within the regulatory range.
- Operators should be competent in the use of test kits.

Photometers or comparators that use tablet or powdered reagents are recommended for all chemical tests and are reasonably accurate. Most test kits use solid (tablet or powdered) reagents, as they are easy to store, transport and contain. Pre-measured packages eliminate the need to dispense precise amounts of reagent to each test.

Figure 20 Photometer



All equipment should be stored away from direct sunlight and kept clean. Inaccurate measurements may result from faded comparator discs or plates, dirty glassware or suspended matter in the sample.

Figure 21 Comparator



Successful use of a comparator may be affected by the operator's capacity to discern colour intensities or colour differences. The background against which a comparator is held may also affect the colours observed.

Figure 22 Dry reagents



Dip strips can be used to indicate that a pool is somewhere within regulatory range. However, it is nearly impossible to quantify the reading accurately, because the scale intervals are too far apart. Dip strips containing syringaldazine are the only ones suitable for indicating free chlorine concentrations.

Always follow the manufacturer's instructions when using a test kit. Specific training in the proper use of test kits is strongly recommended.

Figure 23 Test strips



Test methods

The following test methods are recommended for those tests required by regulatory authorities: free chlorine/total bromine, total chlorine, combined chlorine, pH, alkalinity, cyanuric acid, calcium hardness and some others.

Free chlorine/total bromine

The DPD (dimethylphenylenediamine) test developed by Palin is the swimming pool industry's accepted test method for measuring disinfectant concentrations. DPD No 1 reagent is used for both free chlorine and total bromine tests. Total bromine should be recorded as free chlorine equivalent.

Total chlorine

A DPD No 3 tablet is added to the completed free chlorine test, giving the total chlorine concentration (DPD 1+3). A DPD No 4 tablet also gives total chlorine concentration, but without obtaining the free chlorine concentration first.

Combined chlorine

This is obtained by subtracting the free chlorine/total bromine (as free chlorine equivalent) concentration from the total chlorine concentration.

The formula is:

$$\text{DPD 4} - \text{DPD 1 or (DPD 1+3)} - \text{DPD 1}$$

pH

Phenol red indicator is used, as the colour range operates across that of a properly operating swimming pool. A properly calibrated pH electrode may also be used.

Alkalinity

Any commercially available pool water colorimetric test method can be used. Most indicator tests use a colour range from yellow through green to blue.

Cyanuric acid

Melamine test reagent can be used and forms a cloudy suspension. Accuracy will depend on concentration and equipment factors.

Calcium hardness

A colorimetric tablet method is commonly available to estimate hardness. Hardness is calculated based on the number of tablets required to reach the required colour change. A photometer may be used instead.

All other tests

Colorimetric, titration based reagents or electrochemical methods are available for most other test parameters.

Dilution of samples

When a test result is at the top of the range of a test kit, samples that are measured in ppm may be diluted with distilled water before adding the reagent, to obtain a reading that is on scale. The result is multiplied by the dilution factor.

Excessively high chlorine may bleach the tablet, making it appear that there is no chlorine in the water. This may cause operators to add more chlorine to the pool. Avoid this by crushing a tablet in a small volume of pool water, then completely filling the sample cell with pool water and observing the pink colour turn clear.

Dilute the sample so that the reading is within regulatory range and multiply that reading accordingly, to measure the actual concentration. Refer to test kit instructions to improve this description.

pH measurement samples cannot be diluted. If the reading is off the scale, use another indicator or a pH meter to determine the correct value.

Dilution instructions for free chlorine:

1 in 2 Dilution

- Fill the dilution tube to 50 mL mark with pool water sample.
- Add 50 mL of distilled water to the pool water in the dilution tube, to make up to the 100 mL mark.
- Place lid on the tube and invert several times to mix the solution thoroughly.
- Place the diluted sample in both the blank tube and the test tube, and test in the normal manner.
- The result should be multiplied by two, to give the correct reading of the original sample. If the free chlorine level still exceeds the maximum indicated, a 1 in 5 dilution is required.

1 in 5 Dilution

- Fill the dilution tube to the 10 mL mark with pool water sample.
- Add 40 mL distilled water to the pool water in the dilution tube, to make up to the 50 mL mark.
- Place the lid on the tube and invert several times to mix the solution thoroughly.
- Place the diluted sample in both the blank tube and test tube and test in the normal manner.
- The result is multiplied by five to give the correct reading for the original sample.

Chemical limits

Operators should set their own desired chemical limits for operation—within the range prescribed by the Health (Infectious Diseases) Regulations 2001. A table suitable for recording this type of information is provided in this Handbook see page 53. Operators should ensure that they refer to the most up-to-date Regulations when completing this table.

Keeping records

Operators are required by law to maintain records. A suggested logbook is provided in the on page 54. Logbooks should be kept for at least 12 months after the last date of entry, to be made available on demand to an authorised officer of the Health Act 1958. The records should then be archived for a further six years.

Records should cover the following tests and be carried out at least the frequencies prescribed by Regulatory Standards:

- date
- time
- free chlorine/total bromine
- total chlorine
- combined chlorine
- pH
- orp (where fitted)
- electronic pH (where fitted)
- total alkalinity
- cyanuric acid
- calcium hardness
- comments
- actions
- name of recording operator
- pool water temperature
- clarity
- bather load.

Table 8 Legislative limits for swimming and spa pools

Chlorinated Pools

Chlorine Residual	Spa Pools		Swimming Pools	
	Cyanuric Acid not present	Cyanuric Acid Present	Cyanuric Acid not present	Cyanuric Acid Present
Free Chlorine Minimum	2 mg/L	3 mg/L	1 mg/L	2 mg/L
Free Chlorine Maximum	8 mg/L	8 mg/L	8 mg/L	8 mg/L

Brominated Pools

Bromine Residual	Spa Pools		Swimming Pools	
Free Bromine Minimum	4 mg/L or 2 mg/L measured as a chlorine equivalent		2 mg/L or 1 mg/L measured as a chlorine equivalent	
Total Bromine Maximum	8 mg/L or 4 mg/L measured as a chlorine equivalent		8 mg/L or 4 mg/L measured as a chlorine equivalent	

	Minimum	Maximum
pH	7.2	8.0
Total Alkalinity	60 mg/L	-
Cyanuric Acid	-	100 mg/L
Temperature of Operation		40°C

Frequency of Testing

	Spa Pools	Swimming Pools
Free Chlorine	4 Hourly	4 Hourly
Total Bromine	4 Hourly	4 Hourly
Combined Chlorine	Daily	Daily
Total Alkalinity	Daily	Weekly
Cyanuric Acid	Weekly	Monthly

Sample log sheets

Chemical limits worksheet

Levels		Pools		Spas		Testing frequency
		minimum	maximum	minimum	maximum	
Free chlorine Total bromine (ppm)	Recommendations					
Combined chlorine (ppm)	Recommendations					
Total chlorine (ppm)	Recommendations					
pH	Recommendations					
Total alkalinity (ppm)	Recommendations					
Cyanuric acid (ppm)	Recommendations					
Redox (mV)	Recommendations					
Calcium hardness (ppm)	Recommendations					
Temperature of operation (°C)	Recommendations					

Sample pool operator log sheet

Date: _____

Pool: _____

Time						
Measurements						
Free Chlorine						
Combined Chlorine						
Total Chlorine						
pH						
Redox (mv)						
Electronic Chlorine						
Electronic pH						
Temperature						
Total alkalinity						
Calcium hardness						
Total Dissolved Solids						
Langelier Index						
Cyanuric acid						
Adjustments/additions						
Disinfectant						
pH correction						
Bicarbonate						
Alum/coagulant						
Others						
Others						
Observations						
Filter pressures						
Backwashes done						
Clarity						
Make Up						
Bather load						
Water meter reading						
Backwash (litres)						
Dilution (litres)						
Operator's initials						

Actions/Comments

Microbiological monitoring

Overview

As described in the chapter Health and hygiene, certain infections have been associated with the use of swimming pools and spa pools. Poor management of water treatment processes is the usual cause, leading to the survival of pathogenic organisms introduced by pool users. Where serious illness results, there are grounds for prosecution.

Cryptosporidium is the only organism of pathogenic significance that can withstand properly treated pool water. However, as pool water can provide ideal conditions for growth, other microorganisms of environmental origin can multiply in poorly managed pools.

Most organisms capable of living in water grow best at temperatures between 20°C and 45°C. Those normally associated with humans grow well at 37°C. Most pool bacteria tests are incubated at 37°C for this purpose. Each viable bacterium multiplies to form a colony and is therefore called a colony-forming unit (CFU). Bacterial results are reported as CFU per millilitre or CFU per 100 mL of sample (CFU/mL or CFU/100mL).

Microbiological monitoring for pool operators is a quality assurance activity. Good water treatment practices and control of critical physical and chemical parameters equals quality control. Microbiological standards for pools are used by health authorities to establish the seriousness of non-compliance with chemical parameters and identify causes.

A short-term fall in chlorine residual may not be enough to allow the growth of *Pseudomonas* or rise in plate count within pool water. Such growth may be present if a pool was not chlorinated adequately over many hours or days.

Deficiencies in microbiological parameters resulting from poor management practices can contribute to serious illness and are grounds for prosecution by health authorities.

Frequent monitoring of chemical parameters is necessary to ensure that critical limits of disinfection are not breached. Close attention to filter performance is also required.

When occasional, minor deviations from the regulatory limits occur and are identified and corrected promptly, health or water quality problems seldom occur.

Pools must be closed while chemical and physical parameters are outside regulatory limits.

Occasionally, microbiological problems develop in pools because design inadequacies cause poor circulation and turnover. These may occur in areas such as entrance steps cut away from the side of the pool. When colloidal matter gathers or chlorine levels drop in these areas, microbiological contaminants may be present. Confirm that the water treatment regime is satisfactory by conducting microbiological testing.

Best practice model

- Only pool operators who have a microbiological sampling program can verify the effectiveness of their everyday quality control parameters.
- Monitoring frequency should reflect the relative microbiological risk that each type of pool presents. Quarterly monitoring is sufficient for most pools.
- Where there is a significant deviation in disinfection below regulatory limits, perform microbiological tests and record data for future reference.
- Where microbiological samples do not comply with accepted Standards, re-sample to ensure that corrective actions have restored microbiological quality.
- Document all observations, results and findings.

Microbiological testing

Microbiological samples should be submitted for analysis at a laboratory with NATA accreditation for the particular tests required.

Assessing microbiological quality

Taken together, the standard plate count test, the coliform test and *Pseudomonas aeruginosa* test are the simplest way to assess the microbiological quality of swimming pool water.

Chemical parameters (pH, disinfectant residual, ORP, TDS and cyanuric acid) should be tested and recorded at the time of sampling. Note any other relevant observations, such as bather loading or plant failure.

Standard plate count

The standard plate count grows several bacterial species, without differentiating between them. It gives a good indication of the overall bacterial population within the pool environment. The result is normally reported as colony forming units per millilitre of water (CFU/mL). A standard plate count of less than 10 CFU/mL and the absence of coliforms and *Pseudomonas aeruginosa* can be expected from most well managed pools.

A standard plate count in excess of 100 CFU/mL clearly shows that operating conditions are unsatisfactory and require investigation, regardless of the disinfectant used. It may be related to filter performance or physical matter present in the pool.

Coliform count

Coliform bacteria, particularly *Escherichia coli* (*E. coli*), live in the intestinal tract of humans and other warm-blooded mammals, where they are present in great numbers.

The coliform test is vital in assessing the immediate effectiveness of the disinfection process, especially when bathers are using the pool at the time of testing.

Pseudomonas aeruginosa

Pseudomonas aeruginosa is a pathogenic organism causing ear and skin infections, particularly folliculitis. *Pseudomonas* lives in drains and slimes and can often colonise filter media, particularly where there is not frequent backwashing, superchlorination or other oxidising processes to penetrate the filters. The presence of *Pseudomonas* may indicate the possible presence of other environmental pathogens, such as *Legionella*, which, if unchecked, can thrive in warmer pools.

Other organisms

Provided satisfactory results are obtained for these three specified tests, routine testing of other organisms is not recommended, unless a particular health problem has been associated with a pool.

Staphylococcus is often found where pool users are present and its distribution within the water tends to favour the surface. It is associated with flaking skin, dandruff and nasal secretions, because chlorine cannot immediately penetrate some particles. *Staphylococcus* is further controlled by effective water removal at the surface, by skimmers, spill gutters and subsequent filtration.

Cryptosporidium is a complex issue, as it has wider implications to pool management—refer to the Health and hygiene chapter.

Refer to the Department of Human Services Pool Fact Sheets located at <http://www.health.vic.gov.au/environment/water/swimming.htm> for further advice on *Cryptosporidium*

Health authorities may be required to sample pool water and test for specific pathogens when investigating specific illnesses. Generally, in the absence of notified cases, testing for other organisms other than required by the Health (Infectious Diseases) Regulations 2001 is unwarranted. Pool operators should seek advice from the public health authority prior to taking samples for specific pathogens.

Sampling procedure

About 250 mL of sample is required for all recommended tests. Sterile plastic bottles are recommended, because of the risk of glass breakage. Bottles should be pre-treated with sodium thiosulphate, to neutralise chlorine or bromine, giving a true indication of the water quality experienced at the time of sampling. Laboratories will normally prepare these for their clients.

Take a microbiological sample by removing the cap with one hand, making sure nothing touches the inside of the cap or bottle. The bottle is immersed neck down in the water, to about 30 cm below the surface, then tilted to face horizontally away from the hand and allowed to fill. The bottle can be moved away from the sampling hand until it is sufficiently full. Remove bottle and replace cap. Refrigerate sample immediately and transport to the laboratory without delay. Ideally, testing should be commenced within six hours of sampling. Testing commenced after 24 hours of sampling cannot yield reliable information.

Figure 24 Microbiological sampling technique



Sampling location

In most pools, there is no significant difference between sampling points when it comes to water quality parameters, provided samples are not taken from a return point.⁴

Take water samples near a suction point, where users have not been swimming nearby in the previous 60 seconds. This should allow a reasonable time for any immediate contamination to be treated.

Sampling frequency

When appropriate disinfectant residual and pH range is maintained, the pool has good clarity and is free from extraneous matter. Frequent sampling should not be necessary.

For quality assurance purposes, sampling at the beginning of a season for seasonal pools, commissioning of new pools and at periodic intervals thereafter, is usually enough to confirm that the disinfection regime is adequate.

Quarterly bacteriological testing is recommended as a guide for most pools. Specialty pools—such as toddler pools, hydrotherapy pools and spa pools—can be considered a higher risk because of temperature, high bather loading and pollution sources, justifying more frequent monitoring. Pools with variable water quality or poor circulation and hydraulics should be tested frequently.

Documentation

Documentation is an essential part of a quality assurance program. Data recorded from a quality assurance program will help in making operational decisions based on objective evidence.

⁴ Cited in a 1995 study, commissioned by the Department of Human Services

Physical management of water



Water circulation

Overview

The purpose of circulating water is to ensure that filtered, disinfected water reaches all areas of the pool, and polluted water is removed efficiently. This requires an understanding of the circulation patterns within the pool. Like the circulation rate and turnover period, circulation patterns are influenced by the depth, volume and shape of the pool. Other factors also include the purpose of the pool, for example, free play, lap swimming, wave pools and rivers, since each will have inherent demands on water circulation.

Effective circulation requires attention to:

- overall pool design
- surface water draw-off
- inlets and outlets
- circulation pumps
- flow rates
- turnover
- associated interconnecting pipework
- operating pressure.

Surface water draw-off

Unightly, unhealthy particulate matter will tend to remain on the surface of the water and the majority of organic pollution and contamination is concentrated at or near the surface—irrespective of the mixing effects of the circulation system. Fats, oils, sunscreens and other oil-based contaminants do not mix with water, irrespective of the mixing effects of the circulation system. They tend to remain at or near the surface, becoming a source of potential infection and forming a 'scum line' around the pool.

It is recommended that pools with low bather loads be constructed so that 20 per cent of the surface water is drawn off for filtration. In leisure pools, or those with a higher bather load, this may need

to be as high as 80 per cent. Spas, which have a particularly high bather load for the volume of water they contain, should almost always be designed with the higher figure.

There are three basic systems for removing surface water—in decreasing order of efficiency: wet decks, overflow channels, and skimmers.

Deck level (wet decks)

The water in the pool is at the same level as the pool surround (wet deck). Some water always floods over the edge and through a grill into a perimeter channel. The water entering these channels is transferred to a balance tank—some balance tanks utilise the perimeter channelling as well. The balance tank acts as a reservoir, storing any excess, and keeping an amount available for when it is needed, such as when the pool users get out, or when a backwash is undertaken. This prevents air from being drawn into the filtration plant. Wet decks also reduce wave action and maintain a stable water level.

Care in designing the channelling can substantially reduce the noise created by the water flowing into the channel. Also, ensure that contaminants from the wet deck are not 'washed' into the filtration system—there should be an alternative means of cleaning the wet deck, with suitable drainage.

Figure 25 Wet deck on a modern indoor pool



Overflow channels

These are also known as scum gutters and are common in older pools. Sills around the pool perimeter allow surface water entering them to flow through connecting pipes to the filtration plant. The sills should be uniformly level throughout their length, to avoid problems with variations in water level from bather displacement.

A number of refinements will ensure that the water remains at the optimum level for effective overflow action. Water displaced by pool users can be accommodated in a balance tank, from which it can be returned to the circulation system. The balance tank must be sized to suit requirements for water displacement and backwashing volumes.

An automatic make-up system can be incorporated into a balance tank system, topping up to a given level to keep a minimum amount of water in the system. The automatic make-up system must not be set to fill to the capacity of the balance tank. Otherwise, it may fill when there are no users, or when users enter the pool, so the system will be overfull. Overflow channels can be renovated to incorporate a modified wet deck system.

Figure 26 Overflow channel on an older outdoor pool



Skimmers

This basic device is installed at intervals around the side of the pool. These act as short, self-adjusting weirs which deal with variations in water level arising from bather displacement. Far less efficient than the methods described above, they are only recommended for domestic and low bather load pools.

Figure 27 Skimmer box and lint trap



Inlets and outlets

It is critical for safety reasons that inlets and outlets are fixed securely and are strong enough to withstand any likely impact.

Inlets

Inlets carry water to the pool and must be arranged so that each takes only its required proportion of flow. There should be enough inlets to ensure that the velocity of water entering the pool does not generally exceed 1.5–2 m/s at depths less than 1.8 m. This should perhaps be as low as 0.5 m/s in shallow or sensitive areas—around steps, for example, where turbulence might be a problem.

Procedures for dealing with inlets, which are also water features (geysers, sprays and jets), are usually dedicated for the purpose. These are not regarded as an integral part of the circulation system, since they are intermittent features of a centre.

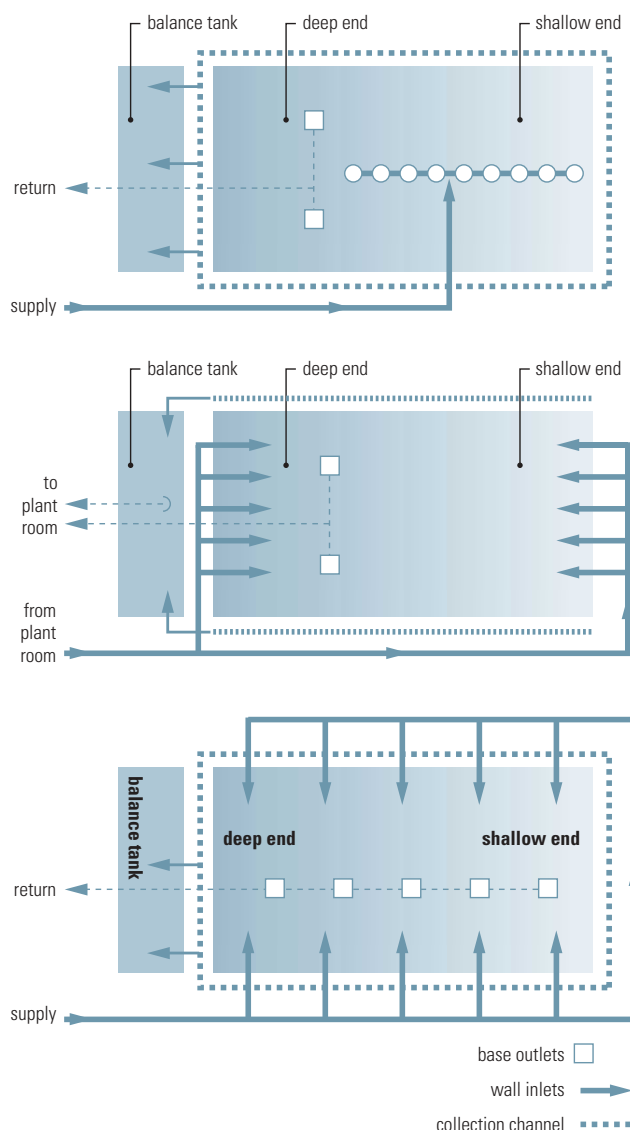
Outlets

Outlets must be arranged so that there is no risk of pool users being drawn towards them, or trapped by them. All suction pipes that are capable of being connected to the full suction pressure of the pump should be connected to at least two separate outlets at least two metres apart, and three metres from the side walls. The velocity of the pumped outlet water should not exceed 0.5 m/s. Outlet covers should be fitted to prevent body parts from being caught by the suction from outlets.

Circulation design

Figure 28 shows three basic circulation designs for a traditionally shaped pool tank. Each has advantages and disadvantages, and careful consideration must be given before choosing the appropriate option and building a pool; changes are often not possible once a pool has been built. Each option is discussed below.

Figure 28 Three circulation options for a 25m pool



Floor inlet, surface outlet

This common arrangement offers good circulation. However, it can be a long distance between the supply and return, so circulation 'dead spots' can occur. Skimmers usually operate around the whole pool, providing consistent recovery of soiled water. A recent improvement has been to introduce a second row of supply outlets along the pool, improving circulation to all points. However, this does increase construction costs.

Side inlet, surface outlet

Filtered water is supplied through the wall at one end of the pool, and taken from the opposing or adjacent edge (skimmer), which often does not go around the whole pool. This can lead to large dead spots in the area furthest from the supply and scum lines on walls without skimmers.

Combination inlet, surface outlet

Supply water enters the tank from both the floor and the walls, in a strategic combination aimed at minimising dead spots. This is by far the most effective method of circulation, often used in less regularly shaped pools. It is also the most expensive.

Floor returns can also be used to return water to the treatment plant. These are often located at the deepest part of the pool tank, and double as drains to allow for maintenance of the tank itself.

Valves can be installed to control the amount of supply and return water where needed, such as for pools with variable depth floors, moveable bulkheads, or other changes which might affect circulation.

It is recommended that pool tests be periodically undertaken at several locations simultaneously, to provide the operator with some knowledge about the

circulation patterns occurring within the pool. A higher concentration in one area than another may indicate either a lower bather load, or a lower flow of treated water to that point.

Multiple pools

It is increasingly common for facilities to offer a combination of pools, each with a separate filtration plant.

Older facilities often have multiple pools operating with only one filtration plant. A single system for two or more pools is quite common. Care should be taken to ensure the hydraulics, chemical monitoring and dosing are properly designed and managed in each pool, not in the overall plant.



Filtration

Overview

Several aspects are important here:

- clarity
- turbidity
- filtration
- backwashing
- flocculation or coagulation.

Clarity of pool water is critical for customer safety. It should be possible to see the bottom of the pool at its deepest point. If not, there is a physical danger to anyone in distress below the water surface. Lack of clarity may also increase bather discomfort and reduce disinfection. In practice, it must be possible to see a small child on the bottom of the deepest part when the pool is being used.

Poor clarity is caused by *turbidity*—colloidal or particulate matter suspended in the water. It is important to establish the cause of turbidity, so that it may be dealt with directly. The most likely remedy however, will be correct *filtration* and *backwashing*, coupled with flocculation or coagulation. This will convert the particulate and colloidal matter into filterable *flocculus* ('floc').

There must be enough filtration capacity, (that is, filter area), circulation rate and turnover period, to cope with the heaviest expected load. It is prudent to over-specify, rather than under-specify, filtration capacity. This allows for a future increase in pool patronage, without loss of water quality.

Filtration principles

In general, the greater the velocity of water through the filter, the less efficiently it filters.

Sand filters are recommended for all non-domestic swimming pools. Cheaper alternatives, such as cartridge filters and pre-coat or diatomaceous earth filters, demand more care and attention than sand filters. They cannot always be relied on to cope with the bathing conditions that public pools may expect at certain times.

Figure 29 Medium rate pressure filter for larger pool



The capacity of the filtration system should be based on expected maximum bathing load, operating 24 hours a day.

Pools benefit greatly from the increased flexibility and safeguards of having more than one filter. Through isolation of one or more filter units, a restricted turnover rate means the pool can be used during backwash, maintenance or repair. This flexibility permits and encourages a planned inspection and maintenance program, which is essential for filter efficiency.

Figure 30 plant room with multiple filters



Types of filters

Pressure filters

Pressure sand filter vessels are usually constructed from fibreglass, glass reinforced plastic, prefabricated mild steel or stainless steel. These may be medium or high rate and are commonly used in conjunction with flocculants and coagulants for commercial pools and spas, as well as hotel, hydrotherapy and school pools that are subject to variable bather loading demands.

Figure 31 High-rate sand filter for spa or small pool



Low-rate filters

These may include vacuum sand, open bed gravity fed filters. Though very efficient, they are rarely used in indoor pools as they tend to be large and expensive. Gravity feed filter vessels are usually constructed from concrete and operate by gravity, rather than pressure. They have been used in many older outdoor pools and are also used in town drinking water treatment systems.

Figure 32 Old style gravity sand filter beds and backwash channel



Specifications

A filter should be designed to the appropriate Australian Standards and it is recommended that the following quality and performance standards should be specified.

- A pressure ('loss of head') gauge should be fitted, to indicate the operating pressure of the filter.
- An automatic air release/vacuum breaker and a safe, manually operated quick air release mechanism should be fitted to each filter.
- A flow meter should be fitted (and regularly serviced), to indicate filtration water and backwash water flow rates.
- A sight glass should be incorporated into the outlet water pipe, to observe backwash effluent.

Figure 33 Filter off-gas bleed and collectors



The sand bed

The normal grade of filter sand size for conventional pool filtration is 0.45 to 1 mm. The bed depth should be at least 0.5 m, with an average between 0.75 m and 1 m. A common rule of thumb: two-thirds filter space for the media bed, leaving one-third for expansion during backwash.

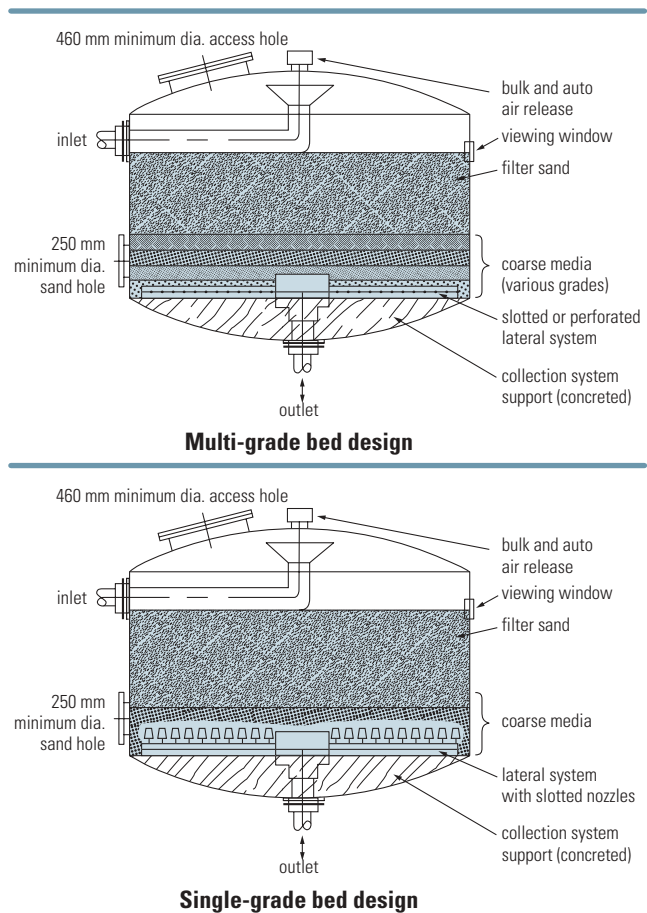
Sand filters can have either single or multi-grade beds. An advantage of multi-grade beds is that in the event of minor collector failure, the large-grade substrate will prevent the finer sand from entering the pool and operation will be uninterrupted. In the event of failure with single-grade media filters, sand will usually enter the pool. Whichever bed design is used, maintain the

specification and minimum depth of the filter sand recommended by the filter manufacturer.

Limits of filtration

The average pore size of a pool sand filter is 100 microns. There is no lower limit to the size of particle that can be removed—given the many passes common in pool circulation. With the aid of a coagulant, a single pass at any appropriate flow rate can almost completely remove all suspended matter—including colour and other colloidal matter of sub-micron size.

Figure 34 Medium rate pressure sand filters pressure differential gauges



Coagulation and flocculation

Coagulants enhance the removal of dissolved, colloidal or suspended material, by bringing it out of solution or suspension as solids (coagulation). These solids then clump together (flocculation) and are more easily trapped in a filter.

Coagulants will be less effective where pH values are above the recommended operating range. A minimum alkalinity of about 75 ppm as calcium carbonate (CaCO_3) is required for effective flocculation. Operators should follow the manufacturer's recommendations.

Ozone treatment

Ozone treatment breaks down colloids and encourages microfloculation. A coagulant may not be needed. If the water is turbid, dull or not sparkling, then alum (aluminium sulphate), or PAC (poly-aluminium chloride or aluminium hydroxychloride) can be used.

Dosing coagulants and flocculants

This can be by means of chemical dosing pumps or by manual hand dosing. Where they are dosed continuously, the pumps must be capable of accurately dosing the small quantities required.

Within a swimming pool circulation system, it is important that coagulants do not build up or reach the pool in any concentration. It is also important that the gelatinous floc does not block filtration. This can be achieved by applying the correct dosage rates and by frequent backwashing, which also contributes to dilution. Increases in pH should also be avoided to prevent the coagulant from disassociating and returning to the pool.

Figure 35 Dosing tanks with mixers for adding coagulant



Injection point

The injection point should ensure that coagulant mixes well with the circulation water before the water reaches the filter media. Injection points should also be located well away from sampling points for chlorine residual, pH value or ORP determinations.

Contamination of the sensors by the localised high concentrations may give a false picture of water quality and adversely affect the sensors themselves. For safety reasons, they should also be sited away from other chemical dosing points.

Backwashing

Reversing the flow of pool water back through the filters (to flush the trapped material to waste) helps care for the filters and maintaining water quality. It should be conducted whenever the differential between the filter inlet pressure and the filter outlet pressure reaches the level identified by the filter manufacturer.

Figure 36 Pressure differential gauges



Backwashing should be conducted from daily to weekly, depending on bathing load. If users are present, take care not to significantly reduce the depth of the water. Consider also the effect cold make-up water may have on pool users (particularly people with disabilities and young children). Therefore, it is best to schedule backwash for the end of day.

Period

The various filter types may differ in backwash duration. The duration recommended by the manufacturer may only *seem* to clean the filter. A viewing window or clear sight glass on the backwash discharge pipe is the only way to positively check progress. It should be possible to observe the clarity of the effluent water throughout the period of filter backwash. Ideally, backwashing should continue until the backwash water is clear. After backwashing, there should be a brief pause before normal flow is restarted. This will allow the expanded filter bed to settle. Some backwash systems have a rinse cycle for this purpose.

Flow

The backwash flow must be fast enough to expand the media bed without losing any media to waste, so the manufacturer's recommendations are critical. Air scouring heavy filter beds first can help separate the media particles and coagulated material, thereby increasing the efficiency of backwash. A viewing window showing the top of the media bed will allow operators to check that correct expansion is achieved.

Backwash flow rates should not be so high that the bed expands beyond the overflow level, resulting in loss of filter media to waste. The backwash water pipe must be large enough to discharge the wastewater, without a build-up of pressure inside the filter tank.

Figure 37 Multiport valve on a large, open gravity filter



Discharge

Backwash water must be discharged according to the requirements of the local water authorities and the Environment Protection Authority. The volume, quality and frequency of the backwash water discharge may be regulated.

Maintenance

A word of caution: it was common practice in filter construction prior to 1970 to use asbestos. This includes pressure sand as well as vacuum sand (gravity fed) filters. Accordingly, any remedial work will need to be conducted by accredited personnel.

Filters should be opened up and inspected internally at least once per year by an expert, familiar with the problems that can arise. This means attention to sand quality/quantity, collector condition, corrosion and structural integrity. Any unusual signs—fissures, an uneven bed, mud balling and channelling—need investigation. Change filter media periodically, according to:

- pool volume
- turnover
- pool water temperature
- bather load
- water balance
- cleaning regime
- location (indoor/outdoor)
- type of filter media
- type of filter
- professional advice.

Heating and air circulation

Overview

Satisfactory environmental conditions in the pool hall and all other areas of the building are essential for the comfort of pool users, staff and spectators—and for the pool to operate successfully over its working life.

Heating and ventilation of the pool hall needs to take many factors into account: bathing load; water temperature and quality; plant room location; integration with the building structure; materials and insulation of the pool hall envelope; capital; operating and life cycle costs.

The temperature of the air and the water need to be linked and balanced, so as to achieve the right humidity, optimise user comfort and minimise evaporation from the pool water. It is also essential that the air circulation system distributes the air effectively over the whole of the pool hall area, to:

- Provide comfortable conditions for occupants.
- Remove any chlorine odours.
- Reduce the risk of condensation.
- Control air movement within the occupied area, so it does not produce uncomfortable draughts.

Pool water heating

The actual heating of the pool water is a relatively simple operation. It is generally carried out by either a closed-loop heat exchange system, or through direct heating of the pool/spa water using a pool/spa heater (and/or solar energy). Heat recovery systems are sometimes used.

The heater is generally sized on the basis of raising the pool water temperature by 0.5°C per hour. If a pool is being heated from cold, the rate must be no more than 0.25°C per hour, or it may cause problems with the pool structure or lining. Particularly in a new pool, designers need to determine the precise rate of temperature rise.

The heating control system must be able to cope accurately with a wide range of temperatures. It may be possible, through the use of mixing valves and associated equipment, to serve different pools at different temperatures from a single heat exchanger.

Separate heat exchangers and controls are recommended for each separate pool water area, so that different temperatures can be more easily achieved.

Figure 38 Closed loop heat exchanger



Figure 39 Gas fired direct pool water heater



Figure 40 Heavy duty gas or electric boilers



Heavy duty or electric boilers supply water to heat exchanger closed loop.

Temperature

There has been a consistent trend towards higher water temperatures in recent years, encouraged by the substantial growth in aquatic leisure activities. The temperatures of multi-function indoor pools, however, need to reflect the aquatic activities being undertaken. Outdoor heated pools tend to operate within a range of 26–29°C.

People with limited mobility may require higher water temperatures to gain therapeutic benefits from aquatic activity. However, operators tempted to join the move towards higher temperatures should bear in mind that this does create a number of problems:

- Microorganisms multiply faster, so filters are increasingly likely to become colonised.
- Pool users get hotter—limiting more vigorous swimming and increasing bather pollution through sweat and body oil contamination in the water.
- Energy costs, direct and indirect, are higher—whatever efficiency or conservation methods are used.
- Higher air temperatures, which are linked to those of the water, rise too—making the atmosphere less comfortable for staff and others (as can the higher moisture levels).
- Moisture in the pool atmosphere, even when relative humidity is controlled at the same level. This carries a risk of condensation, and possibly corrosion and deterioration of the building fabric, structure and equipment.
- Chloramines tend to form more rapidly.

With an increasingly wide variety of pool uses, and operators attempting to program more flexible pool operations, it is difficult to select a single appropriate operating temperature for any particular pool. Rather than catering to any single user group, it may be better to seek a happy medium. The large volumes of water involved make it impossible to vary water temperatures rapidly in any one water area.

The temperature of the pool hall air should normally be maintained at around the water temperature—no more than 1°C above. However, it is recommended that an air temperature of 29°C or more should generally be avoided. There may have to be compromises where, for example, elderly people, parents and toddlers have to be accommodated in the same area as fitness swimming.

Pool hall ventilation and air circulation

This is a complex and critical area. It is generally recommended that air is well distributed over the whole area, and that air movement within the occupied zone is maintained within acceptable conditions for bather comfort.

The ventilation system is the primary means of removing contaminants from the air. It also controls pool hall air quality, temperature, humidity, evaporation from the pool surface and condensation. It is generally recommended that the relative humidity stays between 50 per cent and 60 per cent throughout the pool hall area. Levels higher than 60 per cent produce a risk of discomfort and condensation; levels lower than 50 per cent can increase evaporation and energy use.

The ideal ventilation rate for a pool hall, taking into account varying external conditions, bather loads, evaporation rate and water quality, is very difficult to estimate and changes with varying circumstances. Effective, well distributed mechanical supply and extraction systems maintain satisfactory internal environmental conditions in all situations.

The Australian Standard 1668.2–2002 can offer some guidance in this area. It is generally recommended that advice is sought from a design engineer with experience in swimming pool and handling systems.

Separate areas

Areas for eating and drinking within the pool building are another potential problem. These areas do not necessarily need to be physically separate from the pool hall, but environmental conditions which are different to those around the pool should be considered.

Sources of ventilation

The best source of ventilation is fresh air—this should be the first consideration for new pools. A system with a high ratio of recirculated pool air increases the potential for deterioration of equipment and components made of metal or nylon (for example, structural steelwork, roof and ceiling fittings, air handling plant and equipment). Therefore, if an air recirculation system is used for energy efficiency, it should be possible to vary the ratio of fresh to recirculated air. During periods of very high bather loads, or if high levels of contaminants are present in the pool atmosphere, 100 per cent fresh air may be required. Air intakes should be located away and upwind from exhaust outlets.

Energy management

Swimming pools are one of the few building types operating at high temperature and humidity throughout the year. This results in potentially high heat losses and means that all pool buildings should be well insulated—above basic building regulation standards, if possible. They should also be well sealed from the outside and surrounding areas.

Heating the ventilation air is a major energy load for a pool. A simple heat exchange device, such as a plate heat exchanger or run-around coils, should be provided to reclaim as much energy as possible from the exhaust air and optimise energy efficiency.

Other heat recovery devices and energy sources can be considered, such as thermal wheels (rotary heat exchanger), heat pumps, combined heat/power units, geothermal and solar energy. These should be carefully evaluated over the projected life cycle of the building services installation.

It may be necessary to run the pool ventilation system when the pool is not in use, to maintain environmental conditions within the pool hall and prevent condensation and possible building or equipment damage. An effective pool cover may reduce condensation, evaporation, pool water heat loss and the need for the ventilation system to operate out of hours. This also substantially reduces energy use.

Figure 41 Pool covers



Pool covers save on heat and prevent leaves and windblown debris from entering during closure.



Maintenance



Overview

The maintenance of equipment should only be undertaken by suitably qualified persons and in strict accordance with manufacturers' recommendations. Incorrect maintenance can not only lead to a shortened equipment life span, but in some circumstances may place operator and public safety at risk.

There are two philosophies regarding maintenance. The first is a reactive approach. This involves waiting until equipment is faulty before taking action. This approach is fraught with peril, as there is also the risk of damage to ancillary equipment in event of total failure. For example, circulation pump bearing failure may result in damage to the pump motor. Managers should also consider the unscheduled interruption to operations and customer service.

A more responsible attitude toward equipment maintenance is the proactive or preventative approach. This involves periodical, or programmed, maintenance of equipment within set timeframes—monthly, quarterly and annually. The primary advantage to this approach is that any interruption to operation can be scheduled for a time that will have the least impact on customer service.

Manufacturers are a good source of information as to when and what maintenance is required to keep equipment operational, as well as a budget estimate of cost.

The following plant and equipment should be considered in a periodical maintenance schedule:

- circulation pumps
- dosing pumps/feeders
- heating hot water pumps
- filters
- control panels
- sample cells
- heat exchanger/calorifier
- disinfection system
- pipes and valves
- sensors
- heaters/boilers
- air handling units
- meters and gauges.

Winterisation

Winter and off-season care of a swimming pool is important to prevent potential damage to the pool structure and equipment.

If a pool must be emptied, it is advisable to do so for the minimum amount of time possible. When full, there is equal pressure exerted on the pool structure from the water within as well as from groundwater and the surrounding earth on the outside. When emptied, there is no longer the support for water within the pool. This can lead to movement and subsequent damage to the pool structure, resulting in water leakage when refilled. The consequences can be excessive water usage, inability to maintain temperature (if heated) and a drop in water quality.

It is therefore safer, easier and more economical to keep the structure protected from temperature and pressure changes that may cause cracking and straining of the pool structure and expansion joints, by leaving the pool filled.

Procedure for winter care

Traditionally in Australia, outdoor pools are left full of water and unattended during winter or the off-season. A significant build-up of contamination from organic material (leaves, algae, etc) results. This is usually dealt with by draining the pool and scrubbing the walls and floor, before re-filling and treating in preparation for usage.

Alternatively, use a winter/seasonal maintenance program. This involves periodical water turnover, testing, chemical addition, including superchlorination, and vacuuming to minimise debris, algae and corrosion. This should result in minimum expense and preparation time before reopening for the new season. Algae can be prevented by maintaining good disinfectant residuals and avoiding excessive cyanuric acid levels, as this may reduce the effectiveness of the chlorine in controlling algae.

Winter/seasonal maintenance

It is important that any chemicals used during a winterisation program do not leave any undesirable residues.

- Add fresh water to the pool, to restore the volume to normal operating level.
- Turn on the circulation system and allow it to run for at least one turnover period. Pumps may need to be primed.
- Vacuum the pool.
- Backwash the filters.
- Measure and manually adjust the water chemical parameters (disinfectant, pH, alkalinity, cyanuric acid, calcium hardness).
- Shut down the circulation system.

Chlorine is an effective chemical to use in a winterisation program. It is readily available, easy to use, prevents algae growth and leaves no undesirable residue.

Unattended pools

If the pool is left unattended, the following actions will be necessary.

Pumps

- Disconnect power.
- Remove surface corrosion.
- Periodically rotate pump shaft.

Gas chlorinators

- Decommission and service by suitably qualified personnel, according to the manufacturer's recommendations.
- Incorrect servicing of this equipment can be life-threatening.

Erosion (tablet) feeders

- Decommission and flush clean, according to the manufacturer's recommendations.
- Take adequate safety precautions when opening the feeder, as chlorine gas may have formed.

Sensors

- Remove, clean and store in an appropriate wetting solution⁵.
- Do not let sensors dry out, as this will cause irreparable damage.

Chemical dosage pumps

- Flush head by placing pump's suction hose in a bucket of fresh water, manually operating the pump for a short period.
- While the power is disconnected, clean exterior with warm soapy water to remove any chemical residue.
- Arrange servicing for pumps and injectors.
- Replace any worn or damaged chemical delivery tubing.

Heaters/boilers

- Maintenance, decommissioning and recommissioning should be carried out according to the manufacturer's recommendations and *only* by suitably qualified personnel.

⁵ Manufacturer will usually be able to supply instructions, as well as wetting solution and bottles.

Useful resources



Problem sorter

Overview

This problem sorter should be treated as a guide only. The possible causes listed may not necessarily be the correct, or only, ones. Misdiagnosis or inappropriate action can exacerbate some problems, to a point where patron and staff safety is at risk. Accordingly, only suitably qualified or experienced staff should endeavour to diagnose or undertake corrective action. If there is any doubt whatsoever, it is best to seek professional advice.

Problem	Possible cause(s)	Initial response
Total alkalinity too high		Re-test and confirm reading.
	High supply water levels can cause this problem. Overuse of carbon dioxide can also contribute.	Backwash pool (or dilute) and re-test next day. Repeat until correct level attained. Alternatively, reduce level with dry acid.
pH too high	Not enough acid.	Re-test and confirm reading. If pH is above statutory requirement, close pool/spa until within range. Ensure that pH correction system is turned on and operating normally. Take action as per "total alkalinity too high".
	The pH correction agent (CO ₂ or acid) storage tank may be empty.	Check pH correction agent storage tank level.
	No sample stream flow.	Check that there is no flow restriction to the sensor sample water.
	The pH sensor may be fouled, out of calibration or faulty.	Clean/calibrate/replace sensor.
	Some disinfectants can cause the pH level to rise (sodium hypochlorite). Possible disinfectant over-dosage.	Test the disinfectant level. If above statutory requirements, take action as per 'Disinfectant too high' in this problem sorter.
pH too low	Too much acid.	Re-test and confirm reading. If pH is outside statutory requirement, close pool/spa until within range. Ensure that pH correction system is operating normally. Check system components for malfunction.
	An interruption to sensor sample stream flow may cause inaccurate readings.	Check that there is no flow restriction to the sensor sample water.
	The pH sensor may be fouled, out of calibration or faulty.	Clean/calibrate/replace sensor.
pH unstable	Alkalinity too low.	Check frequency and quantity of pH correction agent dosage.
	Total alkalinity level may be incorrect for the pH level required.	Check total alkalinity level.
	The pH sensor may be fouled, out of calibration or faulty.	Clean/calibrate/replace sensor.
	Electrical, electromagnetic or radio interference may be causing the sensor reading to fluctuate.	Seek technical advice.

Problem	Possible cause(s)	Initial response
pH difficult to change	Total alkalinity may be too high, due to high source water levels. Excessive level of total alkalinity caused by over use of bicarb or CO ₂ .	Check total alkalinity level. Check that pH correction system is operating normally (pumps, injectors, controller set point, etc).
Calcium hardness too high	Very uncommon in source water. Normally caused by inadvertent excess dosage of calcium chloride or calcium hypochlorite.	Re-test and confirm reading. Backwash pool (or dilute) and re-test the next day. Repeat until correct level is attained. Discontinue use of calcium-based products.
Scale build-up appearing	Hardness salts may be coming out of solution.	Test chemical levels and adjust according Langelier Saturation Index.
Disinfectant too low	High disinfectant levels may cause test reagent to bleach, and appear to register 'low'.	Re-test and confirm the reading with a 10:1 dilution test. If disinfectant level is outside statutory requirement, close pool/spa until within range. Check level in disinfectant storage tank.
	The disinfectant sensor may be fouled, out of calibration or faulty. A solenoid failing in the closed position will prevent water from delivering disinfectant.	Clean/calibrate/replace sensor. Check that the dosage control and delivery system are operating normally.
		For sodium hypochlorite systems, check that: <ul style="list-style-type: none"> • power supply to dosage pump is turned on and there is power available • there are no airlocks in the chlorine pump head and delivery tubing • suction/discharge valves are not contaminated • delivery tubing is not leaking • chlorine pump pressure relief valve is not discharging. If it is, a delivery line or injector may be blocked. • dosage controller is turned on and has power • dosage controller set point is correct. (If the controller is at, or above set point, no dosage will occur). May require adjustment.
		For erosion feed systems, check that: <ul style="list-style-type: none"> • dosage controller is turned on and has power • dosage controller set point is correct. (If the controller is at, or above set point, no dosage should occur). • solenoid valve is working correctly.

Problem	Possible cause(s)	Initial response
Disinfectant too high	<p>The disinfectant sensor may be fouled, out of calibration or faulty.</p> <p>A lack of sample stream flow may be causing incorrect readings.</p> <p>The system may be siphoning, due to contamination of the dosage pump valves or pressure retention (anti-siphon) valve.</p> <p>A solenoid valve failing in the open position delivers disinfectant continuously.</p>	<p>Check that there is no restriction to the sensor sample stream.</p> <p>Re-test and confirm the reading with a 10:1 dilution test.</p> <p>If disinfectant level is outside statutory requirement, close pool/spa s until within range.</p> <p>If necessary, reduce disinfectant levels with sodium thiosulphate.</p> <p>Check that dosage control and delivery system are operating normally and clean/calibrate/replace sensor.</p> <p>For liquid chlorine systems:</p> <ul style="list-style-type: none"> • Check dosage pump suction and discharge valves for contamination, as well as the diaphragm of the pressure retention (anti-siphon) valve. <p>For erosion feed systems:</p> <ul style="list-style-type: none"> • Check that the solenoid valve is operating correctly.
Oxidisation reduction potential (ORP) too low	<p>Disinfection too low, pH or cyanuric acid too high.</p> <p>ORP sensor may be fouled, out of calibration or faulty.</p>	<p>Clean/calibrate/replace sensor.</p>
ORP too high	<p>Disinfectant too high, pH too low.</p> <p>ORP sensor may be fouled, out of calibration or faulty.</p>	<p>Clean/calibrate/replace sensor.</p>
Disinfectant level is difficult to maintain	<p>In pools not stabilised with cyanuric acid, sunlight can rapidly reduce disinfectant levels.</p> <p>Excessive contamination may be overloading the disinfection system.</p>	<p>If level is outside statutory requirement, close pool/spa until within range.</p> <p>Check disinfectant delivery and control systems.</p> <p>Add cyanuric acid to at least 30 mg/L.</p> <p>Check bather load history and look for a correlation.</p>
Cannot get test kit readings for free chlorine residual	<p>Reagent may be bleached by excessive chlorine level.</p> <p>The reagent may have deteriorated. They have a limited life span, particularly in a warm environment. Contact the supplier for more information on shelf life.</p>	<p>Test disinfectant level with a 10:1 dilution test. If outside statutory requirements, close pool/spa until within range.</p> <p>Check reagent use-by date.</p>
The water has an offensive odour and is causing eye and/or throat irritation	<p>May be high combined chlorine levels caused by excessive bather load, or contamination from other sources. Quaternary ammonia-based chemicals, for instance, are sometimes inadvertently used for concourse clean-down. These chemicals combine with chlorine, forming the offensive compounds.</p> <p>A build-up of organic material in overflow channels and/or balance tanks can also contribute.</p>	<p>Test combined chlorine level.</p> <p>Superchlorinate during closure, then backwash and add coagulant. It may be necessary to repeat this regularly, as a proactive measure.</p> <p>If the problem persists, continuous dilution of the pool/spa water may be required. Alternatively, it may be necessary to re-evaluate the filtration systems efficacy in managing the bathing load.</p> <p>Cleaning overflow channels and balance tanks during periodic maintenance (if practical).</p>

Problem	Possible cause(s)	Initial response
Slimy growth on the pool walls, floor or grouting	If green/black in colour, it may be algae. If not, it may be biofilm of a bacterial colony.	Superchlorinate during closure, scrub the affected area and vacuum to waste. Backwash and add coagulant. If the problem persists it may be worthwhile having a sample analysed to help identify the organism.
Cyanuric acid too high	High levels of cyanuric acid may reduce the effectiveness of chlorine. This may result in algal blooms.	Re-test and confirm reading. Backwash (or dilute) pool and re-test the next day. Repeat until correct level is attained.
Cloudy water	Circulation pumps may have failed, or flow may be restricted by clogged lint screens/baskets.	Check circulation pump(s) and lint screens/baskets.
	Filters may be dirty and require cleaning.	Check filter(s) pressure differentials. Backwash filters.
	Bather load may be too high for filtration system capabilities.	Reduce bather load and allow the water to recover.
	Filter media may be old and clogged. This may result in channelling and ineffective filtration.	Superchlorinate filter media during closure. If symptoms persist, inspect filter vessel.
	If filtered water collector system is broken, contaminants and filter media may enter the pool.	Inspect filtered water collector system and replace if necessary.
	Mineral salts may be coming out of solution.	Check and where necessary correct pH, alkalinity and calcium hardness—according to Langeliers Saturation Index.
	A high pH may cause coagulant to be present in the water. There is usually a white discolouration.	Check for coagulant overdose and/or high pH.
	Contamination by algae. High cyanuric acid levels may reduce the effectiveness of the chlorine, to a level that allows an algae bloom.	Superchlorinate during closure, backwash and add coagulant. Maintain disinfectant levels at all times. If symptoms persist, check for high levels of cyanuric acid. If high levels of cyanuric acid are present, dilute the pool water until normal levels are attained. Then repeat the above actions.
	In high concentrations, chlorine and bromine (especially) may cause green colouration of water.	Test disinfectant level with a 10:1 dilution test. If outside statutory requirement, close pool/spa until within range. Action as per 'Disinfectant too high'.
	In full-stream ozone/chlorine systems, green coloration common when ozone is off-line for extended periods. Filter systems using anthracite/other carbon products can also cause discolouration.	Coagulation with poly-aluminium-chloride.
Although uncommon, copper presence in the water may also cause green discolouration.	Particularly if the saturation index is tending toward scale forming—according to Langelier's Saturation Index. If the discolouration persists, test for presence of copper.	

Problem	Possible cause(s)	Initial response
Water clarity generally poor	Check for a pattern to establish cause. For example, is it only during periods of heavy usage? Does it clear after backwash?	Check disinfectant residual levels. If an outdoor pool, check stabiliser level is not too high, or too low. Ensure correct backwash frequency and coagulant dosage. Check the filter media for contamination, deterioration or for the need to flocculate or add media.
Temperature too low	Inadequate heat exchange.	Check that thermostat is set at normal temperature. Check that circulation pump(s) are operational. If not, see 'Circulation failure'. Check that the boiler is operational. If not, see 'Heater malfunction'.
	Dilution with cold make-up water after backwashing may cause a temporary drop in temperature.	Check when last backwash performed.
Temperature too high	Wrong temperature setting. Solenoid or valve failure.	Check that thermostat is set at normal temperature. Check that heating valve is not stuck on 'open'.
Heater malfunction	The heating hot water pump may have failed. Note: in some installations, the heating hot water pump is interlocked with the heater operation and will automatically shut down with the heater. Therefore, it may not have caused the fault. Power failure, where the heater did not restart automatically.	Check that heating hot water pump is operational. If not, call service personnel. Reset the heater—once only. If still unresolved, call service personnel.
Circulation failure	Incorrect valve positions on pump(s) or filter(s) can extensively damage filtration system.	Check that there is sufficient water for pump(s) to operate. If water level is low, ensure that the make-up system is functioning correctly. Check that the circulation pump is turned on at the power supply and control panel. Check suction and discharge pressure gauges (as well as any other flow indicators) for normal pump operation. Check valve positions on the pump and filters.
Filter inlet pressure is high; outlet pressure is low	Filter is dirty.	Backwash filter.
	If the problem persists, the filter may be blocked and the media will need replacement. May also indicate that there is not enough water flow to backwash effectively.	Check quantity of coagulant used. Excess may cause the filter media to become clogged, resulting in poor filtration.
Filter inlet and outlet pressures are both high	If a valve on the discharge side of the filter is closed past its normal position, water flow may be restricted and cause increased filter pressure.	Check the valve positions on the discharge pipework of the filter.
Poor air quality		Check that air-handling system is operating normally. Check air filters; clean or replace as required. If necessary, check damper operation.

Glossary

Acid A chemical that lowers pH value when added to pool water.

Acidity A measure of the acid content of water (in mg/L or ppm).

Activated carbon Carbon used as an adsorption filter for removing chlorine, ozone and contaminants.

Algaecide A chemical that aids in killing, controlling and preventing algae (microscopic plant life).

Alkali A chemical that raises pH value when added to pool water.

Alkalinity A measure of the alkaline content of water (in mg/L or ppm).

Aluminium sulphate (alum)
A coagulant, usually supplied as granules.

Ammonia A chemical formed when urea breaks down in urine and sweat.

Amperometric sensor Pool water analysers that measure hypochlorous acid and monitor free chlorine.

Backwashing Cleaning the filter by reversing the direction of water flow, up through the filter media.

Balance tank A reservoir of water between the pool itself and the rest of the circulation system (on the return side of the pump). It maintains a constant pool water level and supply to the pumps and holds water displaced by bathers.

Bather load Number of bathers in a pool over a set period of time. It should be linked to treatment system capacity and pool safety.

BCDMH (Bromo-chloro-dimethyl-hydantoin) A chemical producing hypobromous acid when dissolved in water.

Breakpoint chlorination The point at which the combined chlorine level in the pool, rising as chlorine is added, falls. Indicates that nitrogenous pollution is being oxidised.

Bromamines Products of the reaction between bromine and ammonia.

Buffer A combination of weak acids, weak alkalis and their salts, that resist changes in pH.

Calcium chloride Used to increase calcium hardness.

Calcium hardness A measure of the calcium salts dissolved in pool water.

Calorifier A heat exchanger used to heat pool water indirectly.

Carbon dioxide Gas used to lower pH.

Chloramine 'Pool smell' produced when free available chlorine combines with ammonia and other nitrogenous wastes.

Chloroform Produced when chlorine and organic nitrogen compounds react; one of the trihalomethanes.

Coagulant A material which forms a gelatinous precipitate in water, causing finely divided particles to agglomerate (clump) into larger particles.

Coliforms Intestinal bacteria (*E. coli* is a common example).

Colloids Very fine suspended matter that contributes to water turbidity.

Combined bromine A measure of the bromamines in pool water.

Combined chlorine A measure of the chloramines in pool water.

Cyanuric acid A stabiliser added to pool water, to reduce chlorine loss due to sunlight.

De-ozonation Removing ozone disinfectant from water, before it returns to the pool.

Diatomaceous earth A powder capable of filtering extremely small particles.

Dichlor (dichloroisocyanuric acid)
A type of stabilised pool chlorine.

E. coli A bacterium in faeces. Pools are routinely monitored for signs of this pollution.

Erosion feeder Device that allows a steady flow of water to erode a stick or tablet of disinfectant. Adjusting the flow rate through the feeder controls the erosion rate.

Flocculant A chemical compound (commonly alum) added to some sand filters. Aids filtration by forming a gelatinous mass on the surface of the filter bed, trapping fine particles.

Flooded suction Introducing supply water to the pump, where the level of the supply water is above the level of the pump inlet.

Free chlorine Amount of chlorine (hypochlorous acid plus hypochlorite ion) available for disinfection.

Gas chlorinator Controls release of chlorine gas from a bulk supply.

Halogens Chemical family that includes chlorine, bromine and iodine.

Hardness A measure of all the calcium and magnesium salts in pool water (total hardness). See also: calcium hardness; permanent and temporary hardness.

Heat pump A refrigerant-based heat pumping system.

Humic acid A constituent of water that reacts with halogen disinfectants to form trihalomethanes.

Hydrochloric acid (muriatic) Acid used to lower pool water pH value.

Hypobromous acid The main active factor in all bromine disinfectants.

Hypochlorite Ionic base of hypochlorous acid.

Hypochlorite-based disinfectants (hypo) Sodium hypochlorite is a liquid pool chlorine; calcium hypochlorite is granular.

Hypochlorous acid The main active factor in all chlorine disinfectants.

Langelier Index One measure of pool water chemistry.

Nitrogen trichloride The most irritant of the chloramines.

Oxidation The process by which disinfectants destroy pollution.

Oxidation-Reduction Potential (ORP) Measures oxidative powers of the water (in millivolts).

Ozone (O₃) A gas generated on-site and used to purify pool water by oxidation.

PAC (Poly aluminium chloride) Commonly used liquid coagulant.

Permanent hardness That part which does not precipitate from the water on heating; consists of calcium and magnesium salts (other than carbonates and bicarbonates).

pH A measure of the acidity, alkalinity or neutrality of water on a logarithmic scale of 1.0–14.0. A pH below 7.0 is acidic and above 7.0 is alkaline.

PPE Personal protective equipment, including breathing respirator, safety goggles, hearing protection, gloves and coveralls.

ppm Parts per million—the amount of chemical (by weight in milligrams) per litre of water (mg/L).

Salt chlorinator Electronic device producing free chlorine from salt (chloride) present in pool water.

Scaling Deposits—usually calcium carbonate—on pool walls and pipework.

Sensor Electrical or electronic device measuring a specific parameter. For example, pH, water flow, chlorine, ORP or temperature.

Slipstream ozonation A system that ozonates a proportion of the total pool water.

Sodium bicarbonate (bicarb) Used to raise pH and total alkalinity.

Sodium bisulphate (dry acid) Used to lower pH.

Sodium carbonate (soda ash) Used to raise pH.

Sodium chloride Commonly called 'pool salt'

Sodium thiosulphate A neutraliser used for dechlorination and in the microbiological testing of water disinfected with halogen.

Temporary hardness That part of the total hardness which precipitates from the water on heating. Consists of calcium and magnesium carbonates and bicarbonates.

Total alkalinity Measure of alkalinity used to determine pH buffering capacity of pool water.

Total chlorine A measure of free plus combined chlorine.

Total Dissolved Solids (TDS) A measure of all solids dissolved in pool water.

Trichlor (trichloroisocyanuric acid) A type of stabilised chlorine.

Trihalomethanes Compounds formed by reaction between chlorine or bromine and humic acid, or certain components of human waste.

Turbidity Cloudiness, murkiness or lack of clarity in water, caused by colloidal or particulate matter in suspension.

Turnover period The time taken for water equivalent to the entire pool volume to pass once through the filtration and circulation system.

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