Pool Operators' Handbook

Victoria
The Place To Be

Pool Operators' Handbook

Disclaimer

The information in this Handbook is advisory in nature. *The Pool Operators' Handbook* is intended to provide information and guidelines for the operation of swimming pools used by the public. It is not intended to replace or override legislation.

Pool operators are required to adhere to and consult all relevant acts, regulations, codes of practice, standards and guidelines, as well as industry publications, for additional information. It is the pool operator's responsibility to keep abreast of, follow and have copies of relevant legislation and regulations. Many of these are listed in the Bibliography, but operators should be aware that these may be under review at the time of printing this Handbook. This Handbook should not be used in place of the appropriate legislation, but alongside those statutes. Failure to meet reasonable standards in the provision of a safe environment for the public may carry heavy penalties, regardless of pool operators following the guidelines in this Handbook.

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Victorian Aquatic Industry Council

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

The *Pool Operator's Handbook* is based on the Pool Water Treatment Advisory Group (PWTAG) 1995 *Pool Water Guide*. Where appropriate, text has been extracted from this publication and the Development Committee acknowledges the permission granted by the PWTAG for this use.

Preface

What is a healthy swimming pool? A healthy swimming pool is obviously one that contains water free from disease-causing organisms and bacteria, has clear and sparkling water, with well-maintained surrounds. It should be pleasant to the senses. Well-managed swimming pools are healthy environments–there is negligible risk of infection or illness. But healthy pools are more than just that. Swimming pools are deeply connected with our culture, our dreams of having a backyard pool, a poolside holiday, achieving personal fitness or being an Olympic champion.

For many communities, particularly in rural areas, the public pool is in essence the home pool, the place of meeting friends or of making a hot summer's day bearable. Pool users can receive many health and social benefits from recreational or therapeutic bathing, as well as competitive swimming.

Holiday makers often choose a particular caravan park or a hotel because it has a swimming pool or a spa pool. They expect to be able to use them at their leisure, and that they will be in pristine condition. The operations of tourism accommodation businesses are often judged by the way that their pools are managed.

In order to maintain healthy water and an inviting environment, maintaining the pool structure, and ensuring there is reliable and efficient plant and equipment, is essential. Pool operation and pool management is a challenging profession. The personnel are entrusted with an important responsibility. Investment in staff development through training is essential, and underpins sound plant and equipment.

Newer technologies are being demanded by pool users to improve the chemical quality of pool water, particularly in the indoor environment. There are many new water treatments being marketed, some of which may have a useful application-and others which are either inappropriate or not effective.

The Department of Human Services approached the Victorian Aquatic Industry Council in 1998 with a view to producing a document that would not only support the achievement of water treatment standards required to comply with the Health Regulations, but would be more holistic in its outlook. A diverse committee of professionals with pool operations, pool management, public health, pool user and pool service backgrounds was formed to collaborate and produce this Handbook. We believe it will serve the industry well.

I hope that this *Pool Operators' Handbook* will provide guidance on pool water treatment and associated pool management issues to operators, owners, proprietors, body corporate managers, local government authorities and the various pool industry service providers.

Finally, I thank the contributing authors and their respective organisations, together with the Chair and administrative support of the Victorian Aquatic Industry Council, for bringing this Handbook together.

Dr Robert Hall

Director, Public Health/Chief Health Officer
Department of Human Services

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1. Introduction

Background to the Handbook

Swimming in pool water or relaxing in a spa should be a healthy and pleasant exercise. A clear, safe, sparkling swimming pool, without unpleasant smell or taste, and free from harmful microorganisms is the right of all users and should be the objective of every manager. However, in practice, achieving this can be difficult. A multitude of physical, chemical and microbiological states change in a busy pool–some in seconds, others in hours or days. Only a trained pool operator can identify and manage these changes.

This is the first edition of the *Pool Operators' Handbook* published for use within Victoria. This Handbook was originally modelled on the United Kingdom *Pool Water Guide* produced by the Pool Water Treatment Advisory Group (PWTAG) in 1995. Where appropriate, some text from that Guide has been retained where it is currently applicable to the Australian environment. Other sections have been substantially reworked to meet the needs of Victorian operators.

This Handbook recognises the unique needs of Victorian pool operators, and has been written in consideration of the types of equipment and treatment used, the local regulatory environment and the experience and expertise of the Victorian Aquatic Industry Council (VAIC) committee.

This Handbook has been prepared in association with the VAIC by a committee of industry professionals. These professionals have backgrounds in pool management, water treatment, pool maintenance and service, hydrotherapy, pool user groups and public health.

Aims and Objectives

The purpose of the Handbook is to provide advice on the issues of pool operation and water treatment, so that pool operators will be encouraged to:

- Follow safe working procedures
- Maintain plant and equipment so that it achieves its desired service life
- Achieve regulatory compliance

  and
- 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. These include:

- Pool operators
- Pool owners
- Pool managers
- Committees of management
- Pool designers and consultants
- Pool service companies
- Contract managers
- Environmental health officers.

What Types of Pools are Covered by this Handbook?

This Handbook is intended for use and application to all pools where public are admitted to a pool–as a primary or additional service.

The Handbook is also intended to give guidance to body corporates, retirement village operators and private clubs whose pools have similar operational demands and water treatment requirements as a public pool.

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.

Location of the Pool

The following sites are examples of situations where the information in this Guide should be applied to the pool:

- Resorts hotels and motels
- Caravan and camping parks
- Backpackers' hostels
- Apartments
- Retirement villages
- Hospitals and hydrotherapy centres
- Gymnasiums, health and fitness studios
- Private clubs
- Schools and universities
- Workplaces
- Prisons
- Swim schools
- Sports and leisure centres
- Community and municipal pools.

This Handbook is not aimed at domestic backyard pools of single dwelling properties used by the occupying family.

Staff and Responsibilities

Overview

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

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**.

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.

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.

Training is Required for all Staff

Whether large or small, the maintenance of 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 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 inspections 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 the pool water. Relevant staff should have an appropriate understanding of basic water chemistry to testing, water treatment, plant operation and the general procedures required to maintain good quality water.

Lifeguards may be required to conduct regular and accurate water tests, provide an 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 Regulations, the on-site supervisor should be able to decide if bathing should cease.

Management Responsibility

Managers responsible for large, multi-purpose facilities may delegate some of the 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 good understanding of the pool operations and be able to spot problems and institute remedies. For instance:

- Water can be a vehicle for transmission of disease–see the chapter on 'Pool Water Contamination'.
  Many microorganisms prefer a warm, moist environment with an adequate food source. A swimming pool with poorly maintained water is a perfect breeding ground.
- Careless management of flocculants, filtration, disinfection and chemical balances can produce a degree of turbidity (cloudiness) that obscures swimmers' and lifeguards' vision of the pool floor, even in shallow water.

Operating the Pool Environment

Cost Pressures

With increasing demands on public and private expenditure, the competitive tendering of public services and increased awareness of conservation issues, there is pressure to find more cost-effective ways of operating swimming pools. The costs of water, energy, water treatment and disposal of waste water 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 less than 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 of the pool plant and equipment and ensure that appropriate operational and maintenance activities are undertaken. The pool operator should have a comprehensive knowledge of relevant statutes, regulations, codes and other standards.

In some 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. However, there may be, in the future, a statutory requirement that pool operators adhere to 'all relevant guidelines and standards'. In this case, the Handbook would qualify as 'relevant'. Failure to meet reasonable standards in the provision of a safe environment for the public itself may carry heavy penalties. Therefore, it is sound practice to follow closely the guidelines contained in this Handbook.

Much of the guidance is intended to assist those responsible to meet the requirements of the Health (Infectious Diseases) Regulations, the *Occupational Health and Safety Act* and the *Dangerous Goods Act*. In the event of an accident, the extent to which pool operators have adhered to accepted guidelines will determine the level of vulnerability to legal action for negligence or public liability.

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

A Brief List of 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 the relevant Acts.

- Health (Infectious Diseases) Regulations 2001
- *Occupational Health and Safety Act 2004*
- SafetyMAP
- *Dangerous Goods Act 1985*
- Dangerous Goods (Storage and Handling) Regulations 2000
- Material Safety Data Sheets (MSDS)
- Codes of Practice
- Australian Standards.

These are discussed in detail below.

Safe Working Practices

Apart from adherence to relevant Acts and regulations, employers should establish their own safety policy. This should include written safe work practices, in consultation with employees. The written safety policy should include an assessment of hazards associated with all aspects of operation of the plant, and precautions to control the risks.

Some hazards associated with pool operation include:

- Risks to employees or pool users from chemicals used in disinfection systems. These include: irritation of skin or eyes; enhanced flammability of materials due to disinfectants being strong oxidising agents; and leaks of toxic gases. The most serious risk is of an uncontrolled escape of chlorine gas following the incorrect fitting of chlorine gas lines or the inadvertent mixing of chlorine-based disinfectant with acid.
- Risks from murky water. As well as indicating that water treatment and quality is inadequate, murky water is a safety hazard because it may harbour microbiological contaminants that cause disease and obscure observance of pool users in difficulty.
- Miscellaneous risks to employees, including from work in confined spaces or the use of electrical equipment.

Figure 1 Location of Safety Showers and Eye Wash Facilities

Safety showers and eye wash facilities should be located immediately adjacent to the hazardous area, but not within the hazard.

Training Employees

Adequate training should be provided to employees about all safety measures and hazards. Records should be kept of content and attendance at courses or in-services. Training should:

- Be related specifically to the operation of the particular plant, hazards associated with it and substances used. Employees' attention should be drawn to any manufacturers' instructions, and copies made conveniently available (for example, they may be affixed to the plant itself).
- Be provided for enough employees to ensure that plant need never be operated by untrained staff.
- Include the use, care and maintenance of personal protective equipment (PPE).
- Require those who have been trained demonstrate that they can operate and maintain the plant safely.

Health (Infectious Diseases) Regulations 2001

The Health (Infectious Diseases) Regulations 2001 sets out the parameters within which pools and spas where the public are admitted 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 have an appropriate knowledge of and access to the current Health Regulations.
> A copy should be kept on-site.

Occupational Health and Safety Act 2004

The objectives of the *Occupational Health and Safety Act* are:

- To secure the health, safety and welfare of employees and other persons at work.
- To eliminate, at the source, risks to the health, safety or welfare of employees and other persons at work.
- To ensure that the health and safety of members of the public is not placed at risk by the conduct of undertakings by employers and self-employed persons.
- To provide for the involvement of employees, employers, and organisations representing those persons, in the formation and implementation of health, safety and welfare standards.

Adhering to the Occupational Health and Safety Act includes protecting staff and the public who work at or use a pool. The manager should have the necessary authority to implement reasonable measures to ensure the premises are safe, and all plant and substances are operated, stored and used safely without risks to health.

Identifying the hazards and by taking precautions to control the risks helps managers to reduce their liability. Training, certification and record keeping are fundamental in providing a safe, healthy environment–and they are the manager's key to safeguarding legal requirements and producing a successful operation.

Obligations and Duties

Employers

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

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

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.

Employees

Employees are required to:

- Take reasonable care of their own health and safety.
- Take reasonable care for the health and safety of anyone else who may be affected by their acts or omissions at the workplace.
- Cooperate with their employer with respect to 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*, and in particular the Dangerous Goods (Storage and Handling) Regulations, apply to employers whose business involves substances hazardous to health.

Substances which are hazardous to health include microorganisms, by-products and any substances which create the sort of hazard that might come from a classified chemical. Pool operators should therefore include specific consideration of bacteria and viruses, other pollutants and disinfection by-products in planning storage and use of 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 the premises, as well as Material Safety Data Sheets (MSDS). A formal assessment of the dangerous goods held at the workplace should be conducted, and the health risks to employees and anybody using the premises assessed. This assessment must be regularly reviewed and updated if circumstances change–for example, a change in the type of disinfectant used, or method of its application.

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 and the Dangerous Goods (Storage and Handling) Regulations.

Signage

The Dangerous Goods (Storage and Handling) Regulations replaces the Dangerous Substances (Placarding of Workplaces) Regulations and the Hazchem legislation made under the Occupational Health and Safety Act. These types of acts and regulations are under constant review, and at the time of printing this Handbook may have changed, or had their names changed.

The purpose of the Hazchem part of the Regulations is to ensure that in the event of a fire or spillage involving dangerous goods, the emergency services will be better prepared and equipped to combat any such incident.

The Regulations require that notices be displayed at all workplaces if the quantity of various classes of dangerous goods that are kept exceed a prescribed aggregate amount. This includes schools, shops, factories, warehouses, laboratories, hospitals and swimming pools.

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 Notices

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. (See listing below.)

The are a number of exceptions. These are:

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.

Composite Warning Notices

If a workplace requires notices under the above definition, then a Composite Warning Notice is required for *all* storage of dangerous goods. The Notice must be one of the following:

1. In the case of a storage of **packaged** dangerous goods, a notice of the form shown in Figure 2 must be displayed:
   a) At the entrance to *any building or room* in which dangerous goods are kept

   and

   b) Adjacent to any storage of dangerous goods kept in the open.
2. In the case of **bulk** dangerous goods, that is, a storage tank or bulk container, a notice of the form shown in Figure 3 must be displayed on or adjacent to the tank or bulk container.

Hazchem Codes

1. The Hazchem Code provides advisory information to the emergency services personnel to enable them to take the appropriate action to combat the incident.

For example, the Hazchem Code for chlorine gas is **2XE**.

2. The Dangerous Goods Class Labels are an international system of identifying the primary hazard of various substances. That is, whether the substance is a gas, a flammable liquid, a poison or corrosive substance, etc. The class labels are shown in the diamond on the right hand side of any composite labels. (See Figure 3 for an example.)

Table 1 Example Hazchem Codes

Hazchem Code	Meaning
2XE	Chlorine gas
2	Indicates that the 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 evacuation of the site.

Figure 2 An Example of Hazchem Signage for Packaged Dangerous Goods

*Hazchem codes must be displayed at the entrance to **any building or room** in which dangerous goods are kept and adjacent to any storage of dangerous goods kept in the open.*

Figure 3 An Example of Hazchem Signage Bulk Dangerous Goods

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

Quantities of chemical

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

How Close Together Should Chemicals be Stored?

Separation Distances

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 and Workcover. A risk assessment approach is prescribed by the Regulations.

SafetyMAP

The Victorian WorkCover Authority has developed SafetyMAP as an audit tool designed to assist organisations of all sizes and functions improve their management of health and safety.

The audit criteria within SafetyMAP 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.

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 are the key to protecting 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. The purpose of the data sheet is to provide information needed to safely use the substance in the workplace. If the chemical is also a dangerous good, an MSDS also 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 provides guidance on the format and content of an MSDS.

Pool managers and operators should ensure that all appropriate dangerous goods signage is displayed. It is recommended that signage be inspected by a qualified OH&S Auditor to determine its compliance.

Are MSDS Compulsory?

Occupational Health and Safety (Hazardous Substances) Regulations require manufacturers and importers of hazardous substances to ensure that an MSDS is prepared for the substance before it is first supplied for use at a workplace. A supplier and manufacture is 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 workplace.

Pool managers are encouraged to develop and monitor systems of operation which provide quality management involving water quality and plant operation.

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

What if More Information is Needed?

If employers require additional data or advice about a substance to help protect employees, it may be useful to contact:

- The manufacturer or importer
- Those experienced with handling the substance safely
- WorkCover offices
- Health and safety professionals in industry to trade organisations
- Occupational hygienists or occupational health and safety specialists.

The Four Main Sections of the MSDS

Generally, an MSDS has four main sections. These are described in Table 6.

Table 6 Four Main Sections of the MSDS

Section	Description	Example
Identification	This section describes the product, its ingredients and its 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** Inhalation of mists may produce respiratory irritation and coughing. Inhalation of high concentrations may cause death due to 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.

Codes of Practice

A range of other Codes of Practice exist with which pool managers should be familiar. These include a number of Codes published by Health and Safety Victoria and include:

- First Aid in the Workplace
- Manual Handling
- Noise
- Plant.

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

Australian Standards

Pool operators may find further valuable information relating to the aquatic industry in a number of key publications from the Standards Association of Australia. Table 7 Australian Standards lists some which may be of value.

Guidelines for Safe Pool Operation (GSPO)

The Royal Life Saving Society Australia Guidelines for Safe Pool Operation (GSPO) were first released in 1991 and a second edition was released in 1996. As 'guidelines' the GSPO are secondary to any Act, Regulation or Code of Practice. However, they provide invaluable information on many aspects of public swimming pool operation. Topics include:

- Technical operations
- First aid
- Facility design
- Supervision
- Learn to swim
- General operations.

The GSPO provides advice on bather loads for public swimming pools, wave pools and aquatic competitions. They should be used as the industry guide to the supervision of aquatic facilities. Other areas which may affect bather load and supervision are special design features and activities undertaken in the pool type, for example, hydrotherapy pools, water flumes (slides), inflatables and other water play equipment.

Audits

Audits of aquatic facilities can be carried out to assess and report on compliance with:

- Guidelines for Safe Pool Operation
- Compliance with the Occupational Health and Safety Act
- Dangerous Goods (Storage and Handling) Regulations
- Health (Infectious Diseases) Regulations.

Owners and operators of aquatic facilities should ensure that the audit covers all appropriate aspects of their situation.

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.

SEPPs

The *Environment Protection Act 1970* provides for the formulation of State Environmental Protection Policies (SEPPs). By the end of the 1980s SEPPs had been declared for air, water and noise. 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.

Table 7 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.
AS2610.1–1993	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.
AS3979–1993	Hydrotherapy pools.
AS/NZS4360–2004	Risk management.

Discharge of Waste from Pools

In the SEPP–Waters of Victoria, minimum requirements for discharge from municipal and commercial swimming pools are given. The discharge of wastes from municipal and commercial swimming pools are required to conform to several requirements relating to filter backwash and pool content.

Filter Backwash

According to the SEPPs, the 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, TDS 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 conformance with the SEPP–Waterways of Victoria. The results of the analysis must be submitted to the EPA within 28 days of the samples being taken and the volume of the discharge must also be recorded.

2. 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.

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.

Although this chapter cannot give advice on the details of design, it does indicate the areas that need to be covered in a design brief. Finally, there is advice about 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, which also takes into account existing facilities. 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 retained. 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.

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, which makes these issues central to good water quality.

Water Treatment

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

- Pool type (recreation, hydrotherapy, toddlers, spa and so on)
- Pool temperature
- Method of removal of 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 on 'Chemical Testing').
- 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 full 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**–who can provide independent specialist advice and who are appointed as full members of the design team.
- **Contractors**–who can work to the consultants' brief and specifications, to their own schedule or 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 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. However, the Health Regulations require a half-hour turnover for spas. Australian Standards (AS3979) recommend a two-hour turnover for hydrotherapy pools.

Choice of Treatment System

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

- The nature 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, an assessment should be made of the types and amounts of chemicals required and how they are stored, to adhere to regulations and guidelines on storage. 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, rather than improve the clarity of the water. Effective filtration, well-maintained filter media and a short turnover period will ensure that suspended solids are removed. (More information about filtration operation is provided in the chapter 'Filtration'.)

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, 50–100 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 'Microbiological Monitoring'.)

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. (See also the section on 'How Close Together Should Chemicals be Stored?' and 'Separation Distances'.)

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 both during commissioning of the plant and 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.

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 specification, 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 the consultants' services and owners of the facility should pursue references, and verify the consultants' 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 by utilising 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. The majority of pools are rectangular swimming pools that have no extra water features and are used by people of all ages. The following list describes a range of conventional pools in specific applications as well as a number of non-conventional pools.

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 2.5 m outside 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 water 3.5 m deep 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 infinitely 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 customer 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 design, particularly bathing load, and not 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 Pools

These are generally smaller pools specifically designed for physiotherapy and gentle exercise. Operating temperatures of over 32°C are recommend. Specific design and construction requirements are outlined in AS3979–1993. 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 of filters, pipe and pumps should be resistant to salt water corrosion.

Spa Pools

There are many types of spa pools, but they all have in common their use: they are for sitting in, rather than swimming, and contain water usually between 32˚C and 40˚C, which is filtered and chemically treated. A pool with *untreated* water that is replaced after each user, and water agitation of some sort, is 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 control of 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, or daily when loading is high. Refer to Australian Standard for Public Spas AS 2610.1–1993.

Spas may have particular difficulties over 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. This should be based on the principles and methods given for swimming pools.

Teaching 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: there should be separate 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 due to 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 above 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 for any reason 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 a 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 in 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.

3. Hygiene and Contamination

Pool Water Contamination

Overview

Swimming pools present no special infection risk, provided they are properly managed and disinfected.

Pool users are the primary cause of contamination. Therefore, management of their numbers, according to maintenance capabilities, is necessary. Overcrowding in the pool, in change rooms and at the poolside is to be avoided. Sensible hygiene rules, such as nappy changing in change rooms rather than at poolside, should be encouraged.

'Contamination' is defined as any addition to the water that makes it dirty or impure. If pollution is present there is a risk of bather contamination. This has legal, ethical and health implications. Effective maintenance of water chemistry, balance and quality associated with adequate hygiene standards will counteract most pollutants.

The following principles need to be fully understood by pool maintenance staff.

Sources of Contamination

Contamination is introduced predominantly via pool users, but also via the environment, including source water.

Environment

Environmental contamination is especially relevant to outdoor pools where there is dust, soil, sand, leaves and grass constantly around and in the pool.

Pool Users

Pool users contaminate the pool in three different ways:

- From bodily fluids, solids and wastes–urine, mucus from the nose and chest, saliva, sweat, hair, scales from skin and faecal matter. These are pollutants in themselves, but may also contain harmful microorganisms which could cause illness in other pool users.
- From dirt–collected on the body before bathing, for example, on the feet from the pool concourse, on skin from clothes.
- From cosmetics–perfumes, oils, hairspray, lotions, sunscreen and creams.

Transmission of Infection

Many microorganisms are harmless and normally present in healthy people. However, if they are swallowed in large numbers by a bather who is unwell or has altered immunity (which may be the case during pregnancy or illness), then infection and sickness can result. For this reason the entire pool environment–that is, the change rooms, toilets, concourse, as well as pool water–should be adequately cleaned and managed at all times.

Hygiene Standards

Minimum hygiene standards should be met for all change rooms, toilets and showers. The pool concourse should be cleaned at least daily. Pool users should be encouraged to shower prior to entering the pool to rinse off dust and body oils.

Disinfectants

Some infections can be transmitted through the pool water from one bather to another if there is inadequate disinfectant. Other potential infections are through contamination with spilt blood, vomit or faecal matter. In these cases immediate action is necessary and all pools should have emergency response procedures documented.

Refer to the Department of Human Services website, which is updated every three months. The website address is: http://www.health.vic.gov.au/environment/water/swimming.htm

Infections and Conditions Associated with Pool Use

Gastro-Intestinal Infections, Including Cryptosporidium

Generally speaking, most microorganisms responsible for gastrointestinal infections will be inactivated by the disinfectant residual and removed by the filtration system. Therefore, correct maintenance levels of disinfectant and filtration are necessary. However, two problem organisms–Cryptosporidium and Giardia–remain. These cause watery diarrhoea and abdominal cramping, associated with symptoms of fatigue, fever, loss of appetite, nausea and vomiting. In the healthy individual these symptoms are usually mild, but they can cause severe, chronic, debilitating illness if the recipient is unwell or has a reduced immune system.

Cryptosporidium is resistant to the usual maintenance levels of disinfectant and can remain in the pool system for several months. Normal filtration processes may be ineffective in removing Cryptosporidium parasites due to their tiny size. Because normal disinfectant residuals and filtering processes are not effective in eliminating Cryptosporidium, special care is needed in cases of suspected contamination. Disinfection levels need to be raised to 14 ppm and kept at that level for 12 hours. The addition of coagulant and frequent backwashing of filters is also advisable.

The Department of Human Services is evaluating the use of other chemicals, such as chlorine dioxide and ozone for the treatment of Cryptosporidium. Check the Department of Human Services website for up-to-date information at http://www.health.vic.gov.au/environment/water/swimming.htm

Infected Users

Pool users suspected of being infected with either Cryptosporidium or Giardia are advised to avoid attending a pool for one month after symptoms cease. As the recommended maintenance level for disinfectant is less than 8 ppm, the pool must remain closed until water samples prove no evidence of the microorganism. If a pool is closed due to suspected contamination by Cryptosporidium, signage is advisable to warn infected persons not to visit or potentially contaminate other pools.

Patrons who have suffered a gastrointestinal illness or diarrhoea should be advised not to use the pool until at least one week after symptoms cease.

Foot Infections

Usual maintenance levels of disinfection in the pool water will kill fungi or bacteria associated with foot infections. However, two common conditions can be caught from the damp environment of pool surrounds, change rooms or showers.

Tinea Pedis (Athlete's Foot)

Tinea pedis is a fungal infection causing an itchy scaling between the toes. This is hard to distinguish from soggy skin caused by inadequate drying between the toes. Tinea is spread by contact on damp floor surfaces, such as showers or poolside, where there are infected fragments of skin. Adequate floor cleaning reduces the number of infective particles. Wearing pool shoes or thongs in showers and at the poolside reduces skin contact with a potentially contaminated floor. Exclusion from the pool is not necessary.

Plantar Warts (Verrucae)

Plantar warts are caused by a virus, and may be picked up from contact with contaminated fragments of skin on the surrounds of the pool. As with tinea, adequate cleaning of pool surrounds is necessary and users should wear pool shoes or thongs around the pool. Carriers are advised to cover warts to prevent contamination of pool surround surfaces but exclusion from the pool is not necessary.

Viruses

Viruses are not spread in the pool if adequate sanitiser levels are present.

Human immunodeficiency virus (HIV) and hepatitis are viruses carried in the blood and other body fluids. They are inactivated by the disinfectant residual at normal maintenance levels. Blood, vomit or faecal spills from swimmers with these viruses are treated as above.

Ear and Sinus Problems

Wetting, de-waxing and degreasing of the outer ear may cause swimmer's ear (otitis externa). This may result in skin drying and damage, with or without infection caused by the usual bacteria found on normal, healthy skin. It is most common in endurance and competitive swimmers. High numbers of *Pseudomonas aeruginosa* present in the water may cause an unusually high incidence of this condition (as well as skin infections). Normal sanitation levels should eliminate the presence of *Pseudomonas*.

Infection of the middle ear (*otitis media*) and sinusitis following swimming are usually caused by infected mucus forced into the nose and throat while swimming. People are encouraged not to swim if they have an upper respiratory tract infection, but need not be excluded.

Meningitis

Meningitis associated with swimming is extremely rare in Australia and has not been detected in Victorian pools that are properly treated and maintained. The free-living amoeba *naegleria fowleri* causes it. In each case associated with swimming, the pool has been found to be receiving polluted, warm spring water–and to be inadequately disinfected. Normal disinfection levels are necessary. Pool make-up water must be clean and come from secure sources. Circulation systems, including balance tanks, should be designed to avoid prolonged periods of stagnation. Any debris should be removed regularly.

Legionaire's Disease

Legionella pneumophila bacteria cause a severe form of pneumonia known as legionnaire's disease. For it to be spread there must be an infected spray, such as with spray humidifiers or cooling towers. Legionnaire's disease has not been associated with conventional swimming pools. However, it is easily spread in poorly maintained and disinfected spa pools due to the fine spray (aerosols) generated at the turbulent water surface. Careful maintenance, frequent filter backwashing and close attention to disinfectant levels are critical.

Skin Irritations and Rashes

Skin irritation and rashes can be associated with pool use. Good water management and adequate dilution will keep these to a minimum. Skin rashes associated with pool use are usually due to one of the following factors:

- Drying of the skin due to a reduction in natural body oils–common with prolonged immersion and warm water in hydrotherapy pools and spas.
- Residual disinfectant left on the skin.
- Infection (more common in spas due to higher bather loads) skin abrasion from the aerated water jets and higher water temperature.

These factors contribute to common skin conditions, such as pool rash, bromine itch and folliculitis.

Pool Rash

Pool rash is essentially a mild dermatitis caused by prolonged immersion and the effect of the disinfectant creating a dry, irritated skin. It responds well to unperfumed moisturising creams and/or reduced exposure to the pool.

Bromine Itch

'Bromine itch' is another form of dermatitis caused by sensitisation to bromine and its by-products used to disinfect the pool. Incidence increases with age and exposure, particularly with prolonged immersion. It is intensely itchy and occurs within 12 hours of exposure. It often recurs with repeated exposure to brominated pools.

Folliculitis

Folliculitis is an infection of the hair follicle caused by the bacteria P*seudomonas aeruginosa*. A combination of intense skin wetting and high levels of the bacteria is necessary for the infection to occur. It is most common in spas, where there are higher temperatures (over 35°C), longer exposure times (one to two hours) and inadequate disinfection. Unlike bromine rash, it tends not to be itchy.

Respiratory Complaints

Generally speaking, the warm, humid air around a pool assists respiration. High levels of chloramines, the by-product of chlorine disinfection, may trigger asthma attacks. These levels can be high because the pool is poorly designed, overloaded or poorly maintained. Chloramines themselves, and other substances in the air, do not *cause* asthma, but may provoke an attack.

Summary

The bather load generally introduces pollution to a pool. If this is controlled to avoid overcrowding, at the same time as maintaining standard hygiene procedures and normal pool disinfectant levels, then cross-contamination of pool users is minimised. When appropriate, emergency procedures are established and used in conjunction with regular maintenance, cross-contamination is unlikely to then occur.

People suffering from diarrhoea or gastroenteritis should not use a pool until at least one week after the symptoms have cleared. Faecally incontinent people should not use a pool or spa unless their condition is managed by a health professional. Signage to this effect should be displayed.

Emergency Procedures

Exposure of Pool Water to Faecal Matter

The treatment required will depend upon the condition of the faecal matter introduced. Loose faecal matter (diarrhoea) requires greater treatment than a firm stool, as it is more likely 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.

Loose Stool

The following are guidelines for responding to loose faecal matter in the pool:

1. The pool, in the vicinity of the faecal accident, should be cleared of people.
2. The faecal matter should be removed as thoroughly as possible using a fine mesh scoop net or vacuumed to waste.
3. The pool should be superchlorinated, with the bulk of the disinfectant added to the immediate vicinity of the accident.
4. The pool should be superchlorinated that night.
5. The pool filters should be backwashed that night.
6. Details of the accident and treatment should be noted in the pool operation log.
7. Patrons should only be allowed back into the water when disinfectant and pH levels are within recommended ranges and all faecal matter has been removed from the water.

Firm Stool

A firm solid stool requires the following action:

The pool in the vicinity of the faecal accident should be cleared of people.

1. The stool should be removed.
2. Water should be tested to ensure compliance with the Health Regulations.
3. If the water meets the Regulations, patrons may be allowed to re-enter the water.

Contamination of the Pool Water by Blood or Vomit

If blood or vomit contaminates the pool water, the following action should be taken:

1. The pool in the vicinity of the accident should be cleared of people.
2. Large particles should be removed using a fine mesh scoop net, vacuumed to waste.
3. Allow and assist any remaining contaminant to disperse.
4. Water should be tested to ensure compliance with the Health Regulations.
5. If the water meets the Regulations, patrons may be allowed to re-enter the water.

Disinfection of Contaminated Surfaces

Any contaminant on the pool deck should **not** 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 should be consulted before preparing chemical dilutions.

The procedure for dealing with a contaminated surface is:

1. Wear rubber gloves and remove excess contaminant using disposable paper towels or similar.
2. Wipe non-porous surfaces with hot water and detergent and 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 Hygiene and Cleaning

Overview

Good pool water management and adequate hygiene procedures will prevent pollution and cross-contamination in most cases. The next chapter, 'Pool Water Contamination', deals with types of contamination, and the following chapter, 'Disinfection', deals with maintaining appropriate disinfectant levels. This chapter concentrates on cleanliness and hygiene in the pool surrounds and in the pool itself.

Public Education

Swimmers need to understand the importance to them of pre-swim hygiene; it helps provide more comfortable water. Posters, pool rule handouts and informal education all help to inform the public of their part in keeping the pool clean. However, if the toilet and shower facilities do not accommodate swimmer numbers, or they are inaccessible or dirty, no amount of education will encourage swimmers to use them.

Pool Users' Personal Hygiene

The pre-swim shower will remove most potential contaminants–dead skin cells, fibres from clothes, dirt, body oils and sweat–before the swimmer enters the pool water.

In Australia it is not compulsory to shower, wear a swimming cap or walk through a footbath before entering a pool, as it is in some other countries. However, there seems to be some sense in encouraging the pre-swim shower.

Footbaths were once considered invaluable for preventing contamination with tinea and plantar warts but this no longer appears to be the case. Showers clean the feet more effectively and bring extra benefits of rinsing the body at the same time.

Swim showers should be supplied with fresh water and run to waste. The frequency of cleaning showers will depend on number of swimmers using them, but regular inspection and at least daily cleaning should be part of routine management.

Toilets

These need to be placed so they can be conveniently used prior to entering the pool. Public education is necessary, especially with children, to minimise involuntary urination in the pool. Babies should be in bathers rather than nappies, and be encouraged to empty bladders before entering the pool. Frequency of cleaning will depend on numbers attending, but toilets should be cleaned at least once daily, and more frequently in times of heavy use. Sanitary and nappy disposal units should be made available. Regular inspection should be part of routine management.

Hot Water Systems

Hot water 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 the colonisation of *Legionella* bacteria. The temperature reduction required can be achieved by mixing valves. Tepid water systems or modified tepid water systems that maintain water below 50˚C must be maintained in accordance with the Standards prescribed by the Health (Infectious Diseases) Regulations to minimise colonisation by Legionella bacteria. 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 Systems

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

Cleaning in and Around the Pool and Changing Rooms

From a hygiene perspective to prevent transmission of infection, the pool surrounds and change rooms need to be cleaned regularly. Frequency will again depend on the number of swimmers attending but should be monitored and inspected as part of routine management. Minimising dirt from shoes can be controlled 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 pool. For this reason, pool water can be used as the cleaning solution, as it already has a disinfectant in it. 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 periodically.

It is extremely important that commercial products used for cleaning in and around the pool area are compatible with pool water and 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 interact with other chemicals in a way that can be hazardous. Care should be taken to avoid outright incompatibility between cleaning and pool chemicals–particularly potentially explosive reactions between acids and alkalis.

Bottom of Pool

There should be some method of cleaning debris and algae from the floor of the pool. The simplest method is to use a long-handled, wide, weighted brush and 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 that may require manual handling or may be 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

Generally speaking the pool should not be emptied unless absolutely necessary, due to potential structural damage. Detailed information about this process is included in the chapter on 'Maintenance'.

When emptied, the walls and floor can be assessed for cracked, broken or loose tiles or vinyl and these should be 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 can damage the grouting. In either case, the solution needs to be neutralised then rinsed to waste prior to the pool being refilled.

4. Water Treatment

Choosing a Disinfectant

Overview

Disinfection occurs when sanitation of the pool water is achieved. This means that transmission of infections between persons or from the pool is minimised and that growth of algae and other nuisance organisms is inhibited.

Chlorine and Bromine Based Disinfectants

Disinfectants need to kill bacteria very quickly, and free chlorine or bromine are the most effective treatments available that can be safely used in swimming pools. These disinfectants have another advantage because they also oxidise bather wastes, such as sweat, skin particles, mucus and urine in the pool water.

> 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 has been shown to be beneficial in the breakdown of chloramines. The chapter 'Water Treatment Using Ozone and Ultraviolet Radiation' provides more information about the use of ozone and UV.

Other Disinfection Treatments

There are other disinfectant systems that are marketed in Australia, which involve the use of 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 all pools to cope with a range of bathing loadings.
- Use automatic monitoring and dosing of disinfectant and pH in all spa pools and other pools that are 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.
- Conduct superchlorination 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.
- Dilution reduces bather pollution, disinfection by-products, excessive TDS and cyanuric acid build-up.

Choosing a Suitable Disinfectant

Type of Pool

The type of disinfectant chosen depends on these factors:

- Indoor or outdoor situation
- Swimming pool or spa pool
- The chemical characteristics of the water supply
- The bather loadings that have to be treated
- Circulation capacity and pool design
- Chemical handling and safety issues
- Supervision and maintenance issues
- Pool water temperature.

Chlorine Based Chemicals

Chlorine based chemicals available 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 available include:

- Tablet (BCDMH)
- Sodium bromide with an activator (hypochlorite or ozone).

Chlorine Gas

Chlorine gas is one method available to 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 limit the use of chlorine gas to pools that have sufficient buffer distances from residences and places of public gathering to minimise the risk of injury, should there be a chlorine gas leak. For this reason gas cylinders and injection points are located within 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 the most versatile pool disinfectant and is widely used. It does pose chemical handling risks, however, particularly in a bulk handling and storage situation. Sodium hypochlorite is strongly alkaline and tends to keep high pH levels. It is generally used in combination with acid or carbon dioxide dosing. It is easily dosed by metering pump, therefore it is flexible in meeting demand. It is stabilised in a caustic solution, thereby having a shelf life of some weeks.

Calcium hypochlorite is widely available and suitable for manually dosing pools following closure. It is useful for soft waters in maintaining hardness levels lost by dilution and backwashing. It is generally not used for metered dosing. Tablets are also available which have a number of applications.

Lithium hypochlorite is shelf stable, non-scaling and highly soluble in water. It is ideal for use in 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 contained in the pool water into free chlorine. Salt-water pools involve minimal chemical handling and daily maintenance, are low in complexity and are therefore recommended 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 requires periodic topping up to maintain chlorine production rates.

The output of the chlorinator is related to the size or number of the electrode plates. As the chlorine output is fixed, careful consideration of bather loads and chlorine consumption should be considered when installing systems.

Scaling of the electrode plates may occur if there is too much calcium hardness in the water, however this should be considered in line with protecting the pool surfaces. The plates should be cleaned with acid periodically in accordance with manufacturer's directions.

In outdoor use, cyanuric acid should be present in salt chlorinated pool water.

Chlorinated Isocyanurates

This type of disinfectant (for example, trichlor, dichlor) combines chlorine with cyanuric acid stabiliser and is therefore suited to pools exposed to direct sunlight. In outdoor use a start-up concentration of 25 ppm of cyanuric acid is recommended. When levels of cyanuric acid increase to 100 ppm, more frequent dilution of the pool water is indicated to control cyanuric acid levels.

Trichlor is used in many pools because of the ease of chemical storage and the simple dispensing methods using erosion feeders. It is suitable for hard, alkaline water, as it does not contain calcium and helps keep pH down. It is suitable for outdoor hotel/motel and caravan park pools as the tablets are easily handled. It has also been used in community pools but is not as flexible as gas/hypochlorite systems. Care should be taken to ensure that cyanuric acid does not reach excessive levels. This can be corrected by backwashing or draining the pool on a regular basis.

Chlorine–Chlorine Dioxide

Chlorine dioxide is also an effective disinfectant and oxidant and is not affected greatly by pH. Stabilised chlorinous oxide solutions that form chlorine dioxide when added to water are beginning to be 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.

Chlorine dioxide treatments have been proposed as a treatment for pools affected by Cryptosporidium contamination.

> Check the Department of Human Services website http://www.health.vic.gov.au/environment/water/swimming.htm for latest recommendations.

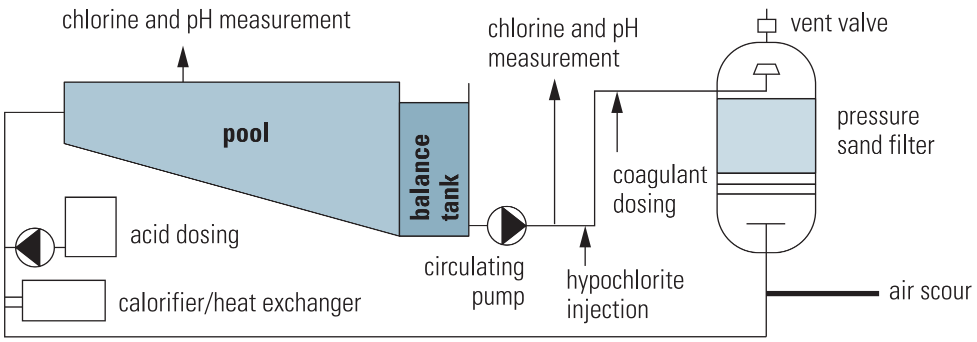
Bromine

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

Bromo-chloro-dimethyl-hydantoin (BCDMH) has been popular in hydrotherapy pools, due to better retention of disinfectant in heated situations and the absence of chlorinous odours. Brominated pools do have a particular 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, or ozone, when injected into the water forms hypobromous acid. After reaction with contaminants, the hypobromous acid reverts back to bromide and so the cycle restarts.

Figure 8 Pool Water Treatment with Chlorine Disinfectant



Bromine can be purchased as a preformed 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 invariably 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. The continuous maintenance of a free chlorine residual, which is 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 an industry term for a periodic maintenance procedure where the free chlorine residual is raised 2–4 times the normal operating level to prevent algae, remove colour and maintain clarity. Superchlorination also assists in reducing 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.

- 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, which is a stable compound that 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 recommended in these circumstances as the best method of removing inorganic chloramines.

For pools using chlorinated isocyanurates as their regular disinfectant, superchlorination using these products may elevate cyanuric acid levels over time. Operators should consider using a hypochlorite for superchlorination purposes when cyanuric acid is at the preferred concentration.

Shock Dosing

Shock dosing is an industry term used to describe the process of superchlorination when it is specifically used to solve problems 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 5–7 times the normal free chlorine residual, may be used to help correct a serious problem, however dosing above this level would lead to excessive waste of 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, otherwise nitrogen trichloride will form.

- 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 by the introduction of fresh water.
- Consideration must always be given to 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.

Dechlorination

Dechlorination can be achieved by adding sodium thiosulphate to the pool water if chlorine levels are above the regulatory limits. This will enable the operator to reduce chlorine levels and allow bathing.

Situations that require dechlorination should be avoided.

When using sodium thiosulphate, it is important to fully dissolve the crystals before adding them to the pool, as inadequate dissolution may prevent satisfactory chlorine neutralisation. Overdosing may result in a higher residual of sodium thiosulphate than required and this may prevent adequate chlorine levels being achieved. Approximately 10 g of sodium thiosulphate per 10,000 litres (10 m^3) of pool water is required to lower chlorine levels by 1 ppm.

Ozone and UV

Ozone is an effective oxidant and ozonated pools have 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 the chapter on 'Water Treatment Using Ozone and Ultraviolet Radiation' for a fuller description.)

Oxygen Based Oxidisers

Oxygen based oxidisers are available, but they 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 ingredient 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 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 that contain 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, and the gradual addition of chlorinated isocyanurate disinfectants to bring up the level may be the easiest method for some operators.

Oxidation-Reduction Potential (ORP) as a Disinfection Parameter

Oxidation-Reduction Potential (ORP, redox) measurements are a reliable indicator of the condition of the water, 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 site-specific to a degree.

If ORP is used as a water quality parameter in its own right, then comparing the sensor response using Light's solution is necessary 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 respectively when placed in Light's solution. Light's solution is available from scientific instrument suppliers.

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 regulatory authorities prescribe that minimum free disinfectant residuals need to be measured by other means.

Control of Algae

Algae are a single-celled green plant which thrives in water and sunlight. Spores are introduced into water via raindrops, wind-borne dust and on the feet of water birds, and can grow rapidly. Conditions conducive to algae growth include high pH, low chlorine, sunlight, warm water and mineral content–particularly phosphates and nitrates.

In a pool that is subject to regular use and is maintained in accordance with the Regulations using best practice, algae problems should never occur. Regular superchlorination should be all that is required to oxidise algae spores.

Algacides should not be present in pool water during the swimming season unless permission to do so has been obtained from the Department of Human Services (Victoria) for exceptional circumstances.

Most algacides are toxic to plants and stream life. Some algacides, particularly those containing metal ions or residual herbicides, have residual 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. Most algacides actually increase the rate of chlorine consumption as metallic compounds and other complexes are oxidised by chlorine. The presence of metallic or other compounds may alter the oxidation profile of the pool water and can inhibit chloramine destruction and disinfection. Algicidal compounds generated from ionising electrodes have no fundamental difference from residual metal-based algacides obtained from liquid or powder.

Unsuitable Disinfectants

Some pool disinfectants sold are not suitable disinfectants for public pool use. This is usually because the rate of disinfection (biocidal efficacy) is insufficient to prevent infectious disease in public pool situations. Some of these include:

- Hydrogen peroxide
- Silver/copper ions
- Polymeric biguanides
- Quarternary ammonium compounds
- Ionisers
- Electromagnets
- Energy polarisers.

Table 8 Summary of the Characteristics of a Range of Pool Water Disinfectant

Chemical or process	Form	Shelf life	Typical concentration of active ingredient	pH when made into solution	Effect on total alkalinity	Effect on calcium hardness	Stabiliser required for outdoor use	Suitable for in line dosing	Comments
Chlorine gas	Gaseous cylinder	Years	100%	2	Decreases	Nil	Yes	Yes	• Mostly used in large pools with trained pool operators. • Dangerous Goods Regulations 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	• 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	Years	65%	9	Increase	Increases	Yes	No	• 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.
	Tablets	Years	65–70%	9	Increase	Increases	Yes	Can be used in erosion feeders but solubility is poor	
Lithium hypochlorite	Granules	Years	35%	10.5	Increases	Nil	Yes	No	• Mostly used in indoor spa pools.
Sodium dichloroiso-cyanurate (dichlor)	Granules	Years	58–63%	6.8	Nil	Nil	No – contains stabiliser	No	• Mostly used in outdoor spa pools. • Has little effect on pH/alkalinity. • Must monitor cyanuric acid levels.
Trichloroiso-cyanurate (trichlor)	Tablets	Years	85–90%	2.4	Decreases	Nil	No – contains stabiliser	Yes (erosion canister)	• 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 8 Summary of the Characteristics of a Range of Pool Water Disinfectant (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	Stabiliser 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	• 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)	• 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	• 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	• 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	• Must be used with chlorine. • Regular superchlorination required to reduce chlorite build-up. • Suitability currently under investigation by the Department of Human Services.

Adapted from AS3633–1989 Private Swimming Pools–Water Quality.

Water Treatment Using 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.

Of the two, ozone is the more established in Australian pools. Ultraviolet radiation is beginning to be explored in commercial pools.

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. Chemically, it is three oxygen atoms ($O3$), as opposed to two in the oxygen molecule ($O2$). It can appear naturally around electrical equipment, for example, photocopiers, but for pool water disinfection it is generated on-site.

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.

As ozone is relatively unstable, it cannot be manufactured somewhere else and transported to the pool in cylinders like chlorine. As it is unstable, ozone is an extremely strong oxidant, and therefore a good disinfectant. As it decomposes into oxygen, no new chemicals are added to the water. However, it is also toxic in significant atmospheric concentrations, so excess (unreacted) ozone must be removed within the treatment system.

Dealing with Contaminants

The chemistry of the relationship between ozone and pool contaminants is complex. Ozone interferes with the reactions that produce contaminants, moreso than actually destroying urea, amino acids or trihalomethanes. And there are also significant reactions that allow subsequent filtration of the organic molecules by a process of microfloccuation. 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; and the O_3 concentration during this period 0.8–1 ppm.

On 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, treatment of 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.

De-Ozonation

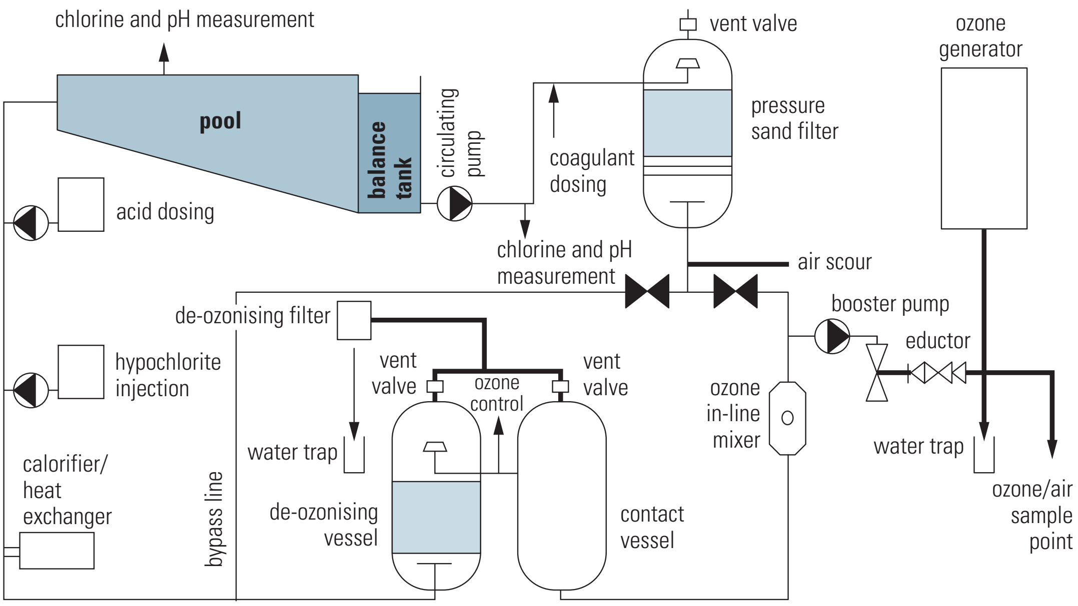
The de-ozonation stage immediately follows ozonation; all traces of ozone must be removed from the treated water before it enters the pool. Granular activated carbon (GAC), activated heat-treated anthracite and thermal destruction methods are commonly used for de-ozonation.

Figure 10 ORP Probes

ORP probes can be installed to detect the oxidation level of the pool water pre and post de-ozonation. These probes check the effectiveness of the ozonation and de-ozonation process.

ORP probes (above) installed detect the oxidation level of the pool water before de-ozonation and after de-ozonation. These probes check the effectiveness of the ozonation and de-ozonation processes.

Figure 9 Pool Water Treatment with Ozone and Hypochlorite



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, however, an ozone leakage detector should 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

Bacterial Colonisation

Chlorine is removed with the ozone. If it is totally removed, there may be bacterial colonisation of the filter. Therefore it is important to maintain some degree of residual disinfection throughout de-ozonation. Bed depth and filter velocity appears to be critical here. Recent experience has indicated that colonisation is likely in the de-ozonation 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-ozonation, the water should be essentially free from bacteria, and the majority of the organic matter oxidised. It does not, however, 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 Regulations. 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 radiation from the ultraviolet section of the electromagnetic spectrum is well established. UV treatment has been used in drinking water, industrial and effluent applications.

The primary action of UV is to kill bacteria, viruses, moulds and spores, thus reducing the risk of transmission of stomach, skin and respiratory tract infections to pool users. UV has an important secondary action: it initiates photochemical and photo-oxidation reactions which destroy chloramines. This is particularly important in leisure pools where features such as water slides and waves give 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 the 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.

A chlorine or bromine based disinfectant must be used in conjunction with UV systems to maintain a disinfectant residual in the pool. UV radiation inactivates bacteria and helps break down chloramines and other pollutants.

Water Balance

Overview

Water balance is a term that 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 four factors:

- pH
- Total alkalinity
- Calcium hardness
- Temperature.

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; whereas, at a pH of 7.5, about 50 per cent is immediately available.

pH change in pools is caused by the addition of 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 water may affect the pH in extreme cases. See Table 8 Summary of the Characteristics of a Range of Pool Water Disinfectant for the pH effect of disinfectants.

Total Alkalinity

Total alkalinity is a measure of the amount of alkaline salts present in the water. Total alkalinity works as a shock absorber to reduce 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 is a measure of 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 as it becomes less soluble as temperature rises.

In areas of high calcium source water, specialist advice should be sought prior to the establishment of 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, marblesheen or tiled pool surfaces may become etched, particularly at low temperatures.

Total Dissolved Solids (TDS)

TDS is a measure of 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

- Dilution of 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 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

Carbon dioxide is often used in preference to acid to lower pH.

For safe handling, always add acid to water when making a dilution and use personal protective equipment.

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 the addition of more sodium bicarbonate (pH 8.2). However, this will cause a further increase in 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. The addition of sodium hydroxide, also known as caustic soda (pH 14) to correct pH will cause high pH problems and should not be use.

Figure 14 The Hazards of Poor Labelling

Putting the wrong white powder in the pool can spell disaster. Have a system of storage that all staff can understand.

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

- Dilution of pool water is the only practical way of lowering calcium hardness. If calcium hardness is high, disinfectants containing calcium should be substituted with those containing sodium.

To 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 below is the most universally accepted method.

Saturation Index (SI)

SI is also referred to as the Langelier Scale. SI is a formula used to determine whether water is balanced and is determined by the following factors:

1. pH
2. Total Alkalinity (TA)
3. Calcium Hardness (CH)
4. Temperature (T(C)
5. 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

Table 9 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

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 that are 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.

Dosage and Control Systems

Overview

All pool disinfection systems should be designed to match the expected rate of disinfectant consumption at the worst conditions 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 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. Systems 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 Dosage Systems

Metering pumps are used to 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 the removal of ozone.

Control Systems

Control systems analyse disinfectant and pH levels using a sensor and electronic meter, and when outside the set parameters, sends 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. 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 (that is, dampening of signal variations). The pumps should be adjusted accordingly to deliver chemical at an appropriate rate per hour given the pool turnover characteristics in order 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

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. Chemical delivery tubing should be inspected at least weekly.

Sensors

pH

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

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, it should be kept 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.

At higher levels of free chlorine residual (> 3 ppm) ORP becomes less sensitive. Accordingly, disinfectant residual becomes increasingly difficult to control at higher levels using ORP controllers.

Other factors may also affect ORP measurements. For example, the presence of cyanuric acid lowers the ORP value. Other substances in the water may also have an effect, but where these factors are constant, they will not adversely affect the operation of the system. The values selected for the control will reflect these factors.

Changes in concentration of combined chlorine can influence ORP readings. At a given free chlorine concentration and pH, water without combined chlorine will have a higher ORP than water with combined chlorine. It is therefore better to set minimum ORP readings when there is no combined chlorine in the water and when bather loads are low. The free chlorine residual must also be set to at least above the minimum regulatory limit when setting ORP. When combined chlorine is formed during the course of the day, extra free chlorine residual will be then maintained in the system until the combined chlorine is destroyed. The free chlorine level should not drop below the original set point when ORP control equipment is set up this way.

Analyser Cell/Probe Buffering

Both ORP and direct chlorine residual methods of measurement or control work best when the pH is kept stable below 7.6 in chlorinated pools. Where this is not possible, and precise chlorine control is required, buffered cell analysers can be used. Buffered cell analysers inject a pH buffer into the water at the point of measurement to give a stable pH reading (usually around pH 6), which ensures accurate measurement of free chlorine. Most pools should not need buffered cells.

Brominated Pools

ORP sensors are often used to control bromine levels. Because bromine is less sensitive to pH change, automatic systems should work well throughout the normal pH range for swimming pools. For direct bromine residual measurements, some chlorine sensors can also measure bromine. Check with the manufacturer for the compatibility. Operators should also note that bromine might affect the response of a silver/silver chloride sensor.

Calibration of Sensors

Chlorine

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

ORP

Calibration is not required for ORP sensors that are 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 measured.

pH

Primary calibration of a pH sensor should be done with two standard solutions. Standard solutions should 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. Measuring the pool water with a separate pH meter or phenol red indicator and adjusting the controller accordingly can be used to make secondary calibration of controllers.

Location of Sensors

Sensors should be located at a point that is indicative of the actual swimming conditions. Sensors can be inserted directly into the circulation loop, subject to manufacturer's 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.

As a general rule, sensors should be cleaned regularly if an accurate readout is required. Sensors that have not been cleaned for several months may prove to be extremely inaccurate. Comparing the controller readout with pool test results will indicate the necessary cleaning frequency. After cleaning sensors, recalibration is required.

Best Practice Model

- Disinfectant dosing systems for all pools should be designed to cope with a range of bathing loadings.
- Continuous dosing that matches consumption rates should be aimed for.
- Automatic monitoring and dosing of disinfectant should be used in all spa pools and other pools that are subject to inconsistent chlorine demand.
- Regular calibration of control systems is necessary to ensure accurate results.
- Dosing systems should be designed so that disinfectants do not come in contact with acids.

5. Monitoring Systems

Chemical Testing

Overview

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.

Test Kits

Photometers or comparators, for commercial applications, using tablet or powdered reagents are recommended for all chemical tests and provide reasonable accuracy. Most test kits use solid (tablet or powdered) reagents as they have advantages in ease of storage, transport and prevention of spillage. The use of pre-measured packages eliminate the need to dispense precise amounts of reagent to each test.

Figure 20 Photometer

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

Figure 21 Comparator

The successful use of a comparator may be affected by the ability of the operator to discern colour intensities or colour difference. The background against which a comparator is held may also affect the colours observed.

Figure 22 Dry Reagents

Dry reagents are shelf stable and reliable.

Dip strips may be of use 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 syringaldezine are the only ones suitable for indicating free chlorine concentrations.

Always follow the manufacturer's instructions when using a test kit. Further training in the proper use of test kits is strongly recommended to ensure competency and to identify problems with the use of test kits.

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 (dimethyl-phenylene diamine) test developed by Palin is the most universally accepted test method for measuring disinfectant concentrations within the swimming pool industry. 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 to obtain total chlorine concentration. (DPD 1+3). The use of 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:

DPD 4 – DPD 1 or (DPD 1+3) – 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 is dependent 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, or a photometer may be used.

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.

If chlorine is excessively high, the chlorine may bleach the tablet and make it appear that there is no chlorine in the water. This result may cause pool operators to add more chlorine to the pool–and finally realise that excessively high levels have been reached. This can be avoided by crushing a tablet in a small volume of pool water before completely filling the sample cell with pool water and observing the pink colour turn clear.

> Dilute the sample so that the reading is within the 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.

Chemical Limits

Proprietors should set their own desired chemical limits for operation–within the range prescribed by the Regulations. A table suitable for recording this type of information is provided in the section 'Example Log Sheets: Chemical Limits Worksheet'. Operators should ensure that they refer to the most up-to-date Regulations when completing the table.

Keeping Records

Operators are required by law to maintain records. A suggested logbook is provided in the section 'Example Log Sheets: Sample Pool Operator Log Book'. Logbooks should be kept for at least 12 months after the last date of entry to made available on demand to an authorised officer of the Health Act. The records should then be archived for a further six years.

Records should cover the following tests and be carried out to *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
- Initials of recording operator
- Pool water temperature.

See the following Example Log Sheets.

Example Log Sheets

Chemical Limits Worksheet

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

Sample Pool Operator Log Sheet

Date ______________________ **Pool** ______________________

Time						
Measurements						
Free Cl_2						
Combined Cl_2						
pH						
Redox (mv)						
Electronic Cl_2						
Electronic pH						
Temperature						
Total Alkalinity						
Calcium Hardness						
TDS						
Langelier's Index						
Cyanuric Acid						
Adjustments/Additions						
Disinfectant						
pH Correction						
Bicarbonate						
Alum/Coagulant						
Others						
Others						
Observations						
Filter Pressures						
Backwashes Done						
Clarity						
Make Up						
No. of Bathers						
Water Meter Reading						
Backwash (litres)						
Dilution (litres)						
Operator's Initials						

Actions/Comments ______________________

Microbiological Monitoring

Overview

As described in the chapter 'Pool Water Contamination', certain infections have been associated with the use of swimming pools and spa pools. These usually result from poor management of water treatment leading to the survival of pathogenic organisms introduced by pool users.

Cryptosporidium is the only organism of pathogenic significance that can withstand properly treated pool water. However, as pool water can provide optimal 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 the human body 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 is 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.

> Microbiological problems should be insignificant in a well-managed pool with an adequate disinfectant residual, a pH maintained at the recommended level and regular filtration and backwashing.

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

> All pools are required to be closed while chemical and physical parameters are outside Regulatory limits.

Occasionally, microbiological problems develop in pools because there is poor circulation and turnover caused by design inadequacies. These may occur in certain parts of the pool, such as entrance steps, which are cut away from the side of the pool. When there is a gathering of colloidal matter or a lowering of chlorine levels in these areas, microbiological contaminants may be present and pool operators should satisfy themselves that the water treatment regime is satisfactory by conducting microbiological testing.

Best Practice Model

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

Appropriate Microbiological Testing

Microbiological samples should be submitted for analysis at a laboratory that is NATA accredited for the particular tests required.

Assessing Microbiological Quality

Taken together, the standard plate count test, the coliform test and *Pseudomonas aeruginosa* test provide the simplest means of assessing the microbiological quality of swimming pool water.

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

Standard Plate Count

The standard plate count grows a number of different 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 indicates 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 *Eschericia coli* (*E. coli*), are normal inhabitants of the intestinal tract of humans and other warm-blooded mammals where they are present in great numbers.

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

If coliforms are found to be present there is likely to have been a serious failure in the disinfection process at the time of sampling, and a risk of gastric illness to pool users from bacteria and viruses found in the intestines.

Pseudomonas Aeruginosa

Pseudomonas aeruginosa is a pathogenic organism and often the cause of ear and skin infections, particularly folliculitis. Pseudomonas is an inhabitant of drains and slimes and can often colonise in filter media, particularly where there is not frequent backwashing, superchlorination or other oxidising processes that 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, it is not recommended that other organisms be routinely tested 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 sometimes cannot immediately penetrate some particles. Staphylococcus is further controlled by effective water removal at the surface by skimmers and spill gutters and subsequent filtration.

Cryptosporidium is an issue of importance to the pool operator. It is a complex issue as it has wider implications to pool management.

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

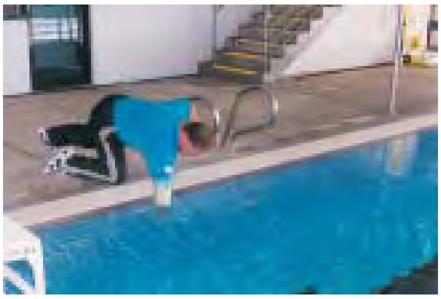
Health authorities may be required to sample pool water and test for specific pathogens when investigating specific illnesses. Generally, in the absence of notified cases, testing for other organisms other than required by the Regulations is unwarranted. Pool operators should seek advice from the public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

Sampling Procedure

About 250 mL of sample is required to conduct 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, thereby giving a true indication of the water quality experienced at the time of sampling. Laboratories will normally prepare these for their pool users.

Take a microbiological sample by removing the cap with one hand and 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 and 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. It is then removed and the cap is replaced. The sample should be refrigerated immediately and transported to the laboratory without delay. Ideally testing should be commenced within six hours of sampling. Testing that is commenced after 24 hours of sampling cannot yield reliable information.

Figure 24 Microbiological Sampling Technique



Sampling Location

A study commissioned by the Department of Human Services in 1995 showed that 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.

It is recommended that water samples be taken from near a suction point in the pool where users have not been swimming nearby in the previous 60 seconds. This should ensure that the tester is assessing the efficacy of the residual treatment process and has allowed a reasonable time for any immediate contamination to be treated.

Sampling Frequency

It should not be necessary to take frequent samples for microbiological examination when appropriate disinfectant residual and pH range is maintained, the pool has good clarity and is free from extraneous matter.

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 and the pool is functioning adequately.

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, and can justify more frequent monitoring. Pools with variable water quality or poor circulation and hydraulics can also justify more frequent monitoring.

Documentation

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

6. Physical Management of Water

Water Circulation

Overview

The purpose of circulating water is simply to make sure 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 (see the chapter on 'Filtration'), 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 design; surface water draw-off; inlets and outlets; circulation pumps; flow rates; turnover; and the associated interconnecting pipework.

Surface Water Draw-Off

Unsightly, 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. Body fats, oils, sunscreens and other oil-based contaminants do not mix with water, and tend to remain at or near the surface. This is also a source of potential infection, and can result in the formation of a 'scum line' around a 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 increased to 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 (best to worst): deck level, overflow channels, and skimmers.

Deck-Level (Wet Decks)

This system is becoming increasingly common. 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, thereby preventing air from being drawn into the filtration plant. Wet decks also reduce wave action and enable maintenance of a stable water level.

Care in the design of the channelling can substantially reduce the noise created by the water flowing into the channel. Attention should also be placed on ensuring 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

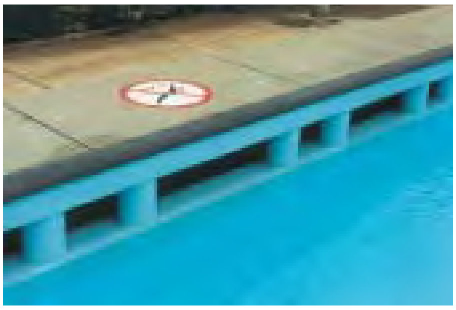
Overflow Channels

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 are available to 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, and when users enter the pool, therefore displacing water, 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. Since their efficiency is far less than the other methods described, their use is only recommended for domestic and low bather loads pools.

Figure 27 Skimmer Box and Lint Trap

Inlets and Outlets

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

Inlets

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

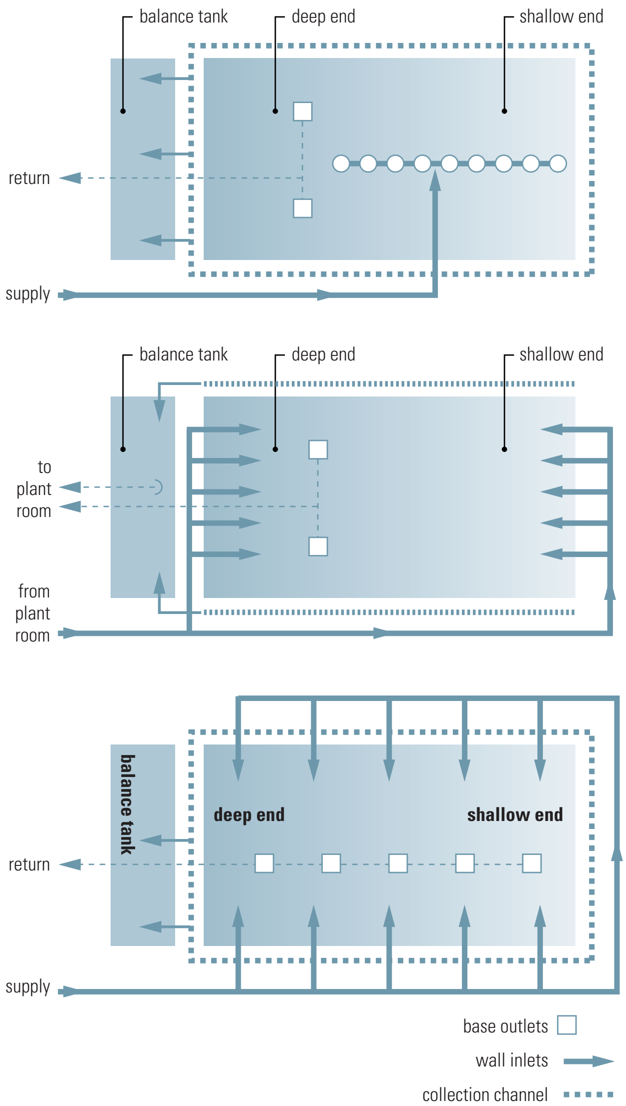
Outlets

These 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 25 m Pool



Floor Inlet, Surface Outlet

This common arrangement offers good circulation. However, it can be a long distance between the supply and return, where circulation dead spots can occur. Skimmers usually run 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 also increases 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–however 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 there is a particular need, 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 (at the same time) 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 in a Complex

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 key areas 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, or floc.

There are a number of factors to be taken into account when specifying filters. However, the baseline is that 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 will allow for a future increase in patronage without loss of water quality.

Filtration Principles

In general, the greater the velocity of water through the filter, the lower the filtration efficiency. In practice, efficiency falls off rapidly at high velocities.

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 will benefit greatly from the increased flexibility and the safeguards of having more than one filter. Through isolation of one or more filter units, a restricted turnover rate can enable the pool to 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 filters vessels are usually constructed from fibreglass, glass reinforced plastic, prefabricated mild steel or stainless steel. These may be medium and 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 utilised in indoor pools because 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 outdoors 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 for the type of filter and material used in its construction, and it is recommended that the following quality and performance standards should be specified.

- A pressure or 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.

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. Depths have tended to increase from 0.75 m on average up to about 1 m. A common rule of thumb is: two-thirds filter space for the media bed, leaving one-third for expansion during backwash.

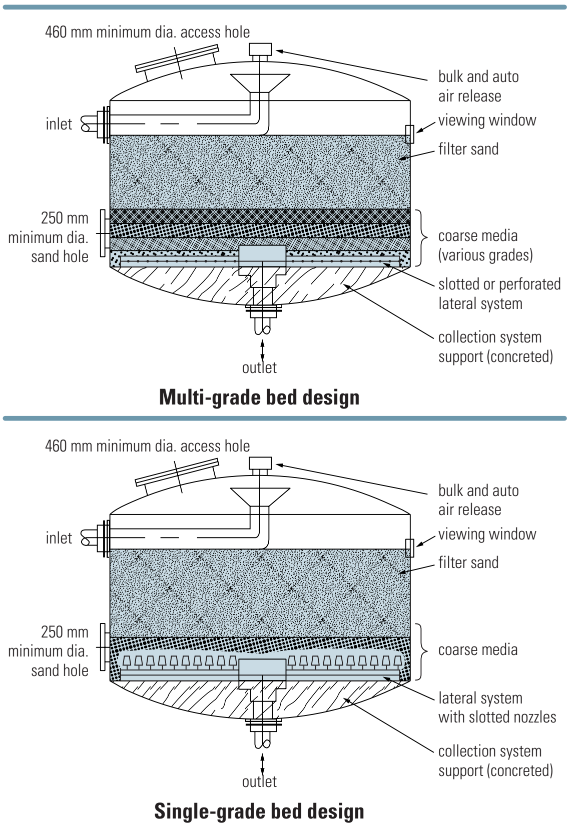
Sand filters can have either single or multi-grade beds. An advantage of multi-grade beds is that in the event of minor collector failure, the large-grade substrate will prevent the finer sand from entering the pool and operation will be uninterrupted. In the event of failure with single-grade media filters, collector failure will usually result in sand entering the pool. Whichever bed design is used, the specification and minimum depth of the filter sand recommended by the filter manufacturer must be maintained.

The 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 an appropriate flow rate can almost completely remove all suspended matter–including colour and other colloidal matter of sub-micron size.

Figure 33 Filter Off-Gas Bleed and Collectors

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), producing a floc, which is 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 for the use of a particular product to achieve best results.

Ozone Treatment

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

Dosing Coagulants and Flocculants

Dosing 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 appreciable concentration. It is also important that the gelatinous floc does not impair filtration by creating blockage. 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

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) is essential in caring 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 at this time, care must be taken not to significantly reduce the depth of the water in the pool. Consideration should also be given to the effect cold make-up water may have on pool users. This may be of particular significance for people with disabilities, pre-school swim lessons and hydrotherapy pool operators. Therefore, it is advisable 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. However, 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 to show 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. The pump(s) must therefore be able to supply the correct amount of water for the correct amount of time, to achieve effective backwash.

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 experts in this area.

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. Changing filter media is periodically required and depends upon a range of factors including:

- Pool volume
- Turnover
- Pool water temperature
- Bather load
- Water balance
- Cleaning regime
- Location (indoor/outdoor)
- Type of filter media
- Type of filter.

Professional advice may be required to assist with decisions to replace filter media.

Heating and Air Circulation

Overview

Maintaining satisfactory environmental conditions in the pool hall and all other areas of the building is essential for the comfort of pool users, staff and spectators–and for the pool to operate successfully over a reasonably extended working life.

The heating and ventilation of the pool hall needs to take into account a wide range of factors. These include: 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 get the right humidity, optimise user comfort and minimise evaporation from the pool water. It is also necessary to ensure that the **air circulation** system distributes the air effectively over the whole of the pool hall area. This is necessary in order to:

- Provide comfortable conditions for occupants
- Remove any chlorinous 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). Sometimes heat recovery systems are used as the primary source of heat.

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, otherwise rates of expansion of materials may cause problems to 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 capable of coping 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. But it is recommended that a separate heat exchanger and controls be provided 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 gas 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 based activity. However, operators tempted to join the move towards higher temperatures should bear in mind that they do 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.
- 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).
- There is more 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 or optimum 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. This means that the selection and accurate control of the optimum water temperature for each pool is essential to maintain operational efficiency and customer satisfaction.

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. However, there may have to be compromises where, for example, the elderly or 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 normally 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 to maintain comfortable environmental conditions. It is generally recommended that the relative humidity be maintained 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, and 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. It will, by necessity, change with varying circumstances. Effective, well-distributed mechanical supply and extraction ventilation systems are, however, essential to maintain satisfactory internal environmental conditions under all potential variations.

The Australian Standard AS1668.2–2002 can offer some guidance in this area. But 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 a potential problem. Their individual requirements should be assessed carefully. These areas do not necessarily need to be physically separated from the pool hall, but environmental conditions which are different from those around the pool should be considered.

Sources of Ventilation

The best source for 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 air 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 will generally be one of the major energy loads for a pool. A simple heat exchange device, such as a plate heat exchanger or run-around coils, should generally be provided to reclaim as much energy as possible from the exhaust air, in order to 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 and pool water heat loss and minimise the need for the ventilation system to operate out of hours. This will also substantially reduce energy use.

Figure 41 Pool Covers

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

7. Maintenance

Maintenance Systems

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 of the water within the pool. This can lead to movement and subsequent damage to the pool structure and can result in water leakage when refilled. The result 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.

General Procedure for Winter Care

Traditionally, in Australia, outdoor pools are left full of water and unattended during winter or the off-season. This results in a significant build-up of contamination from organic material (leaves, algae, etc). 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, utilise 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. It is important that any chemicals used during a winterisation program do not leave any undesirable residues.

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 action should be taken:

Pumps

- Power should be disconnected.
- Surface corrosion should be removed.
- The shaft of the pump should be periodically rotated.

Gas Chlorinators

- Decommissioning and servicing should be according to the manufacturer's recommendations and only by suitably qualified personnel.
- Incorrect servicing of this equipment can be life-threatening.

Erosion (Tablet) Feeders

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

Sensors

- Sensors should be removed, cleaned and stored in an appropriate wetting solution.
- The manufacturer will usually be able to supply instructions, as well as wetting solution and bottles, for this purpose.
- Sensors should not be left to dry out, as this will cause irreparable damage.

Chemical Dosage Pumps

- Flush the head by placing the suction hose of the pump into a bucket of fresh water and manually operate the pump for a short period.
- Clean the exterior with warm soapy water (with the power disconnected!) to remove any build-up of chemical residue.
- Pumps and injectors should also be serviced at this time by qualified personnel.
- Replace any worn or damaged chemical delivery tubing.

Heaters/Boilers

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

Winter/Seasonal Maintenance Program

In addition to the actions described for the above equipment, the following procedure should also be carried on a regular basis by operators utilising a winter/seasonal maintenance program:

- Add fresh water to the pool to restore the volume to the 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, etc).
- Shut down the circulation system.

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.
	In some instances high supply water levels can cause this problem. Overuse of carbon dioxide can also contribute to this problem.	Backwash pool (or dilute) and re-test next day. Repeat until the correct level is attained. Alternatively, reduce the level with dry acid.
pH too high		Re-test and confirm reading. If the pH is above statutory requirement, close the pool/spa until within range. Ensure that the pH correction system is turned on and operating normally.
	The pH correction agent (CO_2 or acid – whichever is applicable) storage tank may be empty.	Check the 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) and may be an indicator of disinfectant over dosage.	Test the disinfectant level. If above statutory requirements take action as per 'Disinfectant – High' in this Problem Sorter.
pH too low		Re-test and confirm reading. If the pH is outside statutory requirement, the pool/spa must be closed to pool users until within range. Ensure that the pH correction system is operating normally. Check the system components for malfunction.
	An interruption to sensor sample stream flow may cause inaccurate readings.	Check that there is no restriction to the sensor sample stream flow.
	The pH sensor may be fouled, out of calibration or faulty.	Clean/calibrate/replace sensor.
pH erratic		Check frequency and quantity of pH correction agent, dosage.
	The total alkalinity level may be incorrect for the pH level required.	Check the total alkalinity level.

Problem	Possible Cause(s)	Initial Response
	The pH sensor may be fouled, out of calibration or faulty.	Clean/calibrate/replace the pH sensor.
	Electrical, electromagnetic or radio interference may be causing the sensor reading to fluctuate.	Seek technical advice.
pH difficult to change	The total alkalinity may be too high. This may be due to high source water levels.	Check the total alkalinity level. Check that the pH correction system is operating normally (pumps, injectors, controller set point, etc).
Calcium hardness too high	High levels of calcium are uncommon in source water. It is normally attributable to inadvertent excess dosage of calcium chloride or calcium hypochlorite.	Re-test and confirm reading. Backwash (or dilute) the pool and retest the next day. Repeat backwashing (or dilution) until the correct level is attained. Discontinue use of calcium-based products.
Scale build-up appearing	Hardness salts may coming out of solution.	Test chemical levels and adjust according Langelier's Saturation Index.
Disinfectant too low	High disinfectant levels may cause the test reagent to bleach and mistakenly appear to be low.	Re-test and confirm the reading with a 10:1 dilution test. If the disinfectant level is outside statutory requirement, the pool/spa must be closed to pool users until within range. Check the level in the disinfectant storage tank.
	The disinfectant sensor may be fouled, out of calibration or faulty. If the solenoid fails in the closed position it will prevent water from delivering disinfectant.	Clean/calibrate/replace the sensor. Check that the dosage control and delivery system are operating normally.
		For sodium hypochlorite systems: • Check that the power supply to the dosage pump is turned on and there is power available. • Check for airlocks in the chlorine pump head and delivery tubing. • Check also the suction/discharge valves for contamination and the delivery tubing for leakage. • Check the chlorine pump pressure relief valve for discharge. If there is discharge, this may indicate a blocked delivery line or injector. • Ensure that the dosage controller is turned on and has power. • Check the dosage controller set point. (If the controller is at, or above set point, no dosage will occur). The set point may require adjustment.

Problem	Possible Cause(s)	Initial Response
		For erosion feed systems: • Ensure that the dosage controller is turned on and has power. • Check the dosage controller set point. (If the controller is at, or above set point, no dosage should occur). • Check that the solenoid valve is working correctly.
Disinfectant too high	The disinfectant sensor may be fouled, out of calibration or faulty. A lack of sample stream flow may be causing incorrect readings. The system may be siphoning due to contamination of the dosage pump valves or pressure retention (anti-siphon) valve. The solenoid valve may be stuck open and delivering disinfectant continuously.	Check that there is no restriction to the sensor sample stream. Re-test and confirm the reading with a 10:1 dilution test. If the disinfectant level is outside statutory requirement, the pool/spa must be closed to pool users until within range. If necessary, reduce disinfectant levels with sodium thiosulphate. Check that the dosage control and delivery system are operating normally and clean/calibrate/replace the sensor.
		For liquid chlorine systems: • Check the dosage pump suction and discharge valves for contamination, as well as the diaphragm of the pressure retention (anti-siphon) valve for contamination. For erosion feed systems: • Check that the solenoid valve is operating correctly.
ORP too low	Disinfection low, pH too high, cyanuric acid too high.	
	The ORP sensor may be fouled, out of calibration or faulty.	Clean/calibrate/replace the sensor.
ORP too high	Disinfectant too high, pH too low.	
	The ORP sensor may be fouled, out of calibration or faulty.	Clean/calibrate/replace the sensor.
Disinfectant level is difficult to maintain	In pools not stabilised with cyanuric acid, the sunlight can rapidly reduce disinfectant levels.	If the level is outside statutory requirement, the pool/spa must be closed to pool users until within range. Check the disinfectant delivery and control systems. Add cyanuric acid to at least 30 mg/L.
	Excessive contamination may be overloading the disinfection system.	Check the bather load history and look for a correlation.

Problem	Possible Cause(s)	Initial Response
Cannot get test kit readings for free chlorine residual	The reagent may be bleached by excessive chlorine level.	Test the disinfectant level with a 10:1 dilution test. If the disinfectant level is outside statutory requirements, the pool/spa must be closed to pool users until back within range.
	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.	Check the reagent use-by date.
The water has an offensive odour and is causing eye and/or throat irritation	This may be attributable to 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 ammonia based chemicals combine with chlorine to form the offensive compounds.	Test the combined chlorine level. Superchlorinate during closure, then backwash and add coagulant. It may be necessary to repeat this course of action on a regular basis, as a proactive measure. If the problem persists it may be necessary to undergo continuous dilution of the pool/spa water. Alternatively, it may be necessary to re-evaluate the filtration systems efficacy in managing the bathing load.
	A build-up of organic material in overflow channels and/or balance tanks can also contribute to the problem.	Cleaning of overflow channels and balance tanks should occur as periodical maintenance (if practical).
Slimy growth on the pool walls, floor or grouting	If the growth is green/black in colour, it may be algae. If not, it may be biofilm of a bacteria 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 – 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) the pool and re-test the next day. Repeat until the correct level is attained.
Cloudy water	The circulation pumps may have failed, or flow may be restricted by clogged lint screens/baskets.	Check the circulation pump(s) and lint screens/baskets.
	The filter(s) may be dirty and require cleaning.	Check the filter(s) pressure differentials. Backwash the filter(s).
	The bathing load may be too high for the filtration system capabilities.	Reduce the bathing load, allow the water to recover.
	The filter media may be old and clogged. This may result in channelling and ineffective filtration.	Superchlorinate the filter media during closure. If symptoms persistent, inspect the filter vessel.

Problem	Possible Cause(s)	Initial Response
	If the filtered water collector system is broken, contaminants and filter media may enter the pool.	Inspect and replace if necessary the filtered water collector system.
	Mineral salts may be coming out of solution.	Check and where necessary correct pH, alkalinity and calcium hardness – according to Langelier's Saturation Index.
	A high pH may cause coagulant to be present in the water. This is usually characterised by a white discolouration.	Check for coagulant overdose and/or high pH.
	The discolouration could be due to 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. It will then be necessary to take action as per above.
	In high concentrations chlorine and bromine (especially) may cause a green coloration of water.	Test the disinfectant level with a 10:1 dilution test. If the disinfectant level is outside statutory requirement, the pool/spa must be closed to pool users until within range. Action as per 'Disinfectant – High' in this Problem Sorter.
	In full-stream ozone/chlorine systems, it is very common to experience green coloration if the ozone is off-line for extended periods. Systems utilising anthracite or other carbon products in the filters can also experience a green discolouration.	Coagulation with poly-aluminium-chloride may assist in the removal of this coloration. Coagulation with poly-aluminium-chloride may assist in the removal of the coloration in this instance also.
	Although uncommon, copper presence in the water may also cause the green discolouration.	Particularly if the saturation index is tending toward scale forming – according to Langelier's Saturation Index. If the discolouration persists it may be necessary to test for copper presence.
Water clarity generally poor	Check for a pattern to the problem. 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.

Problem	Possible Cause(s)	Initial Response
Temperature – Low		Check that the heating thermostat is set at the normal temperature. Check that the circulation pump(s) are operational. If not, refer to 'Circulation failure' in this Problem Sorter. Check that the Boiler is operational. If not refer to 'Heater malfunction' in this Problem Sorter.
	Dilution with cold make-up water after backwashing may cause a temporary drop in temperature.	Check when the last backwash was performed.
Temperature – High	Wrong temperature setting. Solenoid or valve failure.	Check that the thermostat is set at the normal temperature. Check that the heating valve is not stuck 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 shutdown with the heater and therefore may not be at fault. There may have been a power failure and the heater did not restart automatically.	Check that the 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 cause extensive damage to any filtration system.	Check that there is sufficient water for the circulation pump(s) to operate. If the 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 the valve positions on the pump and filters.
Filter inlet pressure is high and the outlet pressure is low	Filter is dirty.	Backwash filter.
	If the problem persists, it may indicate that the filter is blocked and the media requires replacement. It may also indicate that there is not enough water flow to backwash effectively.	Check the quantity of coagulant utilised. Excessive coagulant may cause the filter media to become clogged and result in poor filtration.

Problem	Possible Cause(s)	Initial Response
Filter inlet and outlet pressures are both high	If a valve on the discharge side of the filter is closed past its normal position, the water flow may be restricted and cause an increase in filter pressure.	Check the valve positions on the discharge pipework of the filter.
Poor air quality		Check that the air-handling system is operating normally. Check the air filters and clean or replace as required. If necessary, check damper operation.

8. References

Glossary

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

Acidity A measure of the acid content of water; generally expressed in mg/L or ppm; important for pH value control.

Activated carbon Carbon treated for use as an adsorption filter medium for removing chlorine, ozone and contamination.

Air scour Air forced up through a filter bed prior to backwash for the purpose of expanding the filter media and loosen dirt particles.

Algacide A chemical that aids in killing, controlling and preventing algae.

Algae Simple form of microscopic plant life that contains chlorophyll and thrives on sunlight.

Alkali A chemical which raises pH value of pool water, also called a base.

Alkalinity A measure of the alkaline content of water; generally expressed in mg/L or ppm; a measure of the resistance to change in pH value.

Aluminium sulphate (alum) A coagulant, usually supplied in a granular form.

Ammonia A chemical that forms from the breakdown of urea in urine and sweat.

Amoeba Single-celled organism.

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

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

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 A measure of the number of bathers in a pool over a set period of time; it should be linked to the capacity of the treatment system and pool safety.

BCDMH Bromo-chloro-dimethyl-hydantoin. It produces hypobromous acid when dissolved in water.

Boiler Heats water or air via a heat exchange device, that is, a closed loop boiler.

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

Bromamines Products of the reaction between bromine and ammonia.

Buffer A combination or 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 Produced when free available chlorine combines with ammonia and other nitrogenous wastes.

Chloroform A product of the reaction between chlorine and organic nitrogen compounds; one of the trihalomethanes.

Coagulant A material which forms a gelatinous precipitate in water and causes the agglomeration of finely divided particles into larger particles.

Coagulation The action of a coagulant.

Coliforms Bacteria of the intestine, of which E. coli is a common example.

Collectors (laterals, filter nozzles) Interior bottom part of the filter that collects the filtered return water.

Colloids Very fine suspended matter in water that contributes to 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 that can be added to pool water to reduce chlorine loss due to sunlight.

Decommissioning The process of ceasing the operation of equipment.

De-humidifier A device for removing moisture for the air.

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

Diatomaceous earth A powder consisting of fossilised skeletal remains of microscopic marine plant life that is capable of filtering extremely small particles.

Dichlor Short for dichloroisocyanuric acid. A type of stabilised pool chlorine.

E. coli A bacterium in faeces–one of the coliform organisms routinely monitored for signs of pollution.

Erosion feeder A simple device that allows a steady flow of water to erode a stick or tablet of disinfectant liberating the active ingredient. Adjusting the flow rate through the feeder can control the erosion rate.

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

Flocculus/floc The gelatinous mass that forms with the addition of a flocculant.

Flooded suction Describes the process of introduction of supply water to the pump where the level of the supply water is above the level of the pump inlet.

Fluidisation of sand filter beds Suspending the sand by backwashing force and sometimes air scouring.

Folliculitis An infection of the hair follicle caused by bacteria.

Free chlorine A measure of the chlorine (the sum of hypochlorous acid and hypochlorite ion) that is available for disinfection.

Gas chlorinator A device that controls the release of chlorine gas from bulk supply.

Halogen The chemical family that includes chlorine and bromine (and iodine).

Hardness A measure of all the calcium and magnesium salts in pool water (total hardness). See also calcium, 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 (muratic) An acid used (with care) 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 (liquid pool chlorine); calcium hypochlorite (granular pool chlorine).

Hypochlorous acid The main active factor in all chlorine disinfectants.

Injector Fitting enabling a chemical liquid or gas to be injected into the water circulation loop.

Ions Electrically charged chemical particles.

Langelier Index One measure of balanced water.

Loss of head Describes the loss of operating pressure (at the filter or pump outlet).

Make-up water Fresh water used to fill or top up pools, particularly after backwashing.

Nitrogen trichloride The most irritant of the chloramines.

Oxidation The process of by which disinfectants destroy pollution.

Oxidation-Reduction Potential (ORP) A measure of the oxidative powers of the water which is measured in millivolts.

Ozone (O_3), ozonation A gas generated on-site and used to purify pool water by oxidation.

PAC Poly aluminium chloride– a commonly used liquid coagulant.

Permanent hardness That part which does not precipitate from the water on heating; it 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 Abbreviation for 'personal protective equipment' which may include breathing respirator, safety goggles, hearing protection, gloves and coveralls.

ppm Abbreviation for 'parts per million'. A measurement that indicates the amount of chemical by weight in milligrams per litre of water (mg/L).

Redox (ORP) sensors Pool water analysers that measure only the oxidative power of the water. See Oxidation-Reduction Potential.

Salt chlorinator An electronic device that produces free chlorine from salt (chloride) present in the pool water.

Scaling The deposition (usually calcium carbonate) on pool walls, pipework, etc.

Sensor An electrical or electronic device for measuring a specific parameter. For example, pH, water flow, chlorine, ORP, temperature and so on.

Shock dosing Reactive dose of excess chlorine to combat an algae bloom or other form of contamination.

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

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

Sodium bisulphate (dry acid) Used to lower pH.

Sodium carbonate (soda ash) Used to raise pH.

Sodium chloride Commonly referred as 'pool salt'–added to pools with salt chlorinators.

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

Superchlorination Routine preventative dose of chlorine to control algae and maintain clarity.

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

Thermal wheel (rotary heat exchanger) A heat recovery device that recovers heat from the pool hall return air, and in the process, also de-humidifies the pool hall air.

Total alkalinity Measure of alkalinity to 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 the solids dissolved in the pool water.

Trichlor Short for 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 a volume of water equivalent to the entire pool volume, to pass through the filtration and circulation system once.

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