STANDARD

FOR THE

Operation of Swimming Pools and Spa Pools in South Australia

DEPARTMENT OF HUMAN SERVICES
(SOUTH AUSTRALIAN HEALTH COMMISSION)

Government
of South Australia

First printed December 1991
Reprinted August 1993 incorporating
Corrigendum gazetted 14 May 1992.
Reprinted April 1998.

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Swimming Pools and Spa Pools
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ISBN 0-7243-4062-9

FOREWORD

Under the Public and Environmental Health Act, the Public and Environmental Health Council can initiate measures to promote public and environmental health standards and has the responsibility to keep the operation and administration of the Act under review.

To assist local councils in the administration of the legislation the Council has requested that a code be prepared that takes into account the provisions of Section 47 (5) of the Act and Regulations 3, 6 (1) and 7 (1) relating to swimming pools and spa pools.

This code has been prepared to address the issue of water quality in relation to the operation of a swimming pool and a spa pool. It details measures necessary to ensure that water quality within a pool is of a standard that does not prejudice the health or well-being of pool users.

It describes in detail the disinfection of pool water with reference to other important parameters such as pH, water clarity and total alkalinity that need to be maintained in balance as part of the total water treatment process.

Other areas covered by the code include an explanation of the chemistry of the disinfection processes, pool water pollutants and health effects as a consequence of inadequate pool water treatment.

This code is aimed primarily for use by agencies responsible for the administration of the Public and Environmental Health Act and Regulations. It should also be useful to the operators of swimming pool and spa pool facilities.

Public and Environmental Health Regulation 3 details the facilities to which the provisions of this code apply and defines the circumstances of application.

As provided for under Section 47 (5) of the Act, Regulation 6 (1) (a) and 7 (1) (a), this code is a prescribed code and non compliance with the provisions applicable to the disinfection process, including the maintenance of pool water so that it is chemically balanced, is deemed to be a breach of the legislation and subject to penalty as indicated in Regulation 6 (3) and 7 (3).

CONTENTS

1. INTRODUCTION

This code applies to swimming pools and spa pools as defined by the Public and Environmental Health Regulations.

The growing popularity of swimming and other “in-the-water” activities for sport, fitness, therapy or just enjoyable relaxation has led to the increased use of swimming pools and the establishment of a variety of specific-use pools such as spa pools, waterslides, and more recently, hydrotherapy and wave pools.

These pools are used by a variety of people of various ages, health status and standards of hygiene. Bathers introduce a range of pollutants to the pool water such as micro-organisms, body secretions including saliva, fat, urine and other foreign matter including skin, hair and sunscreen lotions.

In the interest of user satisfaction and ongoing patronage, pool owners should look to provide a facility that is attractive, safe, hygienic and caters for bather comfort.

Disease-causing organisms live and multiply in pool water that has not been properly treated and give rise to eye, ear, skin and intestinal infection. In South Australia fatal cases of Primary amoebic meningo-encephalitis have been associated with poorly maintained pools. Inadequate chemical balance of pool water can also cause skin rashes and conjunctivitis.

This code indicates the essential requirements to maintain a balanced water chemistry within a swimming or spa pool and ensure safe, clean and sparkling water.

Spa pools can create a higher infection risk than swimming pools if poorly maintained. The warm aerated water provides an ideal environment for the rapid growth of many undesirable organisms. With large numbers of people entering the relatively small volume of water in a spa the organic and microbial loading may be high. This can have a dramatic and deleterious effect on the quality of water in the spa and put the health of users at risk. Poorly maintained spa pools have been implicated as a source of skin infection and Legionellosis, but well balanced and operated, they can provide a safe, relaxing and enjoyable experience.

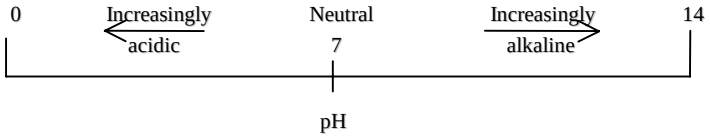
This code sets out the approved methods of disinfection and treatment for swimming and spa pool waters. It has been prepared as a guide to assist local councils with the administration of the legislation. Additionally it is a useful guide for pool owners and operators and will assist them to comply with the provisions of the Public and Environmental Health Act and Regulations and provide a facility that is of a high standard, safe, hygienic, and enjoyable for the users.

All legislation, codes of practice, standards or guidelines referred to in this code include amendments made from time to time, unless otherwise stated. The provisions of this code do not derogate from the need to comply with other laws of the State.

2. DEFINITIONS

acidic	water with a pH between 0 and 7.
algicide	a chemical that is capable of killing algae.
chlorine	hypochlorous acid/hypochlorite ion (irrespective of the mode of addition or formation).
combined chlorine	chlorine that has combined with ammonia, ammonium compounds or organic matter containing nitrogen to form chloramines.
disinfecting agent	a compound or substance which, when applied as instructed to swimming or spa pool water, kills harmful micro-organisms.
free chlorine	chlorine that has not combined but is free to kill bacteria and algae and destroy organic pollutants introduced into the pool water.

knowledgeable person	one who is able to control, manage and operate a pool to ensure that the pool water complies with the requirements of the Regulations under the Public and Environmental Health Act.
mg/L	milligram per litre.
occupier	in relation to premises, means a person who has, or is entitled to, possession or control of the premises and includes a person who is in charge of the premises.
operator	the person who has control and management of the pool, is knowledgeable in its operation and is sufficiently competent to ensure that the pool complies with the requirements of the regulations.
owner	in relation to premises, includes an occupier of the premises.
PH	a scale (ranging from 0 to 14) that indicates the amount of acid or alkali present in the water. Water with a pH of 7 is neutral.



S.A.H.C.	South Australian Health Commission.
spa pool	means a pool or other water-retaining structure designed for human use:- (a) that is capable of holding more than 680 litres of water; *and* (b) that incorporates, or is connected to, equipment that is capable of heating any water contained in it and injecting air bubbles or water into it under pressure so as to cause general turbulence in the water.
stabilizer	a compound which is added to pool water to reduce chlorine loss due to sunlight.
superchlorination	the addition of sufficient chlorine to pool water to raise the level of free chlorine to at least 10mg/L for the destruction of combined chlorine (chloramines), algae, and other impurities.
swimming pool	includes any waterslide, wave pool, hydrotherapy pool or other similar structure designed for human use other than:- (a) a spa pool; *or* (b) a tidal pool or other similar structure where water flows in and out according to the operation of natural forces.
total alkalinity	a measure of the total amount of dissolved alkaline compounds in the pool water.
total chlorine	the sum of combined chlorine and free chlorine.
total dissolved solids	a measure of the total amount of dissolved inorganic compounds in the pool water.
UV+H_2O_2	ultraviolet light plus hydrogen peroxide disinfection system.
mWs/cm^2	microwatt seconds per centimeter squared.

3. MANAGEMENT

Where a swimming pool or a spa pool is available for use by the public the owner of the facility must ensure that the pool is under the control and management of a person who is knowledgeable and competent in the operation of the plant and maintenance of pool water quality. Whilst the facility is available for use by the public it is the responsibility of the owner and the pool operator to ensure pool water quality is maintained in accordance with the requirements of the Public and Environmental Health Regulations.

For the purpose of Public and Environmental Health Regulation 8 (1) (a), possession of a qualification approved by the South Australian Health Commission may constitute prima facie evidence of the knowledge and competence required of the person in charge of a swimming pool or spa pool. The knowledge and competence of the operator may also be assessed by the standard of the water quality within the swimming pool or spa pool, as indicated below.

Owners of pools covered by the ambit of the regulations are responsible for ensuring the pool is correctly operated. Failure to do so could result in legal proceedings being implemented for non compliance.

Where the operator of a pool fails to maintain pool water quality in the manner prescribed the authority may deem the operator not to be competent and require the owner to provide a person who is competent.

4. DISINFECTING AGENTS

To minimise the risk of infection to bathers the pool water must be disinfected with an agent that is:

- specified in the Regulations
- otherwise approved by the S.A.H.C. and indicated in this code
- easily applied
- able to kill a wide range of disease causing organisms
- capable of simple on-site measurement.

4.1 CHLORINE

Chlorine is a disinfecting agent that meets the above requirements and has the additional advantage of being able to oxidise most pollutants not removed by filtration. However, concentrations of chlorine must be controlled, as low concentrations result in ineffective disinfection and high concentrations can cause eye, skin and respiratory irritation.

Because high levels of chlorine can have adverse health affects on bathers it is recommended that bathers should not be present in the pool water during superchlorination or when the chlorine residual exceeds 10mg/L.

Most swimming pools and spa pools are disinfected using chlorine gas or chlorine compounds. Each of these disinfecting agents form hypochlorous acid when reacting with water and therefore disinfect the pool water in the same manner.

For example, the reaction of sodium hypochlorite with water is:-

NaOCl sodium hypochlorite	+	H_2O water	$\longrightarrow$	HOCl hypochlorous acid	+	NaOH sodium hydroxide

Hypochlorous acid partly dissociates to give hydrogen ions and hypochlorite ions.

HOCl hypochlorous acid	$\longrightarrow$	H^+ hydrogen ion	+	OCl^- hypochlorite ion

Therefore, pool water that is treated with chlorine gas or a chlorine compound will contain both hypochlorous acid and hypochlorite ions. Their relative proportions depend on the pH of the pool water. See figure 1.

FIGURE 1 : PERCENTAGE OF FREE CHLORINE RELATIVE TO pH

	Percentage of free chlorine as	
pH	*HOCl*	*OCl^-*
6.0	97	3
7.0	75	25
7.2*	63	37
7.5*	49	51
7.6*	39	61
7.8	28	72
9.0	3	97

** operating range as defined by regulation.*

Hypochlorous acid is a very effective disinfecting agent. It has low molecular mass and no electrical charge. This allows it to penetrate through the cell wall of bacteria to attack enzymes. The destruction of the enzymes results in the death of the organism.

The hypochlorite ion (OCl^-) is about 100 times less effective as a disinfectant than hypochlorous acid (HOCl). This is believed to be so because the hypochlorite ion is negatively charged and this reduces its ability to penetrate the bacterial cell wall which is also negatively charged.

The various chlorinating compounds have differing effects on:-

- pH
- alkalinity
- total hardness
- total dissolved solids
- the amount of cyanuric acid present, if any.

Therefore, it is essential to maintain the balance of pool water to ensure effective disinfection of the water, bather comfort, water clarity and preservation of pool surfaces and structure.

4.2 CHLORINE STABILIZED WITH CYANURIC ACID

Free chlorine in swimming pool water decomposes under the influence of the ultraviolet rays from sunlight. Cyanuric acid and chlorinated cyanurates are used to increase the stability of free chlorine levels in *outdoor* swimming pools.

Cyanurates tie up hypochlorite ions in a complex molecule. This reduces the loss of free chlorine as a result of exposure to sunlight and effectively extends the period of disinfection. However, increased chlorine levels are required in stabilized pools because a large amount of chlorine is attached to the cyanuric acid and is not readily available for disinfection purposes.

Stabilization has the advantage when used in outdoor pools at the recommended levels of 30 - 50mg/L of maintaining free chlorine residuals for longer periods. Stabilizer levels in excess of 50mg/L reduce disinfection efficacy; therefore, it is very important to ensure the upper limit is not exceeded.

Losses of water by evaporation, splashing and vacuuming to waste will gradually reduce stabilizer level and this will require replacement.

Regulations under the Public and Environmental Health Act preclude the use of stabilizers in indoor pool waters.

4.3 ULTRAVIOLET LIGHT PLUS HYDROGEN PEROXIDE

The ultraviolet light plus hydrogen peroxide (UV+H_2O_2) system is approved for disinfecting indoor swimming pools up to 500,000 litres in capacity.

Disinfection occurs when water is passed through the ultraviolet unit. As no residual is produced there is no anti-microbial action in other parts of the system. Therefore, in order to achieve a residual oxidising and microbial capability, hydrogen peroxide must be used in conjunction with ultraviolet light.

Hydrogen peroxide is a powerful oxidising agent and in its concentrated form it is a clear liquid with a sharp odour. It provides a residual capacity to oxidise organic material derived from bather load and other sources in the pool water; thus inhibiting micro-organism growth within the remainder of the system. For the ultraviolet light plus hydrogen peroxide system to be effective it must operate 24 hours a day.

Ultraviolet light has no effect on pH, colour and little effect on the chemical composition of the water. However, the colour, turbidity and chemical composition of the water can interfere with ultraviolet light transmission. Bacteria may be protected by turbidity, clumping and by the presence of slimes. Therefore, the water must be adequately treated prior to ultraviolet light exposure.

Ultraviolet light disinfection is not pH dependent, but the addition of hydrogen peroxide to pool water results in slightly acidic conditions. This combined with the oxidation of bather organics requires pH balance to overcome bather discomfort and maintain protection of the pool surfaces, pool water plant and metal fixtures.

To achieve satisfactory pool water chemistry the total alkalinity level should be maintained within a range of 60 to 200 mg/L.

4.3.1 Ultraviolet light plus hydrogen peroxide operating criteria

To ensure effective disinfection the ultraviolet light plus hydrogen peroxide system must achieve:

- an ultraviolet light dose rate of ≥30,000 microwatt seconds per centimetre squared
- a flow rate of ≤150 litres per minute through the ultraviolet light disinfection system
- a pool water turnover rate of at least once in:-
  - every 6 hour period for a swimming pool
  - every 1/2 hour period for a spa pool
- a minimum hydrogen peroxide level of not less than 40mg/L within the pool water
- a pH value between 7.2 and 7.6
- a total alkalinity level between 60 mg/L and 200 mg/L

5. WATER CLARITY

Clarity of pool water refers to the clearness or lack of cloudiness of the water and it may be regarded as the distance through the water at which an object can be seen. Under the Public and Environmental Health Regulations the clarity of pool water must be such “that a matt black disc, or a disc that contrasts with the colour of the bottom of the pool, 150mm in diameter, is (or would be) clearly visible at the deepest part of the pool”. Removal of suspended and colloidal matter by filtration will assist in maintaining pool water clarity.

The purpose of achieving clarity in swimming and spa pools is to:

- confirm the absence of particles which may shield micro-organisms from direct contact with the disinfectant.
- enable persons to estimate depth, to see subsurface hazards easily and to detect submerged pool users.
- provide a pleasant, attractive and appealing appearance to the water.

The internal surfaces of pools must provide high light reflection from the under water surfaces. This can help in detecting:-

- poor water quality
- poor cleaning practices
- bathers beneath the surface who may be in difficulties.

6. pH AND TOTAL ALKALINITY

The pH of swimming and spa pool water can affect the disinfection efficiency. It can also effect the pool surfaces, metal fixtures, pipework, pumps and bather comfort. Where the pool water is disinfected with chlorine the pH factor is much more critical. Therefore, the pH range must be limited and its tendency to fluctuate must be controlled by ensuring a minimum level of total alkalinity. For the purpose of this code total alkalinity is measured as calcium carbonate ($CaCO_3$).

Pool waters disinfected with chlorine or ultraviolet light plus hydrogen peroxide require a minimum total alkalinity level of 60mg/L. However, where gaseous chlorine is used the minimum total alkalinity level is 150mg/L. This ensures that the water is chemically balanced and can be effectively disinfected

Total alkalinity levels greater than 200mg/L may result in scaling of fittings and surfaces particularly with hard waters. Consequently, hard waters may require treatment prior to being added to a pool.

Tables 1 to 4 detail the range of pH and total alkalinity values for disinfected pool waters.

7. SPA POOLS

Spa pools have a much higher level of suspended matter than swimming pools because of their reduced capacity, higher bather load to water volume ratio, increased operating temperature, aeration of the water body and elevated organic contaminant loading. To lessen the impact of this elevated level of suspended matter on disinfection efficacy the pool water needs to be exchanged and passed through the filter at least half hourly. In those facilities with varying requirements for pool water turnover the spa pool should be provided with a separate filter.

Spa pools must be drained at least weekly to prevent a build up of total dissolved solids. This is to ensure the efficacy of disinfection and to enable cleaning of the floors and walls to be done prior to refilling with clean fresh water. Inground spa pools must be constructed and installed to prevent movement due to external pressure when drained.

7.1 WATER TEMPERATURE

Spa pool water should not be heated to above 40^{o}C. An ideal range is 35-37^{o}C. Refer to tables 2 and 3.

Any thermostatic device controlling the spa pool water temperature should be capable of maintaining the temperature to within ±0.5^{o}C of the set range. A high temperature alarm should be installed to inform users that the water temperature exceeds 40^{o}C.

7.2 POTENTIAL HEALTH EFFECTS

Infection is usually associated with high levels of micro-organisms in poorly maintained spa pools. The spa ecosystem being both warm and aerated promotes growth of a range of harmful organisms such as those listed in table 5.

7.3 BATHER WARNING NOTICE

A sign displaying the following advice should be positioned in a prominent position immediately adjacent to the spa where it can be read by bathers intending to enter the spa.

DO NOT put your head under the water.

DO NOT use the spa while under the influence of drugs or alcohol.

DO NOT use the spa for more than 20 minutes at a time.

DO NOT allow children to use the spa unsupervised.

DO NOT swallow spa water.

DO NOT use the spa if you have an open wound, feel unwell or are pregnant.

8. DISINFECTION & TREATMENT OF WATER

8.1 SWIMMING POOLS

The following conditions must be achieved whenever a swimming pool (excluding hydrotherapy pools, wave pools and waterslides) is available for use:

- the swimming pool water must be disinfected by chlorine or by an ultraviolet light plus hydrogen peroxide system so that the disinfection values set out in tables 1 and 4 are maintained.
- where chlorine is used the pH, total alkalinity and cyanuric acid (for stabilized pools only) values for the swimming pool water are to be maintained in accordance with tables 1 and 2.
- where an ultraviolet light and hydrogen peroxide system is used the pH, total alkalinity and pool water flow rate must be maintained in accordance with the requirements set out in table 4.
- the swimming pool must have a filtration system that provides a continuous circulation of the pool water through the filter.
- all water in the swimming pool must pass through the filter as often as necessary to ensure that the water is maintained in a clean and clear condition and in any event at least once in every six hours.
- the swimming pool must be fitted with automatic dosing and monitoring equipment that continuously analyses and controls the pH and disinfectant levels in the pool water within the range as indicated in tables 1 and 2.
- pool water clarity must be maintained in a clean, clear condition so that a 150 mm diameter matt black disc, or a 150 mm diameter disc that contrasts with the colour of the bottom of the swimming pool, is (or would be) clearly visible when viewed through the pool water at the deepest part of the swimming pool.

8.2 SPA POOLS

The following conditions must be achieved whenever a spa pool is available for use:

- the spa pool water must be disinfected with chlorine or by an ultraviolet light plus hydrogen peroxide system in accordance with the values set out in tables 3 and 4.
- for chlorine disinfected spa pools the pH and total alkalinity of the water must be maintained in accordance with the requirements set out in table 3.
- where an ultraviolet light and hydrogen peroxide system is used the pH, total alkalinity and pool water flow rate must be maintained in accordance with the requirements set out in table 4.
- the spa pool shall be fitted with a filtration system that provides a continuous circulation of water through the filter and passes all water in the spa pool through the filter at least once in every 30 minutes.

- the spa pool shall incorporate a weir off-take or skimmer system that continuously takes away surface water whilst the spa pool is in use.
- the spa pool must be fitted with automatic dosing and monitoring equipment that continuously analyses and controls the pH and disinfectant levels in the pool water within the range as indicated in table 3.
- the spa pool water clarity must be maintained in a clean, clear condition so that a 150 mm diameter matt black disc, or a 150 mm diameter disc that contrasts with the colour of the bottom of the pool, is (or would be) clearly visible through the pool water at the deepest part of the spa pool when there is no turbulence in the spa pool water.
- the spa pool must be drained at least weekly and the floor and walls of the pool cleaned before it is refilled.

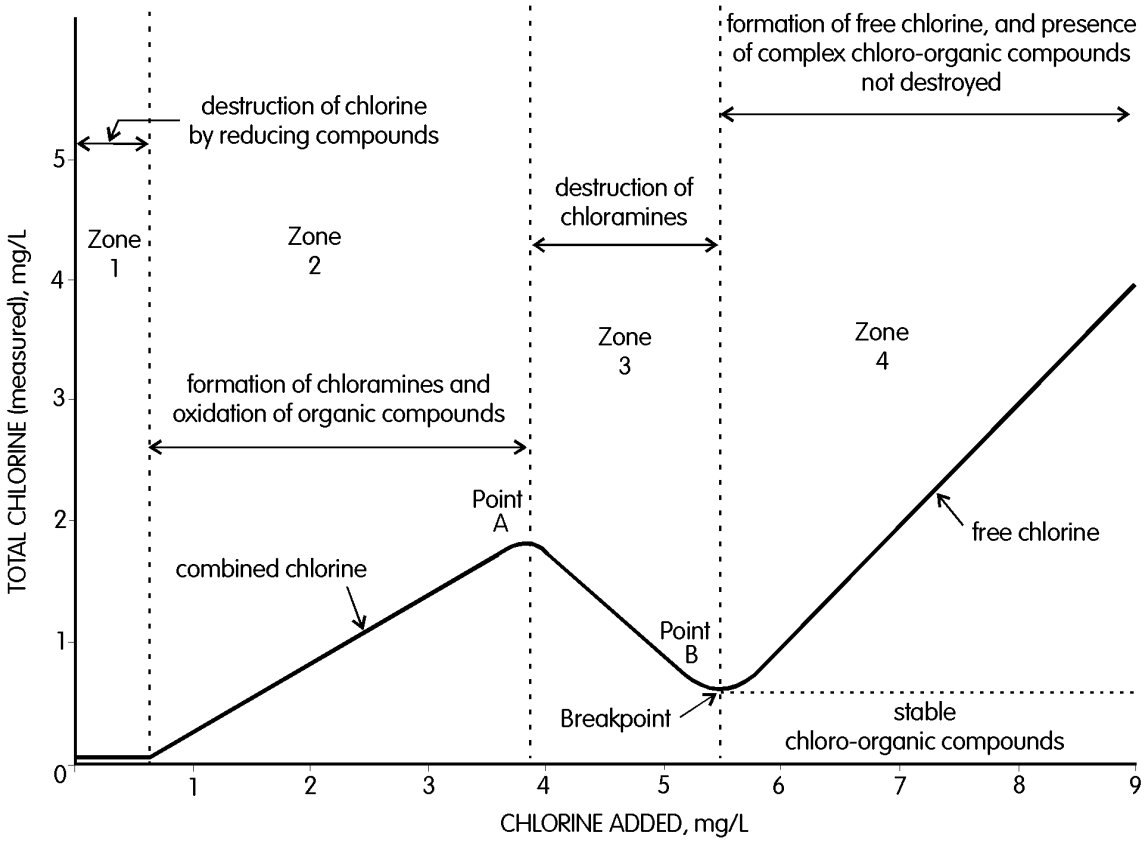
9. BREAKPOINT CHLORINATION

9.1 EXPLANATION

Breakpoint chlorination is the process of maintaining sufficient free available chlorine in the pool water to chemically convert chloramines and ammonia-nitrogen compounds to inert nitrogen gas. The process is described in more detail below and as indicated in figure 2.

When chlorine is first added to the water it is destroyed by reducing compounds present in the water as depicted in zone 1 of figure 2.

FIGURE 2 : BREAKPOINT CHLORINATION



As further chlorine is added the level of total chlorine in the water, mainly chloramines, will steadily increase until a peak is reached, shown as point A in zone 2 of figure 2. The chloramines, mainly monochloramines, arise from the reaction of chlorine with nitrogenous compounds which have been introduced into the pool by organic

matter such as perspiration and urine from bathers. These nitrogenous compounds e.g. urea, uric acid, amino acids and creatinine react with chlorine to form monochloramines. Point A in figure 2 depicts the stage when all the nitrogenous compounds in the water have reacted with chlorine to form monochloramines.

With the further addition of chlorine an unexpected phenomenon occurs; instead of the total chlorine measurement continuing to rise it begins to drop to almost zero as indicated in zone 3 of figure 2. Here the continued addition of chlorine oxidises the monochloramines to dichloramines and the dichloramines to either nitrogen or trichloramines. This means that from this point, indicated as point A in figure 2, the total chlorine level reduces as the monochloramines and dichloramines are oxidised out of solution. At point B, as shown in figure 2, only the stable chloro-organic nitrogen compounds remain. Finally, the continued addition of chlorine results in free chlorine being available in the pool water as indicated in zone 4 of figure 2. Point B, as indicated in zone 4 of figure 2, is known as the “breakpoint” and thereafter all the additional chlorine results in increased free chlorine concentrations. It is this free chlorine that provides the disinfection capability within the pool water.

9.2 CHLORAMINES

The following chemical equations illustrate the reactions of hypochlorous acid with water containing ammonia from urine, perspiration and other sources to form chloramines.

$$\underset{\text{ammonia}}{NH_3} + \underset{\text{hypochlorous acid}}{HOCl} \longrightarrow \underset{\text{monochloramine}}{NH_2Cl} + \underset{\text{water}}{H_2O}$$

This reaction is usually completed within a minute at pH 7.0 when the chlorine to ammonia nitrogen ratio is 5:1. As the chlorine to ammonia nitrogen ratio begins to increase above 5:1 the monochloramine reacts to form dichloramine.

$$\underset{\text{monochloramine}}{NH_2Cl} + \underset{\text{hypochlorous acid}}{HOCl} \longrightarrow \underset{\text{dichloramine}}{NHCl_2} + \underset{\text{water}}{H_2O}$$

This reaction is very much slower than the first reaction. Further addition of chlorine before the breakpoint can result in the formation of volatile trichloramine (nitrogen trichloride).

$$\underset{\text{dichloramine}}{NHCl_2} + \underset{\text{hypochlorous acid}}{HOCl} \longrightarrow \underset{\text{trichloramine}}{NCl_3} + \underset{\text{water}}{H_2O}$$

The monochloramine and dichloramine also react with each other to release nitrogen.

$$\underset{\text{monochloramine}}{NH_2Cl} + \underset{\text{dichloramine}}{NHCl_2} \longrightarrow \underset{\text{nitrogen gas}}{N_2} + \underset{\text{hydrogen chloride}}{3HCl}$$

The above reactions may be summarized as follows:-

$$\underset{\text{ammonia}}{2NH_3} + \underset{\text{hypochlorous acid}}{3HOCl} \longrightarrow \underset{\text{nitrogen gas}}{N_2} + \underset{\text{hydrogen chloride}}{3HCl} + \underset{\text{water}}{3H_2O}$$

Chloramines produce a characteristic chlorine-like smell. Trichloramine is particularly noticeable because it is volatile and is readily aerated out of water by agitation. Trichloramine is one of a number of chlorinated compounds present in pool water and can cause severe eye irritation.

The trichloramine reaction is most pronounced at low pH levels. The reaction lessens as the pH level rises, it is minimal at the pH level of 7.5 to 8.0 and does not normally form above this level. This is one of the main reasons for keeping the pH level within the range of 7.2 to 7.6.

Maintenance of breakpoint chlorination is required to minimise the effects caused by trichloramine.

Not all eye irritation can be attributed to trichloramine. Chlorine can also react with phenolic compounds to form chlorinated phenols which also given rise to severe eye irritation and unpleasant tastes in the water. Phenolic compounds are present in a number of cleaning products and have been used in the past for foot baths. The use of phenols or phenolic compounds is not recommended in or around swimming pools and spa pools.

10. POOL POLLUTION

Bathers are the chief source of nitrogenous compounds in swimming and spa pool water. Ammonia nitrogen and organic nitrogen are discharged to the water via perspiration and urine. The amounts of each may vary but generally children are responsible for the greatest proportion of urine in the pool. High pool water temperature and air temperature increase the rate of perspiration.

Dust, tree leaves and lawn clippings also contribute to the pollution of swimming and spa pool water.

10.1 ALGAE

Algae are microscopic plants of which two varieties of importance are found in pools; one variety which floats freely in the water and a more persistent variety which imbeds itself into pores and crevices of the water contact surfaces. The presence of sunlight, carbon dioxide, mineral matter and nitrogenous compounds or atmospheric nitrogen and other organic nutrients is essential for algal growth.

Algae will harbour and foster bacterial growth and retard the action of some disinfectants such as chlorine. For pools disinfected with chlorine, algal growth is objectionable because it reacts with the chlorine to create odours, cause turbidity, discolour the water and produce slimes that can contribute to accidents in and around the pool.

A heavy algal growth may increase the chlorine demand in pools disinfected with chlorine to a point where the ordinary levels of free chlorine will not kill the algae. It is then necessary to *superchlorinate* the pool by maintaining a free chlorine level in excess of 10mg/L whilst the pool is not in use. Following this treatment the algae should brush off quite readily. If not, the dose should be repeated until all the algae is destroyed. The dead algae should be removed by physical means before the pool is made available for use.

The presence of algae in pool water disinfected with chlorine is an indication that free chlorine is not being maintained.

Algae can also be controlled by the use of an algicide.

10.2 AMOEBAE

Acanthamoeba species and *Naegleria fowleri*, are ubiquitous protozoan organisms naturally occurring within the environment. Under suitable conditions such as those found in poorly maintained pool water they can cause a fatal form of meningo-encephalitis. These protozoa invade the swimmer through the cribriform plate in the nasal cavity and then migrate to the brain. They are readily destroyed by maintaining the required level of disinfecting agent within the pool water. Refer to tables 1, 3 and 4.

10.3 BACTERIA

The presence of organic matter in pool water provides a suitable medium for the growth of bacteria. This pool water pollution is derived from humans, animals such as birds and the environment. Disinfecting agents are used to destroy or inactivate these harmful bacteria and it is for this reason that health authorities require disinfection of pool water.

Pathogenic micro-organisms found in inadequately disinfected pools include *Escherichia coli*, *Staphylococcus*, *Streptococcus*, *Pseudomonas aeruginosa*, *Mycobacterium marinum*, *Salmonella* and *Neisseria* species. *Escherichia coli* is used as an indicator for the presence of faecal pollution. Staphylococci and Streptococci are used as indicators for pollution originating from the nose, throat, mouth and skin of bathers. They are more resistant to the disinfecting agents than the coliform organisms. *Pseudomonas aeruginosa* is an opportunistic pathogen which can cause eye, ear and skin infections in users of pools where the pool water is inadequately disinfected. *Mycobacterium marinum* cause skin granulomas and it can be found on wet pool surrounds.

Table 5 provides further information on a range of potential health effects associated with pool use.

10.4 CORROSION PRODUCTS

Corrosion in pool structures is caused by prevailing acidic conditions i.e. a pH of less than 7.0. Such conditions can cause deterioration of structural concrete, cement rendering, other surfaces and cause tiles to lift. Metal fittings including pumps, ladders, underwater light fittings, heat exchangers and pipework will also corrode. This will effect flow and have an impact on water quality management.

It is very important to ensure that the pool water is chemically balanced to reduce the effects of corrosion on pool water quality and the materials used in the pool system.

10.5 ORGANIC NITROGEN

To ensure effective disinfection in pool water the presence of organic nitrogen must be controlled. This can be achieved by ensuring breakpoint chlorination is maintained at all times.

A swimmer may lose up to 1 litre of perspiration per hour when active in pool water at 24^{o}C with an ambient air temperature of 38^{o}C. Perspiration contains sodium chloride, calcium and magnesium salts, and nitrogenous compounds consisting of large amounts of organic nitrogen, ammonia nitrogen, urea, creatinine and amino acids. The pH of perspiration is in the range of 4.0 to 6.8; however, the nitrogen content will vary according to diet.

The chemical composition of urine includes urea, creatinine, uric acid, hippuric acid and inorganic salts, it is more complex than perspiration and it is difficult to treat because of its high nitrogen content.

Ammonia and urea from both perspiration and urine are the main products which adversely effect the chlorination process. Ammonia nitrogen reacts with chlorine within minutes to form chloramines; however, urea must first go through a hydrolysis reaction before it can combine with chlorine and this can be accelerated by the presence of certain enzymes. This hydrolysis takes 3 to 4 hours under normal conditions.

10.6 VIRUSES

Humans and animals pollute pool water with viruses which can then infect other users. Many viruses can be transmitted from one person to another via pool water. Most viruses, especially the enteroviruses, are more resistant to chlorine than bacteria such as *Escherichia coli*. Adenoviruses are associated with pharyngitis, conjunctivitis and fever. The enterovirus group includes polio, coxsackie and hepatitis A. These agents may produce gastro-enteric infections, jaundice, involve the nervous system and cause a variety of skin rashes.

Disinfection concentrations required by the legislation and as indicated in figures 1, 3 and 4 will destroy the harmful viruses and render the pool water safe for use by bathers.

11. TABLES

TABLE 1 : SWIMMING POOLS DISINFECTED WITH CHLORINE

	pH	*Total alkalinity mg/L*	*Unstabilized pool water mg/L*		*Stabilized pool water mg/L*		
Pool water temperature	Min-Max	Min-Max	Minimum free chlorine*	Maximum total chlorine*	Minimum free chlorine*	Maximum total chlorine*	Min-Max cyanuric acid
< 26^{o}C	7.2 - 7.6	60 - 200**	1.0	Free chlorine as measured + 1.0	2.0	Free chlorine as measured + 1.0	30-50
≥ 26^{o}C	7.2 - 7.6	60 - 200**	2.0	Free chlorine as measured + 1.0	4.0	Free chlorine as measured + 1.0	30-50

** Disinfection values*

*** If gaseous chlorine is used the total alkalinity value must be in the range 150-200mg/L.*

***NOTE:** Stabilizers are not to be used in indoor swimming pools*

TABLE 2: SWIMMING AND SPA POOL CHARACTERISTICS

Characteristics	*Range: Min - Max*	*Comments*	
pH	7.2 - 7.6	If pH is below 7.2, then the possibility of:- - eye discomfort due to accelerated formation of chloramines - rapid loss of chlorine - etching of exposed cement finished pools, and - corrosion of metals	If pH is above 7.6, then the possibility of:- - reduction of chlorine disinfection efficiency - increased chlorine requirement - eye discomfort - drying of skin - cloudy water, and - scale formation
Total alkalinity when disinfected with:- - calcium hypochlorite - sodium hypochlorite - salt chlorinator - gaseous chlorine	60 - 200 mg/L 60 - 200 mg/L 60 - 200 mg/L 150 - 200 mg/L	If total alkalinity is below 60, then possibility of:- - pH fluctuation due to weak buffering effect - corrosion of metals	If total alkalinity is above 200 then the possibility of:- - high pH - cloudy water, and - scale formation
Stabilizer cyanuric acid	30 - 50 mg/L	If stabilizer value is below 30, then the chlorine residual is rapidly destroyed by sunlight	If stabilizer value is above 50, then the time to destroy pathogenic organisms becomes unacceptably long
Temperature	Swimming pools - 28^{O}C max Spa pools - 40^{O}C max Ideal 35 - 37^{O}C	If the temperature is too low, then bathers may experience discomfort	If the temperature is too high, then the possibility of:- - increased use of chlorine - bather discomfort - increased evaporation, and - increased scaling potential

***NOTE**: Stabilizers are not to be used in spa pools or indoor swimming pools*

TABLE 3: SPA POOLS DISINFECTED WITH CHLORINE

pH	*Temperature*		*Free chlorine mg/L*	*Total chlorine mg/L*	*Total alkalinity mg/L*
Min - Max	Ideal	Maximum	Minimum	Maximum	Min - Max
7.2 - 7.6	35 - 37^{O}C	40^{O}C	4.0	Free chlorine as measured + 1.0	60 - 200

***NOTE:** Stabilizers are not to be used in spa pools*

TABLE 4: OPERATING CRITERIA FOR THE ULTRAVIOLET LIGHT PLUS HYDROGEN PEROXIDE SYSTEM

Ultraviolet light	≥ 30 000 mWs/cm^2*
Pool water flow rate	≤ 150 L/min
Pool water turnover rate	≤ 6 hours for swimming pools ≤ 1/2 hour for spa pools
Hydrogen peroxide (H_2O_2) level	≥ 40 mg/L *
pH	7.2 to 7.6
Total alkalinity	60 to 200 mg/L

** Disinfection values*

NOTE: *The ultraviolet light plus hydrogen peroxide system has been approved for use in spa pools and in indoor swimming pools having a capacity up to 500,000 litres.*

TABLE 5: POTENTIAL HEALTH EFFECTS ASSOCIATED WITH SWIMMING AND SPA POOLS

	HEALTH EFFECTS	***CAUSATIVE ORGANISMS / AGENTS***	***PREDISPOSING FACTORS TO INFECTION***
1.	**Follicular dermatitis**	***Pseudomonas aeruginosa***	- High numbers of micro-organisms - Long exposure or high temperatures
2.	**Skin, ear and eye infections**	***Pseudomonas aeruginosa*** ***Ps cepacia*** *Mycobacterium marinum* Papilloma viruses ***Acanthamoeba***	- Injury - Spa environs and materials - Skin lesions from recent trauma or immune deficiency
3.	**Skin irritation**	Chloramines	- Inadequate dumping frequency - Low chlorine disinfectant levels
4.	**Respiratory infection**	***Legionella, Pseudomonas*** spp Enterobacteriaceae, aerobic amoebae, adenoviruses	- Aerosol dispersion of contaminated water - Poor disinfection practice - Immersion of the head - Pre-existing respiratory disease
5.	**Genito-urinary infection**	***Pseudomonas*** spp, Enterobacteriaceae, *Trichomonas*, yeasts and fungi	- Excessive exposure to spa water - Bather practices
6.	**Gastro-intestinal**	***Giardia, Cryptosporidium,*** Enterobacteriaceae - *Klebsiella, Yersinia*	- Ingestion of water - Faecal pollution of water
7.	**Heat stress (hyperthermia)**	Excessive exposure	- High temperature, especially above 40^{o}C - Long exposure time - Predisposition to stress, heart conditions

Information by courtesy of the National Health and Medical Research Council, Australia, Guidelines for Heated Spa Pools

12. ACKNOWLEDGEMENTS

This Code of Practice was developed by a working party comprising representatives from the following organisations ...

- Australian Institute of Environmental Health (S.A. Division)
- Australian Institute of Swimming and Recreation Centre Management (S.A. Division)
- Local Government Association of South Australia, Legal Services
- Swimming Pool and Spa Association of Australia (S.A. Division)
- South Australian Swimming Pool and Spa Industry
- South Australian Health Commission, Environmental Surveillance Section

The Public and Environmental Health Council wishes to convey its sincere appreciation to the supporting organisations for making a representative available and to each member of the working party for their valued technical contribution.

13. REFERENCES

Public and Environmental Health Act, 1987 and Regulations.

Australian Standards:-

2610 Spa Pools
2610.1 Part 1: Public spas
2610.2 Part 2: Private spas
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