ISRM
Managing and Developing Sport

Disinfection of pool water

The purpose of disinfection is to remove the risk of infection rather than to attempt to sterilise the water in the pool. This would be impractical. There are many ways to disinfect a pool and the choice of disinfection should be made based upon:

- Compatability with source water supply
- Type and size of pool
- Bathing load
- Operation, supervision, and management arrangement
- Comparative costs

The most frequently used disinfectants are chlorine based.

Sodium hypochlorite and calcium hypochlorite

Systems using sodium or calcium hypochlorite are suitable for all types of pool.

Free chlorine level

To achieve the best possible water quality, it is recommended that the free chlorine residual should be at the lowest level that gives satisfactory microbiological quality. This should be possible at less than 1mg/l to an absolute minimum of 0.5mg/l with a pH of 7.2 to 7.4, provided everything about the design and operation of the pool is in line with the recommendations in this manual and in *Swimming Pool Water* (available from ISRM). Ideally, no pool should aim for more than 1.5 - 2.0mg/l.

Combined chlorine level

The combined chlorine residual should be as low as possible, less than the free chlorine level, ideally half or less.

Pools that do not operate to an optimum design may need to have higher residuals - but in consequence may have to live with water that is less attractive. Pools that occasionally have large influxes of extra bathers need to accommodate this extra demand on disinfection.

pH correction

Hypochlorites are alkaline based and their addition will raise the pH of pool water. For hypochlorite disinfectants to work properly, the pH value of the pool water is critical. It is recommended that the pH value should be maintained between 7.2 and 7.4; as disinfection will be more effective (as may be coagulation) (see later). If, however, there is a 'chlorine' smell or irritation, then the disinfectant dosing rate may need to be reduced, and pollution from bathing overload corrected and pre-swim hygiene promoted.

Dosing with an acid is normally required with both these disinfectants to maintain the correct pH value. It is recommended that:

- dosing pumps linked to a pH value monitor should be used if possible.
- if manually controlled dosing pumps are used, they should be carefully controlled by pool operators, and monitoring of pH values should be regular.

In waters with a low natural alkalinity (maximum alkalinity of 150mg/l $CaCO_3$, maximum hardness 300mg/l $CaCO_3$), carbon dioxide can be used for pH reduction. Otherwise, sodium bisulphate or hydrochloric acid may be used.

Chlorine gas

A pool using chlorine gas as a disinfectant maintains the same disinfectant level as a hypochlorite pool. Chlorine gas is chlorine in its pure form. Chlorine gas is acidic, so pH values will be driven down with the addition of chlorine. So a solution of sodium carbonate is normally added, by a manual or automatically controlled pump, to maintain the pH value.

The system now preferred (see diagram) operates with the gas under pressure only at the cylinder (in the store), and uses either a cylinder-mounted chlorinator or a vacuum regulator. The rest of the dosing system is under vacuum, the loss of which produces a fail safe shutdown. The dosing system may be in the chlorine gas store; the dosing regulator is best placed near the control system.

The system is motivated by a water-operated injector fed by a booster pump, which generates sufficient vacuum to draw chlorine through flow regulating valves, gas control valves, or gas changeover devices, back to the vacuum regulator and gas cylinder. The gas mixes with the water in the throat of the injector, dissolves and is forced into the pool circulation water.

Changing cylinders and operator error are the biggest sources of accidents with chlorine gas. So a formal training policy for all operators is critical – for routine jobs and for emergencies. Written instructions must be available. The manager is responsible for this.

Material safety data sheets (Unit 12) should be incorporated, along with HSE guidance documents. Chlorine gas is highly corrosive when wet, and only approved materials and equipment can be used – and that applies also to repairs. Inspection and maintenance must also be in accordance with HSE guidance.

Managing chlorine levels in pools

Pools can be operated safely at low levels of free chlorine. Always providing that the pool meets the microbiological standards of PWTAG and that this is closely monitored. A pool operated at a low free chlorine level is going to be a much healthier, non smelly pool for chloramine production is also minimised, and so too is the amount of chemicals used. Bathers want good clean water to swim in with no risk of cross-infection. They don't want to swim in a chemical soup.

Free chlorine – absolute levels

The free chlorine residual should be at the lowest concentration that gives satisfactory microbiological quality; this should be possible at less than 1mg/l (0.5mg/l for fully ozonated pools and full treatment UV pools). The absolute minimum free chlorine level given that there needs to be a residual of active disinfectant to prevent the risk of cross infection is 0.5 mg/l. When operating at low free chlorine levels the pH value of the water must be around 7.2 to 7.4 to obtain the greatest disinfection effect. See note earlier.

This standard of performance is, however, only possible or recommended where pools have been designed to good, high standards with the turnover period, pool hydraulics etc. in accordance with 'Swimming pool water: treatment and quality standards.'

- Ideally free chlorine should be no more than 1.5 – 2.0mg/l.
- Free chlorine residuals above 2mg/l should not be necessary unless water re-circulation is slow, water distribution poor or bathing loads very heavy.
- Free chlorine residuals above 3mg/l are unlikely to be necessary and chlorination should be reduced.
- Above 5mg/l free chlorine, chlorination should be stopped immediately.
- Above 10mg/l bathing should cease.

Combined chlorine

The combined chlorine residual should be as low as possible. Ideally nothing and always half or less than the free.

Pools of poor design and/or using inappropriate operational methods such as hand dosing, infrequent testing, non-automatic dosing or overloading, may need to have higher residuals – and in consequence may have to live with water that is less attractive.

Pools that occasionally have large influxes of extra bathers need to anticipate and prepare for this demand on disinfection.

pH value

For hypochlorite disinfectants to work properly, the pH value of the pool is critical. It is recommended that:

The pH value should be maintained between the acceptable range of 7.2 and 7.8; the bottom of the range should be the target, as disinfection will be more effective as may be coagulation. This is particularly important when operating at low levels of free chlorine. If, however, there is a "chlorine" smell or irritation, the pH value may have to be raised towards the upper part of the range and any bathing overload corrected.

Understanding chlorine and ammonia (combined chlorine)

The reactions between hypochlorite and nitrogenous matter or ammonia in the pool are complex and it is dangerous to over-simplify the meaning of test results.

The combined chlorine residual should be as low as possible (none if achievable). It should always be at least half the free chlorine residual and never more than 1mg/l, where the pool water treatment is operating well.

Combined chlorine – mainly monochloramine

Where combined chlorine levels are excessive, and DPD reagents indicate the presence of mainly monochloramine, then the chlorine dose should be checked, to make sure it is at the right level.

If it is, then the chances are there is just too much ammonia present, which may be as a result of poor pre-swim hygiene, bathing loads being too high, poorly designed or undersized water treatment plant, or an equipment or operator error.

Combined chlorine, comprising of mainly monochloramine, should decrease in an hour or so by the process of breakpoint chlorination. Monochloramine is stable at normal pH levels, but given enough free chlorine, by maintaining the dosing level it converts to dichloramine.

Dichloramine will disappear

Dichloramine irritates the eyes and nose, but is unstable and disappears providing pH is correct and there is enough free chlorine. In practice this reaction is complicated by the slow formation of ammonia from the breakdown of urea, a constituent of urine and perspiration and skin cells, the recycling nature of the swimming pool water, and new bathers contributing additional ammonia and organic material to the pool.

Organic chloramines – shown as dichloramine – are stable – unaffected by increased chlorine
As well as reacting with ammonia, chlorine reacts with organic nitrogen compounds derived mainly from the proteins in bather pollution. Creatinines, for example, are found mainly in sweat and urine. The resulting chlorinated organic amines contribute to combined dichloramine readings. But they are stable and are increased rather than reduced by the presence of high free chlorine levels. Only dilution will significantly reduce them, except where pool water is treated with ozone, carbon filtration or ultraviolet.

If maintaining the normal level of free chlorine reduces the combined chlorine, the pool water is satisfactory with little or no organic chloramines present.

If increasing free chlorine also increases the combined chlorine, the pool water is unsatisfactory and organic chloramines are present. Similarly if after an overnight rest period with continuous additions of chlorine the combined chlorine is still too high then organic chloramines are present.

Getting rid of organic chloramines

When the combined chlorine is over 1mg/l, but monochloramine levels are low, then organic chloramines must be present; in this case the pool water should be diluted by replacing some of it with fresh make-up water. Organic chloramines will not breakdown as mono or dichloramines will, neither can they be avoided as they are the unwanted by-products of chlorine's fight against the pollution that bathers bring into a pool.

Dichloramines and trichloramines – the cause of smelly pools

Organic chloramines, as part of the dichloramine fraction of combined chlorine and dichloramines, together with nitrogen trichloride, are the principal cause of a smelly or chlorinous pool, smarting eyes, skin irritation and upper respiratory tract irritation.

Dichloramines will be kept under control providing there is adequate free chlorine present, ideally double the combined chlorine level. However, as noted earlier (Unit 8), where pollution levels, mainly urea, are high then nitrogen trichloride will be formed so monitoring combined chlorine is essential. To identify the true combined chlorine level it is necessary to find out by testing if organic chloramines are present, interfering with the breakpoint equation.

Any explanation or advice given on a single set of test results may be unsatisfactory as much depends on trends within the system. A build up of organic chlorine residuals is the normal cause of difficulty. So these readings need to be watched to ensure that there is not

a gradual increase over a period of days or weeks. If there is a persistent problem of this sort, the basic operation of the pool may be flawed.

If your normal testing process of free, total, combined and pH reveals a build up or unacceptable level of combined chlorine then you need to conduct a full test to find out what form combined chlorine takes.

Testing for combined chlorine analysis using a comparator

Use dedicated cells for chlorine and pH. Cleanliness of the operative's hands and all glassware is crucial – even the smallest particle of pollution or carry over of chemical reagent will corrupt and invalidate the test.

Rinse two dedicated chlorine cells with sample water, leaving a few drops in the free chlorine cell. Fill the other cell (cell 2) with sample water up to the 10ml mark.

To the free chlorine cell add a DPD No. 1 tablet; crush with rod to dissolve; top up to 10ml with sample water from cell 2. Take reading instantly.

DPD No 1 shows the free chlorine. **Reading 1**.

Add a DPD No. 2 tablet to the contents of cell 1; dissolve by shaking and take the reading instantly.

DPD No 1 + No 2 > free chlorine + monochloramine. **Reading 2**.

Reading 2
− Reading 1
= Monochloramine

To the contents of chlorine cell 1 add a DPD No. 3 tablet; mix; and stand for 2 minutes to allow for full colour development. Take the reading.

DPD No 1 + No 2 + No 3 > total chlorine.
Reading 3.

Reading 3
− Reading 2
= Dichloramine and/or organic chloramine

i.e. free chlorine + monochloramine + dichloramine + organic chloramine = total chlorine.

Interpreting test results

Example 1

Free chlorine	0.8	Combined chlorine 0.7 Action: Maintain the dosing level and leave for breakpoint reaction to reduce combined chlorine.
Monochloramine	0.5	
Dichloramine and organic chloramine	0.2	

Example 2

Free chlorine	0.8	Combined chlorine 1.0 Action: Maintain dosing levels and gradually dilute pool water with fresh make up water to reduce organic chloramines and lower combined chlorine.
Monochloramine	0.3	
Dichloramine and organic chloramine	0.7	

Getting rid of combined chlorine

Full treatment ozone and full treatment UV will eliminate combined chlorine. If you don't have these forms of treatment you will need to remove combined chlorine particularly organic chloramines and nitrogen trichloride by dilution with fresh water.

How much to dilute?

Diluting pool water with fresh water is part of the water treatment process just as significant as disinfection or pH control and cannot be disregarded in providing a healthy, attractive swimming pool.

30 litres of fresh water per bather per day is the UK recommended level for fresh water dilution and is best provided on a gradual metered basis in response to bather loading.

In Austria and Germany 30 litres per day must be provided and many pools do this automatically with a device that links the entrance turnstile with the fresh water make up valve.

Interestingly, backwashing requirements for a 25m pool with two 2.7m filters cleaned twice each week for a period of 5 minutes each filter would use a total of 45,000 litres or put another way, would meet the dilution standard for over 200 bathers each day or 1,500 bathers a week.

That might be all you need to do to limit combined chlorine and provide refreshing, sparkling, odour and irritant-free swimming pool water.

Ideal pool test results

Here's a very quick summary of where your pool water testing values should be in an ideal world, using common disinfection methods.

Pool test	Idea range		
	Chlorine gas disinfectant	**Calcium hypochlorite disinfectant**	**Sodium hypochlorite disinfectant**
Free chlorine	0.5-1.5 mg/l		
Combined chlorine	Nil to less than half the free chlorine (maximum)		
PH	7.2 – 7.4		
Calcium hardness	75-150 mg/l	75-150 mg/l* *The normal range for a pool using CH may extend to 350>mg/l but not exceed 500 mg/l	75-150 mg/l
Alkalinity	130-200 mg/l	80-120 mg/l	120-150 mg/l
TDS	Mains water TDS + 1000 mg/l (max)		
Langelier index	+ 0.1 to 0		