

THE FUNDAMENTALS OF PRIVATE SWIMMING POOL OPERATION AND CHEMICAL TREATMENT

By Bryce Lang A.S.T.C. (Chem. Eng.) A.R.A.C.I.

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1. INTRODUCTION

Swimming pools in the early days were of the fill and empty type.

This consisted of filling the pool at intervals of approximately two weeks and when it became grossly polluted, it was drained out and refilled with fresh water.

The first pool using filtered water and chlorination in Australia was recorded in Wickham Street Brisbane followed by the Tattersalls club pool in Sydney in 1924. Followed by the Y.M.C.A. building in Melbourne in 1925 and in 1926 a tender was accepted for chlorination and filtration of the Melbourne City Baths. However, these pools operated on marginal chlorination.

The modern treatment of swimming pools was introduced in England about 1950 and was mainly due to the work done by Palin with the understanding of chloramine formation and breakpoint chlorination. This was followed up in 1953 by Burgess, Burns and Tidy of the London County council in converting pools under their control to breakpoint conditions.

In Australia, it was not until about 1957 that modern treatment methods were introduced into public pools, and now there are very few public pool operators who do not have some understanding of the basic principles involved. However, private swimming pools operation has lagged far behind that of public pools, and it is only within the last few years that the general standard has risen.

Because there is no organised system of training, there is still a lot of secrecy in the chemical treatment by service operators of swimming pools, and even though an operator may be knowledgeable he still gets into difficulties.

2. PURPOSE OF TREATMENT

The chemical treatment of private pools is basically the same as for public pools.

The aims in water treatment can be broadly listed as follows:

1. To sterilise the water in order to prevent the spread of infectious diseases, and others that cause sore throats, earaches, etc. also parasites that cause ringworm, etc., can be destroyed.
2. Prevent algae growth formation.
3. Eliminate odours and obnoxious tastes.
4. Prevent irritation to eyes and mucus membranes.
5. Prevent scale formation.
6. Keep the water clear, attractive and sparkling.
7. Prevent corrosion to fixtures and fittings.

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3. BASIC REQUIREMENTS OF A SWIMMING POOL

To achieve these previous aims a pool must be properly designed and have certain basic requirements.

1. A pump with a circulation rate sufficient to give a minimum 6 hour turnover for the larger pools used for motels and schools. Small pools with very light loadings can achieve satisfactory results with longer turnovers, up to 12 hours.
2. A lint catcher to remove large solids, such as grass clippings, leaves, hair, paper etc.
3. A sand filter or diatomaceous earth filter.
4. Scum gutters should be provided for larger pools of 50,000 - 100,000 gallon capacity.

For the smaller pools, skimming devices should be used. These are required to remove hair oil, body fats, make up preparations, sputum etc. which float on the surface of the water and would otherwise concentrate if a take-off below the surface is used.

5. The type of circulation is important in the larger type pools. The water should have the shortest travel, i.e. in rectangular pools the water should enter the ports along one side of the pool and out over scum gutters on the opposite side of the pool (some old pools the water entered at the shallow end and was drawn off at the deep ending giving the maximum travel).

With the small pools the type of circulation is not so vital because of the light loadings. However odd shaped pools have to be considered on their merits.

Chemical Treatment

With small pools, hand dosing at night is generally practiced, whereas with larger pools with heavier loadings, facilities for continuous dosing of chemicals are necessary to maintain good conditions.

4. FACTORS AFFECTING CHEMICAL TREATMENT

The principle of treating swimming pool water is similar to that of town water supplies in so far as clarification is carried out by settling and filtration. In the case of sand filters: normally with a flocculation using alum.

This is then followed by disinfection using chlorine, to kill harmful bacteria and to eliminate tastes and odours.

However, town water has only to be treated once, while swimming pool water requires more exacting treatment because it is continually going through a cycle of purification and re-pollution at various levels due to the number of bathers in the water.

The amount of chemicals required to treat the water to a safe standard, i.e. good drinking water, will vary with the following factors:

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1. The volume, depth and condition of the water in the pool
2. Type of circulation and turnover
3. The number of people using the pool, also the age and sex
4. Weather conditions
5. The environment i.e., subjects to windblown leaves or grass clippings etc
6. pH level
7. Temperature of the water
8. The type of chemicals used

5. CHLORINATION

Chlorine as such, or in its various forms is still the main sterilisation chemical used. This paper is limited to its application.

The amount of chlorine required to maintain a free chlorine level in the water depends in part on the chlorine demand of the water, i.e. the pollution brought in by the bathers in the form of albuminoid and nitrogenous compounds, mainly from urine, perspiration, dead skin, hair and mucus. Other factors that increase the chlorine demand are windblown dust, leaves and grass clippings etc.

Bright sunlight is the most important factor in causing the loss of free chlorine from open air pools due to the presence of ultra violet light. This depends on the intensity and duration of the sunlight. During early morning and late afternoon, the effect is not as great as at mid-day. Also the ultra violet light is more intense in summer time or in locations closer to the equator.

By the same token, on cloudy days the ultra violet light is filtered out and the loss of chlorine is negligible without loading. Free chlorine is more reactive with bacteria at a lower pH level. Rise in the temperature of the water also increases the chemical activity of the chlorine and it reacts faster with pollution water.

When the chlorine or chlorine compounds are added to the water it reacts with organic or inorganic mater and at the same time starts to destroy bacteria.

Some of the pollution brought in by the bathers breaks down to form ammonia compounds. The chlorine reacts with these compounds to form chloramines. When all the free chlorine is used up to form chloramines this is called "Marginal chlorination". Combined chlorine in the form of chloramines is bactericidal and is more stable than free chlorine to the action of sunlight.

However, its rate of sterilisation is much less (it takes about 50 times as long to kill bacteria than free chlorine, and gives rise to tastes and odour forming compounds that irritate the eyes. Also combined chlorine does not control algae.

FREE RESIDUAL CHLORINATION

With certain stabilising compounds, or continuous dosing equipment, it is found that a free chlorine level can be maintained in the presence of combined chlorine. Maintaining this free

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chlorine level will continuously destroy the objectionable chloramine compounds and, what is most important, will ensure a safe biological condition.

For every part of ammonia in the water it will take 8 to 10 times the quantity of chlorine to destroy it. The destruction of the chloramines is a slow process and takes two or three hours to complete. As chloramines are being destroyed, fresh ones are being formed by additional pollution introduced by other bathers.

It is therefore only during periods when the pool is not being used, or at night-time, that sufficient chlorine can be added to destroy the chloramines. If sufficient chlorine has been added at night it will be found that the next morning the chlorine in the water will all be in the free form.

BREAKPOINT CHLORINATION

To explain breakpoint chlorination we shall take for example a swimming pool, which has been chlorinated, to breakpoint conditions. We shall allow any free chlorine to disappear to zero.

Now we shall let a group of school children enter the pool for an hour without any chlorination being produced. This will allow a build-up of natural pollution.

We shall then have the children leave the pool and whilst nobody is in it, we shall commence to chlorinate. By referring to figure 1, as we add chlorine to the water, we shall notice that we get an increase in the total residual as measured by the orthotolidine test. This will continue to rise as we add chlorine till we reach a point A.

Now from this point a strange phenomenon occurs: Instead of the total chlorine residual rising with the increase in chlorine dosage, it begins to get less until we reach a point B when the chlorine residual is nearing zero. Further additions of chlorine from this point will show a corresponding increase in total chlorine residual.

The reason for this change in total chlorine residual is that when the children left the water, they left behind a certain amount of pollution in the form of organic compounds and also ammonia compounds.

On part (1) of the curve we have chlorine oxidising organic matter and being consumed, at the same time it is reacting with ammonia compounds to form monochloramines. When all the ammonia compounds in the water have reacted to form monochloramine, point A of the curve has been reached.

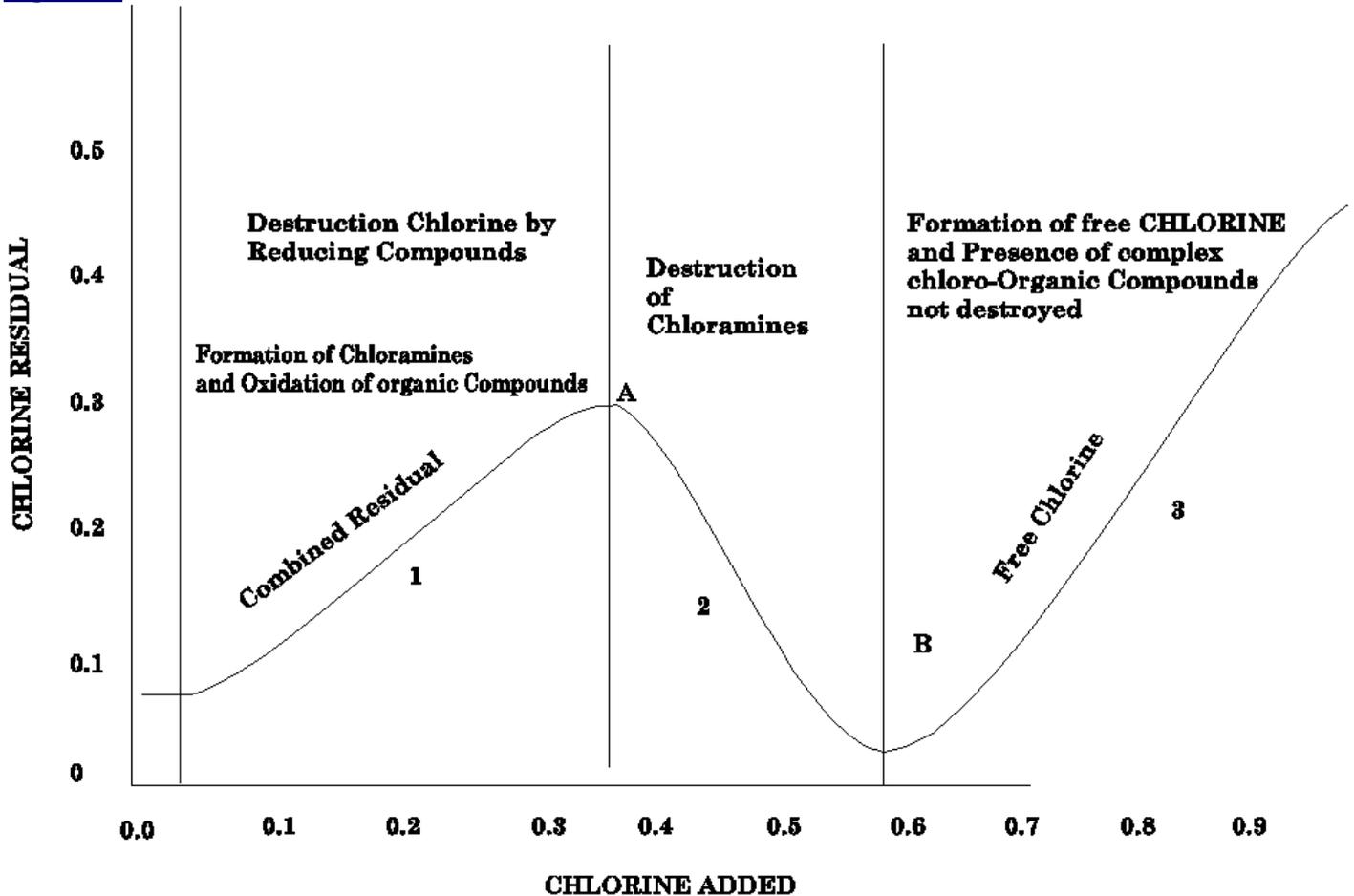
From then on, any further additions of chlorine start oxidising the monochloramine to dichloramine then to trichloramine and then finally to nitrogen. This means that from point A the total chlorine residual is getting less as the chloramines are oxidised to nitrogen until point B is reached. This is the breakpoint when all the ammonia compound have been destroyed and from then on, any further additions of chlorine will give a corresponding increase in free chlorine residual as shown by point 3 in the curve.

As explained before this breakpoint curve can only be achieved overnight or when there is no loading in the water. However sufficient chlorine should be added so that a certain amount of it is always remains in the free form.

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Figure 1:



6. FACTORS WHICH INFLUENCE THE STERILISING ACTION OF CHLORINE

The main ones are:

- a) pH
- b) Temperature
- c) Concentration

pH

When chlorine is dissolved in water it is rapidly hydrolysed to hydrochloric acid and hypochlorous acid, which in turn are partially ionised. The Chlorine Cl_2 ion, hypochlorous acid (H OCl), and hypochlorite ions (OCl) from the hypochlorous acid exist in equilibrium. However their relative proportions are governed by concentration, pH value and temperature.

Similarly when bleaching powder or calcium hypochlorite 70% is added, hypochlorous acid is formed as follows:



This also holds true for sodium hypochlorite and the chlorinated cyanurates.

The pH level of the water is the most important factor in maintaining good conditions in the pool. pH can be described as the measure of activity of the acidity or alkalinity in the water, but not the quantity.

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Reserve alkalinity, however, is a measure of the actual quantity of soluble alkali salts in the water and is normally expressed as the equivalent parts per million (ppm) of calcium carbonate.

For normal swimming pool operation the pH should be kept within the limits of 7.5 - 8.2.

The pH level of the water has a very important bearing on the ratio of monochloramines, dichloramines and trichloramines, which exist together during break-point chlorination.

At too low a pH for example, pH 7, an appreciable quantity of nitrogen trichloride (trichloramine) can exist side by side with free chlorine after point B on the curve and will not oxidise out of solution; the concentration increasing as the free chlorine level rises.

As the pH rises, the amount of dichloramines and trichloramines formed during breakpoint become less.

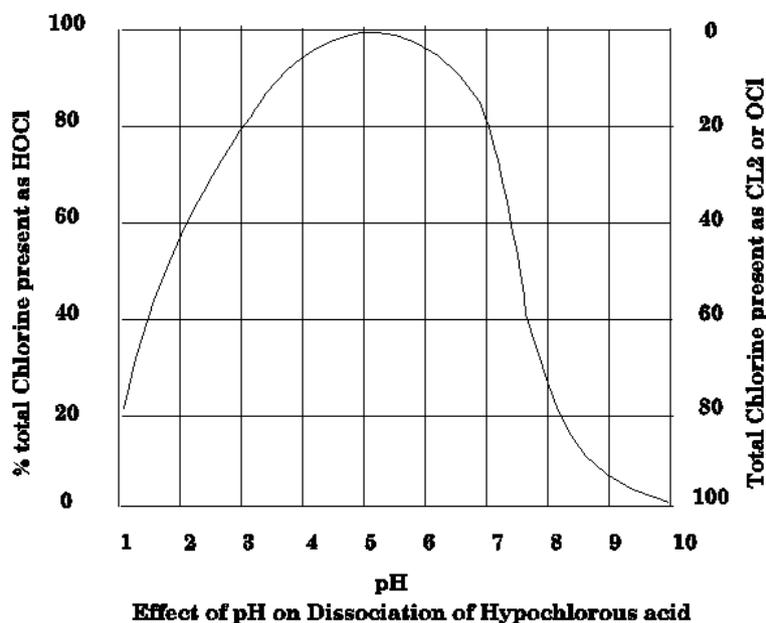
However at pH levels of 8.0 and over the monochloramines formed initially exist for a time with free chlorine and is then oxidised to nitrogen without the apparent intermediate formation of dichloramines and trichloramines, which cause eye stinging and the so-called odour of chlorine.

The efficiency of free chlorine as a sterilising agent is practically all due to the hypochlorous acid, see chart No.2.

It can be seen that as the pH rises the killing rate of bacteria decreases.

pH	% Free Chlorine as Hypochlorous Acid
pH 7.0	72%
pH 7.5	45%
pH 8.0	20%
pH 8.2	15%

Chart 2



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7. CHEMICALS USED FOR DISINFECTION

The following chemicals are the ones commonly used in practice.

1. Chlorine gas
2. Sodium Hypochlorite, 11½ % available chlorine
3. Tropical Bleaching Powder, 33 % available chlorine
4. Calcium Hypochlorite, 70 % available chlorine
5. Chlorinated cyanurates

1. When chlorine gas is used, the end product of its reaction with organic matter, or by the action of ultra violet light (sunlight), is hydrochloric acid. The continued addition would lower the pH and would eventually turn the water acid (pH below 7.0). This would cause the formation of the higher chloramines (nitrogen trichloride) that cause eye irritation and the so called smell of chlorine.

It is therefore necessary to add 1½ lb. of soda ash, or 2.4 lb. of sodium bicarbonate, for every 1 lb. of chlorine gas added to the water in order to maintain a constant pH.

2. Sodium Hypochlorite, 11½ % available chlorine, is not a stable product and should be stored in a cool area out of direct sunlight (ultra violet light decomposes the available chlorine). It contains free caustic soda as a stabiliser. The continued addition would increase the pH above the desired range because of this caustic soda. For every gallon of sodium hypochlorite added it may require up to 8 oz. of muriatic acid to keep a constant pH.
3. Tropical Bleaching Powder contains free lime as a stabiliser. This should not be added direct to a pool. A stock solution should be made up and the lime allowed to settle out and the clear solution decanted off. This, however, will contain soluble lime, which will require neutralising as the pH of the water rises.
4. Calcium Hypochlorite, 70 % available chlorine. Although this product has little insoluble matter and can be added direct to the water, it also contains free alkali and for every 1 lb. added it will require about 2½ - 3 oz. of muriatic acid to neutralise it.
5. Chlorinated Cyanurates. These are a group of products now being used, comprising:
 - sodium dichloroisocyanurate
 - potassium dichloroisocyanurate
 - trichloroisocyanurate
 - dichloroisocyanurate
 - cyanuric acid

The sodium dichloroisocyanurate containing 60% available chlorine is the one commonly used. This product is highly soluble (24%). Has an almost neutral pH, therefore will not alter the pH of the water, contains no calcium or scale forming compounds and is compatible with other chemicals.

The available chlorine is readily released in the water to react with bactericidal and organic matter and after the chlorine is used up, cyanuric acid is left behind. When the cyanuric acid level builds

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up to 25 - 30 ppm it acts as a screening agent and filters out the ultra violet light from the sun's rays. Therefore, after this stage, chlorine is not dissipated by the action of sunlight but only on organic matter.

It should be noted that cyanuric acid also retards the activity of chlorine in killing bacteria in the same way as ammonia does, although to a very lesser degree. This is shown in the following table giving the relationship of cyanuric acid concentration to killing time for bacteria at a constant free chlorine level of 0.25 ppm, and constant pH and temperature.

Cyanuric Acid (ppm)	Time for 100% Kill
0	1 minute
25	3 minutes
50	15 minutes
100	27 Minutes

This is one reason why the United States Public Health Service has recommended that because of this retarding action of cyanuric acid the limit should not exceed 100 ppm.

NOTE: - With a normal daily dosage of sodium dichloroisocyanurate a figure of 200 ppm of cyanuric acid could be built up in a swimming pool using diatomaceous earth filters within a season.

However, to offset this, it is possible to maintain a higher free chlorine level without loss to sunlight (killing rate is proportional to concentration of free chlorine). This is shown in the following table where the cyanuric acid is kept at 25 ppm with constant temperature and pH, the rate of bacterial kill is given for different free chlorine levels.

Chlorine Concentration (ppm)	Time for 100% Kill	Ratio Concentration
0.25	2 minutes	0.28
0.5	3 minutes	0.42
1.0	7 minutes	1.0

The obvious conclusion is therefore to change to another form of chlorine dosage after the cyanuric acid level is built up to 25 ppm.

Cyanuric Acid

In order to get maximum screening action at the start, cyanuric acid as such can be added to the water as a conditioning agent and then the chlorinated cyanurates can then be added as a daily dose or any other form of chlorine.

To obtain the recommended level of 30 ppm, 3 lbs. of cyanuric acid should be added for each 10,000 gallon capacity in the pool.

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However, as cyanuric acid has only a low solubility (3 lbs. per 100 gallons at 77°F), it should be mixed into a slurry (2 - 3 lbs. per bucket of water) and broadcast evenly over the surface of the pool, preferably at night with the circulation running all the time to ensure that the chemical has dissolved by the morning.

The slurry should not be added directly to the inlet of the filter as the powder may "hang up" on the filter material and be lost during backwash.

8. DOSAGE OF CHEMICALS

Dosages vary widely, much more being required under hot conditions or heavy loadings. The following table is for average conditions for a pool of 10,000 gallon capacity.

Chemical	Form as supplied	Dose	Frequency
Sodium Hypochlorite	Liquid	2 pints	Daily
Bleaching Powder or Chlorosene	Powder	1lb.	Daily
Calcium Hypochlorite 70% available chlorine	Powder or tablets.	5 - 8 oz.	Daily
Sodium Dichloroisocyanurate	Powder	8 oz.	Once weekly

NOTE: - The above small doses for sodium dichloroisocyanurate apply only after the cyanuric acid content of the pool has reached 25 - 30 ppm.

To reach 25 - 30 ppm of cyanuric acid, dose 4 oz. of sodium dichloroisocyanurate each day for 20 days.

After the cyanuric acid content has been built up to 30 ppm, then 8 oz. of sodium dichloroisocyanurate can be added weekly or sodium hypochlorite, bleaching powder or calcium hypochlorite at approximately 1/4 of the above rates.

When a pool has been stabilised with cyanuric acid it is essential that super chlorination be carried out every week or fortnight by adding 2 - 3 times the normal daily dosage. This will oxidise or "burn out" any accumulation of nitrogenous compounds and reduce the chloramine content of the water.

It will be found that after rain that free chlorine content of the water will disappear rapidly due to the impurities washed out of the air. Therefore irrespective of the normal dose given, more chlorine will be required to maintain a free chlorine level immediately after rain has ceased.

9. FREE CHLORINE LEVELS

With non-stabilised water, a free chlorine level of 0.2 - 0.5 ppm during the day is satisfactory.

With water stabilised with cyanuric acid, the following levels are required:

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25 – 60 ppm cyanuric acid requires 1.0 ppm free chlorine

60 - 100 ppm cyanuric acid requires 1.5 ppm free chlorine

It is not recommended that the cyanuric acid level should exceed 100 ppm.

10. SCALE FORMATION

The formation of scale in swimming pools is due to the precipitation of calcium or magnesium in the water as carbonates.

There are several factors that influence this as follows:

1. Amount of calcium or magnesium in the water
2. pH
3. Total Alkalinity
4. Dissolved carbon dioxide
5. Total dissolved solids.

Langelier developed an index for determining when water would become scale forming or corrosive. In practice to control this entails the adjustment of one or more of the following, value, alkalinity and calcium hardness. Increase of any of these values beyond a certain point will cause scale formation.

As mentioned before, sodium hypochlorite will raise the pH but does not add calcium salts. Calcium hypochlorite adds calcium as well as raising the pH. However, sodium dichloroisocyanurate does not add any scale forming impurities and does not affect the pH.

However, a factor that is often overlooked is the concentration of salts in a pool due to solar evaporation. In tropical and sub-tropical climates the evaporation rate from a pool could be as high as 60" in a season. This means that if there is no loss due to backwashing, the solid contents in the water could be doubled in a season. This is because the salts are left behind as the water evaporates and their additional salts are added in the make-up water. This is more noticeable in diatomaceous and Hi Rate sand filters where the back wash rate is small.

The obvious method to reduce this is to empty a portion of the pool water periodically and make up with fresh water. However, this will lower the cyanuric acid level required for stabilisation.

The pH can be reduced by adding hydrochloric acid or sodium bisulphate 2.4 lb of hydrochloric acid (33 %) or 2 lbs. sodium bisulphate will neutralise 1 lb. of calcium carbonate. (NOTE: 5 ppm of calcium carbonate is equivalent to 1 lb. in 20,000 gallons)

Another method is to precipitate the calcium as tricalcium phosphate by the addition of trisodium phosphate. 1 lb. of anhydrous trisodium phosphate will precipitate 1 lb. of calcium carbonate. This is readily removed from the bottom of the pool by vacuuming.

In very hard waters it is possible to use a sequestering agent such as "Calgon" (sodium hexametaphosphate) at the rate of 1/3 lb. per 5000 gallons, which is repeated at intervals. This compound ties the calcium up in a complex compound that prevents it precipitating out.

When scale has built up, the pH should be reduced by adding not more than 3 pints of hydrochloric acid to 10,000 gallons at one time. At least an hour should elapse before checking the pH and repeating the procedure if required. The dropping of the pH will increase the solubility of the water for the calcium deposits that will slowly redissolve with subsequent rise in pH. This is called "pH bounce" and will continue until such time as all scale has redissolved. Similarly with

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new concrete work, the pH will continually rise without the addition of chemicals, due to the leaching out of calcium deposits in the fresh cement. This may take several months before the pH can be stabilised.

Sudden growths of algae in a pool will also raise the pH due to the removal of carbon dioxide from the water by the algae for food.

11. ALGAE CONTROL

Algae are free floating microscopic plants and animals known as plankton and are divided into many classes. They are found in the free floating and clinging varieties. The clinging type will embed itself into pores and crevices in concrete and between tiles and is the more persistent type.

Whenever water is exposed to air and sunlight, algae will gain access in the same manner as weeds grow in a garden. If conditions are favourable, profuse growths of great variety and many colours will develop.

Sunlight is essential to their growth as well as carbon dioxide (CO₂), mineral matter and suitable temperature. Organic matter in the water does not have much influence as a food. Temperature plays an important part in the type of algae that grows at that particular time and there are types that grow in winter conditions as well as summer. However, the summer growths are usually more active and are probably due to the presence of longer sunlight.

The presence of algae in the swimming pool will develop turbidity, produce odour and taste in the water and will necessitate more frequent backwashing due to their clogging action on filter beds.

Algae growths are objectionable in appearance. As they are slimy they are the cause of most accidents in and around a swimming pool because of this slippery nature. They also create a high chlorine demand should heavy growths develop; these growths then harbour and tend to foster bacterial growth and retard the action of chlorine. They also give rise to odour problems when reacting with chlorine.

These conditions in a swimming pool are an indication that a regular free chlorine residual is not being maintained in the water. Provided a free chlorine level is maintained at all times, algae growths will not appear. However, should these conditions develop and heavy growths become established, the chlorine demand is increased to a point where the ordinary levels of free chlorine residuals will not kill them off.

It is necessary then to apply super chlorination, e.g. maintaining a free chlorine level of 10 ppm or over during the night when the pool is closed to bathers. This is the most effective treatment and next day it will be found that the dead algae growth will brush or slough off quite readily. This can be achieved by adding 1½ lbs. of calcium hypochlorite 70 % to 10,000 gallons of water.

However, with stabilised pools using cyanuric acid, the problem is getting rid of the high chlorine level before bathing commences. This can be achieved by de-chlorinating next morning by adding sodium thiosulphate (photographic "hypo") at the rate of 2 lbs. per 10,000 gallons. Sodium sulphite or sodium bisulphite can also be used to de-chlorinate.

At pH levels below 8.0 most waters contain increasing amounts of carbon dioxide necessary for their growth; with waters above a pH 8.0 the amount of carbon dioxide becomes negligible and this, together with chlorine will reduce the incidence of algae trouble.

There are also a number of other chemicals that are sometimes added to water as algicides. They act in two ways. One is to prevent growths (algistatic) and the other to kill growths (algicidal). In

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most cases the amount required to kill a growth in four hours may be 3 - 8 times greater than that required to prevent one forming within ten days.

The most common algicide that has been used over the years is Copper Sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$). The normal dose is in the region of 1 -2 ppm. However, if the growth is well established, higher rates will be required.

The difficulty involved in using copper sulphate in swimming pools is that the effective portion, copper, is precipitated out of solution by the bicarbonate content of the water and rendered ineffective, usually in a period of 5 - 7 days and is removed in filtration. Another side effect is that in conjunction with chlorination, the compound formed may discolour bathing costumes and turn hair green.

Another most effective metallic salt which will kill algae in a few minutes at 1 ppm is phenyl mercuric acetate. However, as this is a highly poisonous material to handle, it is not recommended for swimming pools.

Newer ones have come on the market in recent years. The amine types and the quaternary ammonia compounds such as Rosin amine D, acetate, Cetyl trimethyl ammonium bromide, lauryl pyridium chloride, etc.

When evaluating algicides, it is probably most important to know whether the concentration recommended for the product is to prevent growths of algae (algistatic) or it will kill established growths (algicidal). In most cases there will be a loss of algicide as the water is continuously filtered due to absorption on sand or diatomite of the filter bed and it is usual after the initial dose to follow up with smaller weekly doses.

Some algicides possess a high chlorine demand and therefore rob the water of its chlorine residual. Others cause severe frothing in the water and in the filters.

It should also be noted that some strains of algae will build up a resistance to some types of organic algicides.

Porous surfaces or cracks in a swimming pool make it difficult to control or eliminate algae as the spores may be protected by the "dead" water in the porous structure and will readily give rise to spontaneous growth should the free chlorine level in the water be lost for any length of time.

During winter months when the pool has been left full of water and without treatment, the growth of algae can be quite alarming before the start of the next swimming season. To prevent or minimise the growth, it is recommended that at the close of the season, the pH of the water should be raised to 8.3 in order to lower the level of dissolved carbon dioxide. At intervals of approximately a month, depending on the visual observation of the development of growth, the plant should be turned over during the night and super chlorinated with chlorine. Another alternative is to cover the top of the water, by floating black polythene sheet and thereby eliminating sunlight necessary for growth.

12. FILTRATION & CIRCULATION

The ability of a system to keep a pool clean is a function of filter size, grade of sand or diatomite, strainer size, pipe sizes, type and number of skimmers, number of inlets, turnover ratio and characteristics of the pump (pressure vs. volume). This will vary with each pool and will be conditioned by the size and shape of pool, the normal and maximum expected loadings and also whether it is to be an inside or outside pool.

Turnover rates may be from 6 hours to not more than 12 hours.

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Once a system has been designed, any one component should not be altered in capacity without considering its relationship to the capacity of other components.

A pump is always selected to meet the requirements of the filter, i.e. the normal filter rate per sq. ft. of filter area at a certain back pressure with a designed pumping capacity for back-washing with reduced back-pressure. If these are not mated, then continual trouble can be expected in the filtration cycle and standard of filtration.

13. TYPES OF FILTERS

The following are the types of filters commonly used:

1. Diatomite (pressure or vacuum)
2. Sand: (a) rapid gravity (b) pressure (c) Hi Rate

Each type of filter has advantages and disadvantages. Power costs, chemical cost and water usage, size of plant and initial cost all vary.

The gravity and pressure type sand filter are easy to operate. However, water usage is high, about 10% of the water in the pool is lost during backwash. With the diatomite and Hi Rate sand filters, only about 1% of the water is lost in backwash.

Power costs for Diatomite vacuum type filters and pressure sand filters cost about the same, whereas Diatomite pressure type filters and Hi Rate sand filters cost twice as much.

Diatomite Filters

Diatomite or diatomaceous earth filters were first developed for swimming pools after 1945. Although they are widely used in private swimming pools, their application to public pools in Australia is only just beginning.

The Diatomite filter is designed to receive a charge of diatomite powder on a porous septum. The filter itself does not clarify the water; this operation is carried out by the filter aid (diatomaceous earth). The design of the diatomite filter is very important because it is essential that the filter aid be applied in a uniform thickness over all the septa. This diatomite or diatomaceous silica is composed of the fossil remains of tiny aquatic plants called diatoms. Under the microscope, the fossils are revealed as unbelievably thin, transparent valves or shells of diverse shapes with ornate and symmetrical markings. The average diatom is so small that more than a thousand would have to be laid end to end to equal one inch.

Under favourable conditions of light, temperature and nutrition, such plants grow in great profusion and, during the geological past, many deposits of these plant skeletons were built up in different areas of the earth. Each skeleton is an extremely porous framework of nearly pure silica.

The type of filter developed for large swimming pools consists of a vertical, cylindrical tank in which a number of hollow tubular filter elements are suspended. The pool water entering the tank is filtered through the diatomite cake on the outside of the elements, flows inside the tubes to the outlet and then back to the pool.

The elements themselves are finished in a variety of construction materials and designs. The most common is porous aluminium oxide or porous metal cylinders, helically wound wire on plastic or metal cores, and metal or plastic cores covered with either metal or synthetic fibre filter cloth. Each design has its own particular advantages.

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In the operation of the filter a layer of diatomite, called the precoat, is formed on a filter cloth or screen. The filtration is performed by this fine porous layer of diatomite, not by the filter septum itself. The main purpose of the filter septum is to form a framework on which to build the filter cake that actually does the work. The porous precoat of diatomite allows free flow of the water but traps the particles of dirt as the water flows through.

Only after the precoat is in place is the swimming pool water circulated through the filter. As the water passes through the precoat, suspended solids are screened out. Usually, there are enough suspended solids in the water to plug the tiny openings in the surface of the precoat, causing too rapid pressure increases and decreasing flow rates. For this reason, most pools can be operated more satisfactorily by intermittently or continuously feeding a small amount of additional diatomite. This operation is called the body or slurry feed. In this procedure, fine porous, freely filtering cake is built up. The precoat feeder must be large enough to deliver an initial charge of two ounces of diatomite per square foot of filter area. The body feeder must have the capacity to deliver 1 - 4 ounces per 1,000 gallons of water recirculated per day.

Although high filtration rates can be achieved with these filters, the higher rates give short filter cycles. The compromise in the cost of filter units with that of power, labour and filter aids is a filtration rate of 1½ to maximum of three gallons per square foot per minute, with backwash rates of 10-12 gallons per minute per square foot.

The circulating water cannot be shut off and on indiscriminately on these filters otherwise the filter cake may fall off the septum and when started up again some of the filter aid and dirt may pass through before the water pressure binds the filter aid to the septum again.

Rapid Gravity Filters

This consists essentially of a clean bed of fairly coarse graded sand supported on several grades or rock with a distribution and collection system on the top and bottom of the filter.

In order to remove finely suspended or colloidal impurities from the water, a coagulant such as alum is added to the filter. Filtration rates normally operate at 3 gallons/sq.ft./minute.

Backwashing of Filters

This is one of the most important operations and should be carried out when the loss of head equals the distance from the water surface on the filters to the bottom of the sand layer or when the effluent is no longer satisfactory. Backwashing consists of shutting off the inlet line and opening the sewer line, then running clean water from the pool in the reverse direction through the under-drainage system. Most manufacturers recommend that the backwash rate should be 12 gallons per minute per square foot of filter area.

The rate of flow for backwashing operation is that which will expand the sand bed until the individual grains are not continuously in contact with each other but will "vibrate" back and forth and dislodge any dirty material adhering to the surface of the sand grains. The backwash rate should be great enough to raise the small dirt particles and soil vertically and carry them to waste. Effective sand washing normally occurs when the sand bed is expanded about 40 per cent.

Too great an expansion of the sand will make the backwashing less effective as the sand grains may be too far apart as not to infringe on each other to obtain the effective degree of scrubbing action. The size of the sand grains specified by the manufacturer is such as to give the desired expansion at the rate of flow.

To prevent loss of sand in backwashing, a free board of at least 50% of the filter depth is required.

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The normal operation of a rapid sand filter is a relatively simple procedure and it is not until some of the component parts fail to function that the operator is faced with any difficult problem. Good operation, however, includes activities on the part of the operator which tend to prevent some of these failures occurring. Many of these impending difficulties may become evident by simple observations during both the filtering and backwashing operations.

For example, the presence of "mud balls" in the sand, indicates incomplete washing. The existence of cracks in a sand bed or the pulling away of the sand from the walls indicates that the sand grains are being cemented together by some material in the water and that parts of the filter bed may become ineffective. Uneven distribution of wash water may often be observed directly or it may be indicated by the formation of mounds, craters or sand "boils", particularly if the under-drains or strainers are broken. The possible loss of sand during backwashing may be checked by collecting and making visual observations of water samples taken from the backwash troughs. Observance of any of these conditions should be thoroughly investigated, so that the cause may be eliminated.

Pressure Filters

These are similar to an ordinary rapid sand filter except that it is completely enclosed in a steel tank and the entire unit is operated under pressure. Rates of filtration, backwashing, sand and gravel sizes are the same. Filter units of this type require much less head room than the gravity filters but require the same surface area as the gravity filters. Pressure filters must be equipped with pressure gauges on both the inlet pipe and outlet pipe for determining the loss of head or back pressure in the filter medium.

The main disadvantage of pressure filters lies in the fact that the operator is unable to observe the filter operations. The sand becomes encrusted or develops "mud" balls or backwashing may become unsatisfactory, all without the operator's knowledge. Air relief valves are necessary on these filters and should be located on the top of the filter shell to release entrained air after backwashing and at other regular intervals.

Alum Flocculation

Rapid Gravity and Pressure Sand Filters must be coated on the surface media with a gelatinous floc of aluminium hydroxide in order to filter out the very fine or colloidal soil which would otherwise block the interstices between the sand particles or else become trapped and form mud balls in the filter bed. Besides removing very finely suspended matter the floc will also remove algae, colouring matter and portion of the bacteria in the water.

Alum (aluminium sulphate $\text{Al}_2(\text{SO}_4)_3 \cdot 17\text{H}_2\text{O}$) is the common coagulant used. As this material is acidic it requires a reserve alkalinity in the water for the reaction to form the aluminium hydroxide floc.

For every pound of alum added to the water it will require $\frac{1}{2}$ lb. of soda ash or slightly more than $\frac{3}{4}$ lb. of sodium bicarbonate to complete the reaction.

Therefore before alum is added, the water should have a pH between 7.5 - 8.0 and a reserve alkalinity between 150 - 200 ppm.

If the pH of the water is below 5.5, or above 8.5, the alum will not form a satisfactory floc and some if not all of it will remain in solution.

It is only necessary to add the alum after backwashing. The amount to use to obtain efficient filtering will depend on the design of the filters and experience. As a general guide, 2 to 4 oz. of alum per sq. ft. of filter area should be added. It should be added as a solution, 10% or less over a period of 1 -2 hours by drip feed to the inlet side of the filters, preferably at the skimmer boxes.

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If the alum is added too quickly the pH of the water may be depressed below 5.5 at which level it will not form a floc but will pass through the filters. However, when this water mixes with the pool water the pH will rise causing the alum to floc in the pool causing cloudiness.

In the normal operation of a pool, backwashing will be required on an average once per week. This depends on loading, size of filters and turnover rates. If the loss of head gauges do not indicate that backwashing is required after a week's operation, this may indicate that a weak spot has developed in the sand and that most of the water is passing through this area of least resistance and is therefore only partially filtered. This can usually be indicated by the condition or clarity of the water. It is good practice therefore to backwash at least once per week. In doing so, the high velocity of backwashing expands the sand bed and resettles the sand in a more uniform layer, thereby eliminating the tendency for weak spots or holes to develop in the filter bed.

Hi-Rate Sand Filters

This is a comparatively new type of filter principle, which has now been applied to swimming pools in Australia. In appearance it resembles the conventional pressure sand filter. However, it operates on a completely different set of principles in its retention of solids. Flocculation of alum is not used on these filters. The incoming water is directed towards the surface of the sand so as not to cause turbulence, or disturbance of the media, passes down through the sand at high flow rates. The solids, which are in the pool water, do not remain at the surface of the media of the Hi-Rate Filter (as in the case in the conventional sand filters). They are washed down progressive into the media.

The choice and grading of the media is of the greatest importance. The sand grains have to be exactly the same size; in other words, the uniformity co-efficient must be less than 1.6. When observing the high rate filter it is seen that the solids move down into the media at a steady rate. The rate at which they travel is dependent on the quantity of the solids in the water rather than the rate of flow or the length of the filter cycle. Each volume of sand can retain a given quantity of collected solids and this is the true limit of the capacity of the filter.

Comparatively, the flow rate on the Hi-Rate Filters is at least five times larger than for the conventional filter. Even though the Hi-Rate Filter only has 1/5th the Filter area, its dirt holding capacity is as great as the sand filter as it uses considerable depth of media compared to the shallow surface layer of conventional filters. Having forced the solids deeply into the media, the backwashing efficiency must be excellent in order to discharge the collected solids. This depends on a perfectly designed and balanced internal hydraulic system. These filters operate at rates of up to 16 gallons/sq./min. and backwash at the same rate. An air release device is necessary on top of these filters.

14. CONSECUTIVE DILUTION

It is important to know and recognise that all the pool water is not filtered out on a single turnover. When filtering begins, the first portion will be all dirty water. Shortly the dirty water in the pool will be diluted by the returning filtered water. For this reason the filtration and purification of a pool is accomplished by what is known as consecutive dilution.

For example in a pool containing a given amount of soil, about 67% will be removed on the first turnover, 86% on the second and so on as follows:

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No. of Turnovers	% of Dirt Removed
1	67
2	86
3	95
4	98
5	99.3
6	99.7
7	99.9
10	99.99

In actual operation, however, the pool will be in use while the water is being filtered and dirt will therefore be continuously added and filtered out. So that after a period of time, the dirt content of the pool will reach equilibrium and remain relatively constant, subject to fluctuations in the bathing load.

If the amount of dirt added every day is just equal to the amount present in the pool when filtration started, the following table shows what can be expected if filter efficiency is 100% and distribution of filtered water is perfect:

Turnover Rate In Hours	Days to Reach Equilibrium	Percent (%) Dirt in Pool at Equilibrium (Original Dirt = 100%)
48	19	155
24	9	58
12	4	16
8	3	5
6	2	2

It can be seen therefore, what effect turnover rate has on the clarity and sparkle of the pool water and why filters should be operated 24 hours per day.

15. INITIAL FILL OF A SWIMMING POOL

If a pool has been drained in order to affect a repair or it is the first fill of the season, in all cases it will be found that the quality of the water used for refilling is very poor. In a number of cases it will be found to be dark red in colour with a considerable amount of turbidity. If this water is to be clarified by normal method of filtration it may take several days as the filters build up back pressure so quickly that they may need backwashing several times in one day.

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The quicker method to clarify the water is to flocculate the alum in the pool itself as follows:

1. Build up the reserve alkalinity in the water as it is filling by adding either 2.5 lbs. of soda ash or 5 lbs. sodium bicarbonate for every 10,000 gallons.
2. Add alum at the rate of 5 lbs. for every 10,000 gallons by dissolving in water and distributing over the surface of the water in the pool, followed by running the pumps for ten minutes or until the alum has dispersed and starts flocculating.
3. Stop the pumps and allow the floc to develop and settle overnight. Next morning, suck off the deposit which settles on the bottom by means of the vacuum sweeper.
4. Follow by the normal filtration treatment and chlorination and the water should be ready for use by the end of the day.

16. THE BIOLOGICAL QUALITY OF POOL WATER

The majority of micro-organisms found in pool waters are not dangerous. In purifying the water no attempt is made to destroy all micro organisms which consist of bacteria, viruses, algae and fungi, but to reach a point where the destruction of all harmful bacteria has been achieved.

Secretions from the mouth, nose, skin and urination are the main sources of organisms such as bacteria and viruses which can be disease producing.

When routine bacterial tests are carried out on water, no attempt is made to identify specific disease producing micro organism.

The bacteriological examination to determine the microbiological quality of pool water is based on the total colony count and presence of coliform organisms (or *Escherichia coli*).

The presence of bacteria detected by these tests does not mean that they are all dangerous, but it acts as a warning to indicate that harmful bacteria could also be present.

It is generally accepted that pool water, free from coliform organisms, is regarded as having a satisfactory bactericidal purity. It is generally agreed also, that this condition can be reached if the pool practices continual filtration and the maintenance of a free residual chlorine level.

However, to make sure that the treatment and chlorine level is adequate, samples should be taken under the worst peak load conditions and submitted to the Department of Health or bacteriological examination at regular interval.

Total Colony Count - This indicates the degree of general contamination of the water from all sources. It is usually found that the total colony count rises in proportional relationship to the bathing load. Pools practising free residual chlorination are indicated by very low counts. A total colony count of less than 200 colonies/mL should be the objective.

Coliform Bacteria - The presence of *Escherichia coli* which is found exclusively in excreta of warm blooded animals is a reliable indicator of faecal contamination of water.

Recommended Bacterial Limits - The New South Wales Department of Health has recommended the following limits for closed circuit public pools with continuous purification treatment:

1. 75% of samples covering any period of time from any pool shall not have a total colony count exceeding 50 colonies per 100 mL and the remainder should not exceed 200 colonies per mL.

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2. The arithmetic mean coliform density of all standard samples examined per month shall not exceed 1 per 100 mL. Coliform counts per standard sample shall not exceed 4 per 100 mL in two consecutive samples.

When coliform counts in a single sample exceed the above limits, confirmatory samples are required and shall be examined daily until results obtained from at least two consecutive samples show the water to be of satisfactory quality.

17. CHEMICAL TESTING REQUIRED TO CONTROL SWIMMING POOL WATER TREATMENT

For trouble shooting or more accurate control of swimming pool water, it is essential that reliable test methods and reagents be used.

Routine Tests Required:

To obtain the maximum benefits from a modern well designed swimming pool, it is very essential that regular tests be carried out for:

- a. Free chlorine
- b. Total chlorine
- c. pH
- d. Reserve Alkalinity

Correct test procedure and knowledgeable interpretation of the results will result in good plant control and the most efficient and economical usage of chemicals, water and power.

Samples of water for testing should be taken from about one foot to 18 inches below the surface. The position of sampling should be next to the exit from the pool (not at the inlet or in between, as this may give higher free chlorine readings). Also for comparison purposes the same exit position should be used for all regular sampling and this should preferably be somewhere near the shallow end or area of greatest loading.

The common apparatus used for the measurement of free chlorine residuals, total chlorine and pH, is the Lovibond Comparator.

The basis of each test with the comparator is that a colour developed by the addition of an indicator solution to a specially prepared sample of water is matched against a scientifically calibrated colour disc. The procedure adopted in preparing the sample for colour comparison varies for each type of test. Colour discs are provided to cover the different ranges of residual chlorine. Various indicators with appropriate discs are also available to cover different ranges of pH.

It is good practice to replenish test reagents at the beginning of each season. During the season test solution may be affected by sunlight, or contaminated during use.

Difficulties in maintaining good conditions in the pool have often been traced to faulty reagents that give false readings resulting in incorrect dosage of chemicals with subsequent discomfort to bathers.

Other contributing causes to false colour development are the test procedure incorrectly performed; dirty glassware and comparator discs; temperature error; colour that is developed by interfering impurities such as iron, manganese and nitrates in the water.

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Tests should always be carried out in a clean area where solutions or stoppers from bottles will not pick up chlorine chemicals, alkali or alum dust from bench tops. It is bad practice, therefore, to carry out tests in the same room where solutions of these are prepared or stored.

Plastic beakers should be used for collecting the samples of water. (When using glass containers there is always a hazard associated with breakage).

The sample should be taken immediately to the testing room and kept out of sunlight during this period. Tests should be made without delay otherwise true chlorine readings will not be obtained. All test tubes or cells should be clean and rinsed with sample water before use. The operator's hands should be washed before tests in case he may have been handling other chemicals prior to sampling.

Test for Free and Total Chlorine Residual.

Reagents required:

- Standard acid orthotolidine solution
- Standard sodium arsenite solution
- Colour disc range - 0.1 to 1.0 ppm chlorine
- 0.15 to 2.0 ppm chlorine

Procedure:

1. Fill one cell with sample of water, up to 10mL mark, and place in left hand side of comparator.
2. To another cell add 0.1mL acid orthotolidine solution from a graduated dropper. Fill to 10mL mark with sample, stir with glass rod, and leave for 5 minutes before placing in right hand side of comparator. This will show the total chlorine (reading 1).
3. Take two cells, to one (a) add 0.1mL of sodium arsenite solution and to the other (b) add 0.1mL of acid orthotolidine solution.
4. Add 10mL of sample water to (b) and within 5 seconds pour this into cell (a) containing the sodium arsenite. Place in right hand side of comparator, this will show free chlorine (reading 2). Reading 1, minus Reading 2, will give the combined chlorine residual (or total amount of chloramines present).

Blank Test:

Sometimes impurities in the water may give a false colour reading due to the presence of manganese, iron or nitrites. This can be checked by the following procedure:

1. Take two cells, to one (a) add 0.1mL of orthotolidine and to the other (b) add 0.1mL of sodium arsenite solution.
2. Add 10mL sample of water to (b). This is the reverse procedure for free chlorine. The sodium arsenite will destroy any chlorine residual present.
3. Pour (b) into (a) and let stand for 5 minutes and take (reading 3).

Should a reading be recorded, this reading (3) should be subtracted from reading (1) and (2) to get a true free and total chlorine reading.

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It should be stressed that these false readings from interfering substances can occur more frequently than one would imagine.

In one particular case, a pool was registering a free chlorine level of over 1.0 ppm with very little addition of chlorine. It was found by doing a blank test that interfering substances were showing colour equivalent to reading 1.0 ppm of free chlorine. It was subsequently found out that at a recent school carnival, brown discolouration had been noticed at one end of the pool. As the blank reading was due to manganese it was surmised that a schoolboy had added potassium permanganate (Condy's crystals) to the pool for a prank.

PALINS D.P.D METHOD

This is a recent addition to the methods for testing free and total chlorine residuals and has the advantage that the reagent chemicals are in tablet form. This reduces the chances of contamination and the addition of the wrong amount of reagent. The test for free chlorine is also more positive and reliable.

Reagents required D.P.D. tablets (active constituent is diethyl-p-phenylene diamine).

1 bottle of No. 1 tablets.
1 bottle of No. 3 tablets.

Colour disc range –

No. 3/40B 0.2 – 4.0 ppm chlorine

No. 3/40A 0.1 – 1.0 ppm chlorine

A filter is also supplied for use with the discs.

Procedure:

1. Fill one tube with water and place in left-hand side of comparator.
2. Take two tubes, rinse with sample water and leave about 1/4 " (no more) of water in one cell.
3. Add one D.P.D. tablet No. 1 to this tube and wait until tablet is broken up.
4. Fill tube to 10mL mark with water sample and mix by pouring backwards and forwards between the two tubes.
5. Place full tube in right hand side of comparator. Take reading and record as free chlorine.
6. Now add D.P.D. tablet No. 3 to the right hand tube.
7. Mix by pouring backwards and forwards with another tube.
8. Replace tube in right hand compartment. Take reading after two minutes and record as total available chlorine.
9. The difference between the two readings will show the combined chlorine content (or the total amount of chloramines present).
10. By the use of another D.P.D tablet, No.2, the monochloramine and dichloramine fraction of the combined chlorine can be estimated.

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For obtaining greater accuracy in reading, comparators can also be obtained which have larger cells. The colour change for the greater depths of solution is more easily recorded. On such type is the Nesslerise that has a cell holding 50mL of sample water.

Lovibond Comparator discs should not be used with fluorescent or uncorrected tungsten light, as they are match for daylight or its equivalent. When good daylight is not available, a special artificial daylight cabinet is available for supplying a source of white light equivalent to natural diffused daylight.

AMPEROMETRIC TITRATOR

The most accurate method of determining chlorine in water is by means of measuring the flow of current in a buffered solution (Amperometric titration). The inherent disadvantages of the comparator methods such as the effects of temperature, turbidity, colour, iron, manganese and nitrites are eliminated by this method. The various forms of chlorine in water (free, total, monochloramines, dichloramines and trichloramines) can be estimated with extreme accuracy down to 0.01 ppm from the one sample.

The instrument needs a source of power to operate it. The time required to do the test is not much longer than the comparator method, once the instrument has been set up. However, greater care is needed in handling the instrument and keeping it in a clean condition free from contamination. The titrator is only valuable for research and development work or for troubleshooting.

pH MEASUREMENT

In measuring pH values, advantage is taken of the fact that certain dyes, known as indicators, change their colour in definite and reproducible manner and degree, according to the pH value of the solution with which it is mixed.

The simplest and best known is litmus paper, which is red in acid solution and blue in alkaline solution. However, to determine to what degree a solution is acid or alkaline, resort is made to different indicators with varying colour changes at different pH ranges.

The same Lovibond comparator is used for measuring pH of the sample water.

To cover the pH range that is likely to be encountered in swimming pools, the following indicators and corresponding discs are available:

pH Range	Indicator	Standard Disc
6.0 - 7.6	Bromo Thymol Blue	2/1H
6.8 - 8.4	Phenol Red	2/1J
7.0 - 8.6	Diphenol Purple	2/1O
8.0 - 9.6	Thymol Blue	2/1L

Indicators for the above may be obtained as a solution, or in tablet form. In the case of Phenol Red, which is the most common indicator used, a dulling screen must be used with the colour disc.

When determining the pH of water containing a high residual of free chlorine, it is necessary to destroy this free chlorine before adding the appropriate quantity of indicator solution. If this is not done, then the strong oxidising power of the free chlorine will alter the colour of the indicator

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solution and give a false reading. In the case of Phenol Red, a free chlorine residual will gradually intensify the colour and indicate a higher pH.

To destroy the chlorine present it is recommended that analytical grade (A.R.) of sodium thiosulphate be used.

One only small crystal of sodium thiosulphate should be added to the beaker of sample water after the chlorine tests have been carried out and stirred thoroughly with a glass rod.

As sodium thiosulphate is an alkaline substance, excess should be avoided otherwise a higher pH reading may be recorded. It is preferable to make up a solution of sodium thiosulphate A.R. grade containing 1.3 grams per litre of distilled water. One drop of this solution will destroy 5 ppm of free chlorine in 15mL of water without affecting the pH.

Procedure for pH measurement using Phenol Red:

1. Fill one tube with sample water and add to left hand side of comparator.
2. To another cell add 0.5mL of Phenol Red solution from a graduated stopper.
3. Fill up to the 10mL mark with water sample previously de-chlorinated with sodium thiosulphate. Stir with glass rod.
4. Place in right hand compartment of the comparator and record reading.

NOTE: Make sure that the dulling screen has been inserted for the Phenol Red disc.

RESERVE ALKALINITY

The reserve bicarbonate alkalinity of the water is expressed chemically as the equivalent amount of calcium carbonate in the water. Experience has shown that the reserve bicarbonate alkalinity should be kept at about 150 - 200 ppm for public pools using gaseous chlorine. However, for private pools using other chlorine products this figure will increase considerably.

The estimation of reserve alkalinity is carried out by means of simple titration requiring the following apparatus and chemicals:

- 10mL burette (automatic type)
- 25mL graduated cylinder
- White basin or evaporating dish
- Glass stirring rod
- Dropper bottle for methyl orange indicator solution
- N/50 sulphuric acid solution
- Methyl orange indicator or bromo-cresol green indicator solution (0.04% strength)
- Supply of A.R. grade sodium thiosulphate

Procedure:

1. Measure out 25mL of sample water into the evaporating basin.
2. Add one small crystal of sodium thiosulphate and stir until dissolved. Alternatively add 2 drops of thiosulphate solution (0.13% strength) to destroy any free chlorine.

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3. Add 2 drops of methyl orange or 6 drops of bromo-cresol green indicator solution, by means of a dropper bottle, and stir with a glass rod. Sample will turn a light yellow colour with methyl orange or from deep blue to apply green for bromo-cresol green.
4. Fill the burette to the zero mark with N/50 sulphuric acid.
5. Add the acid slowly to the basin, stirring gently with a glass rod until the colour changes to orange. (Do not continue adding acid until the colour changes to pink, stop at orange). Read the number of mL of acid that is required to reach this point and multiply by 40. This will give the bicarbonate alkalinity of the pool water expressed as "calcium carbonate in parts per million".

The reserve alkalinity in a pool system is not susceptible to rapid change as in the free chlorine reading or in most cases the pH. Once this reserve has been built up a test once per week should be sufficient. However, should there be any mal-operation of plant or sudden change in pH level a test for reserve alkalinity should be carried out immediately.

Tests for free and total chlorine and pH should be carried out each day, preferably early morning before the sunlight reaches the pools, and also in late afternoon before further addition of chemicals.

CYANURIC ACID TESTING

When conditioning with cyanuric acid or dosing with chlorinated cyanurates, it is important to know when the maximum stability to ultra violet light has been reached, also after continual usage, the cyanuric acid level should not be allowed to go over 100 ppm.

The test is a simple one and consists of:

- I. Mixing bottle.
- II. Special test reagent (buffered melamine solution).
- III. A reading column.

Notes:

- A. The temperature of the test mixture should be kept below 70°F.
- B. The reading of the test should not be made before one minute after mixing, nor should it be made 5 minutes after mixing.

Directions:

1. Fill the mixing bottle to the lower mark with pool water.
2. Add test reagent to the upper mark and mix.
3. Carefully add the mixture to the reading column until the black spot on the base disappears from sight when viewed down through the column (blocked from view by the cloudy nature of the solution).
4. The height of the liquid in the column is compared with the scale on the side of the column and reading made directly.

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