9 WATER TREATMENT & POOL CHEMISTRY

9.1 Introduction

It is essential for the Operator to know what quality of water is needed and why it is important. Swimming pool water should be free of bacteria (particularly the disease producing kinds), turbidity, algae, and colour and be low in scale forming chemicals.
Because bacteria is introduced into the pool water from many different sources, it is necessary to maintain constant vigilance to keep them under control.

Whilst turbidity will result in visually unpleasant water quality, it should be also accepted that highly turbid water is dangerous - a bather in trouble must be seen to be rescued. Bacteria may develop in sufficient amounts to cause cloudiness. These growths may result from heavy bathing loads and poor disinfectant practices.

Algae is controlled by the same disinfectants and or processes that are used to maintain the water free of bacteria. Colour may develop from one or more causes. Minerals such as iron, manganese and copper are frequently present in very low concentrations. Manganese may not be noticed until extra chlorine is added or until it is necessary to raise the pH.

Copper is relatively colourless until or unless ammonia is present. Urine contributes ammonia such that copper can frequently impart a light blue or green cast to the water. Iron is less common, but is present in some mains water supplies. Whilst minerals are not necessarily dangerous; the resultant colour can be objectionable.

Scale may make a beautiful pool so rough that it is dangerous to brush against the sides of the pool. The scale may be calcium carbonate (which precipitates from the pool water) or it may be silica which forms much more slowly. The same chemicals which, can form scale may precipitate in the water to make it cloudy; this can be common when a pool is filled with "hard" water.

In summary swimming pool water should be pleasing to the eyes of the onlookers and bathers. It should also be safe for the swimmer in being free from disease bacteria and irritating chemicals.

9.2 Disinfection

Without proper management swimming pools can be breading places for most of the water-borne infection and disease-producing organisms known to man. Modern swimming pools are less apt to contain many of these organisms which were transmitted by people years ago in less enlightened times. Sanitarians generally agree that bacterial standards set for pools must be observed in order to minimise cross infection. This is particularly important as modern pools are characterised by increasingly heavier bathing loads and higher operating temperatures. Some of the essential criteria for a good disinfecting agent are as follows:-

(a) that it have a measurable residual;
(b) that it be easy to apply; and,

(c) be readily available at a reasonable cost.

Other desirable characteristics are that it be compatible with other pool chemicals used; that it not impart an unpleasantnesses to the water; and that it not be detrimental to the bather's health in the normal use situation. In the main the swimming pool Industry has settled on the use of relatively few chemicals for this purpose. It is not particularly surprising that these chemicals are members of the halogen family when one considers the fact that chlorine and chlorine bearing compounds were the original materials used for general water treatment.

9.3 Water Chlorination

Chlorination of water can be achieved through the use of elemental chlorine, calcium, lithium or sodium hypochlorite, and or chlorinated isocyanurates. In each instance, disinfection is obtained through the formation of hypochlorous acid, a reaction product of any of the above chlorine forms and water.

Hypochlorous acid (HOCl) dissociates to the hypochlorite form (OCl-) according to the pH of the water. This relationship between pH and the form of chlorine exists in when dissolved in water can be seen in the following table:-

Table: Chlorine Efficiency at Different pH Levels

pH Level	% of Chlorine as OCI	% of Chlorine as HOCI
6.0	3.5 %	96.5 %
6.5	10 %	90 %
7.0	27.5 %	72.5 %
7.5	50 %	50 %
8.0	78.5 %	21.5 %
8.5	90 %	10 %

Since the HOCl form is considerably more effective than OCI (for killing bacteria and other microorganisms) the importance for proper pH control can be understood. For example, at a high pH the chlorine present in pool water is less active as a disinfecting agent.
Ammonia and other nitrogen containing compounds when present in pool water will react with chlorine to form chloramines. Chlorine in the combined or chloramine form is considerably less active in killing bacteria than the free or uncombined form.

Notwithstanding, it should be noted that chloramines or the combined form of chlorine will give a positive test when using a standard pool water test kit. To provide the desired free residual in a conventional chlorine pool and to avoid chlorine odours and eye irritation (from the presence of chloramines) superchlorination of the pool should be done at least weekly. Superchlorination, which consists of raising the chlorine residual to 5 to even 10 ppm, will also allow control of algae which may develop at normal chlorine residual levels. Whilst the need to superchlorinate a well managed pool is comparatively rare, bathers should not be allowed to use the pool if and when it is

necessary to raise chlorine levels above normal readings.

If it were necessary to de-chlorinate a conventional hypo pool, sodium thiosulphate (photographic hypo) would be used at the rate of 1 Kg per 50 m3 of pool water. Chlorine demand, or the amount of chlorine required, for any particular pool or spa cannot be predicted and must be determined by frequent tests of the water.

To reduce the extent of such manual testing, water chemistry controllers are provided to measure and proportional dose according to set point need. Chlorine is consumed when destroying bacteria and other organisms and when reacting with metal salts such as iron and manganese, if present. Sunlight, water temperature, bather load, and numerous contaminates carried into the pool water will effect the chlorine demand.

The residual sanitiser at Darwin City Waterfront is via electrolytic salt chlorinators. The electrolysis process generates Hypochlorous Acid which is injected into the pool on a needs basis.

9.4 Dry Chlorine

The plant has installed a dry feed chlorine backup system. Calcium Hypochlorite is stored in a hopper in the plantroom. Once signalled that Chlorine is required, a worm gear drops a specified amount of chlorine into the hopper. The venturi system then injects this into the water on a needs basis.

Calcium Hypochlorite (frequently referred to as dry chlorine) is commonly used as a chlorine source for treating swimming pools. The chemical is sold in granular form with an available chlorine concentration of approximately 65 %.

For every 100 m3 pool capacity, 0.3 kg of Calcium Hypochlorite would be required to introduce one milligram per litre. Chlorine tends to be decomposed by sunlight, heat and some metal contaminants. The decomposition rate or loss of strength rate is many times faster than for the dry chlorine chemicals. Therefore, it is necessary to keep it stored in its original plastic container in a cool place.

The same free alkali that forms the basis of calcium based chlorines tends to drive up pH of the water in the pool when it is introduced. This can necessitate the need for an increased acid (or Carbon Dioxide) requirement to maintain a balanced water with acceptable total alkalinity and in proper pH range. When Calcium Hypochlorite is diluted prior to use with hard water, or when it is introduced through feeding equipment into hard water, calcium deposits and precipitates may form. This necessitates the need to periodically pump a dilute solution of Muriatic acid through the equipment to remove the deposits. Calcium Hypochlorite solution is introduced to the pools via chemical solution venturi pumps that are controlled by Water Chemistry Controllers - see **Section 6.3** for details. Care should be taken not to spill Calcium Hypochlorite on pool fixtures, equipment or clothing, since it is corrosive and a strong bleach. Spills should be flushed immediately with large quantities of water.

9.5 Basic Water Chemistry

Here we are concerned with the need to keep the water balanced chemically with respect to pH, total alkalinity, water hardness, and to some extent, the total solids.
A chemical balance in the pool water is needed:

(a) To increase the effectiveness of the disinfectant used
(b) To prevent scale formation, blocking of the filter and cloudy water.
(c) To prevent at the other extreme, corrosion of plaster and metal fixtures and or extreme eye irritation.

9.6 pH versus Total Alkalinity

First we should differentiate between the pH and total alkalinity. The term pH can be defined technically as the negative log of the hydrogen ion concentration and is often referred to as just the hydrogen ion concentration of the water. Generally in the pool Industry, we speak of pH as relative acidity or relative alkalinity balance at a particular time. It is a term of relative intensity, expressed on a numerical scale of 0 to 14 as illustrated below.

Table : pH Scale

Strongly Acid						Neutral							Strongly Alkaline	
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Muriatic Acid has a pH of about 0. Pure water is 7 (neutral). Weak Lye solutions have a pH of about 13 - 14.

REMEMBER; *Chemicals that are acid..... lower pH.*
Chemicals that are alkaline..... raise pH.

In the treatment of swimming pool waters we normally are concerned with the pH range of 6.8 to 8.4 as generally illustrated below.

Table: Common pH Range

6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.4
Add soda ash or sodium bicarbonate	Marginal		Ideal		Marginal		Add acid	

The pH changes abruptly or gradually, it may go up or down from time to time, depending not just upon what chemicals are added to the water but to a very great extent it is dependant upon the total alkalinity of the water. Now the total alkalinity on the other hand, is the total amount of certain alkaline chemicals in the water. These alkaline chemicals continue to affect the stability and changes in pH. The total alkalinity of the water, more or less holds the strings that regulate pH. We

could use an analogy here of a flashlight battery. The voltage of a car battery can be compared with pH and the capacity of the battery compared to the total alkalinity. For example, a certain voltage is required to light up a flashlight bulb, but just how long it will keep will depend on the capacity of the battery.

Total alkalinity tells you how much; pH more or less tells you the degree or intensity at a particular time. At normal swimming pool pH levels, the total alkalinity is usually a measure of the amount of bicarbonates in the water. At high pH you would have some carbonates such as soda ash and hydroxides (such as lye) that may be measured as part of the total alkalinity. However, once the pH is adjusted to below 8.4, these two will no longer be present. Usually a pH of 7.4 - 7.6 is recommended for pool water in order to increase the effectiveness of the chlorine residual present.

At low pH a greater percentage of the chlorine residual will be in the form of the considerably more active hypochlorous acid form and less in the less active hypochlorite ion form. In order to maintain pH effectively in the 7.4 - 7.6 range, it has been found that total alkalinity should be balanced in the range of 80 - 100 ppm. This is a good preventative maintenance.

With ideal initial water balance you will be able to resist sudden undesirable changes in the condition of the water due to influences such as the addition of chemicals, addition of make-up water etc. It is highly desirable to adjust the total alkalinity of the water to the 80 - 100 ppm range as soon as possible.

NOTE : THE FOLLOWING SECTIONS 9.7, 9.8, 9.9 DISCUSS WATER PARAMETERS FOR PH AND ALKALINITY LEVELS. ON COMMISSIONING, MAINS WATER TESTED AT THE DARWIN CITY WATERFRONT WAS FOUND TO BE GENERALLY STABLE WITH A PH LEVEL OF 7.5 AND AN ALKALINITY LEVEL OF 80PPM.

9.7 Low Total Alkalinity

In many areas of the country the total alkalinity of the water source is quite low. You might say that the pH is more or less under-stabilized. In this type of area:

(a) The pH changes abruptly and frequently with small additions of chemicals.
(b) The water tends to be more corrosive to plaster and metal fittings with this low total alkalinity. This often results in stains on the plaster or rough finish to the plaster.
(c) Low total alkalinity often results in low pH and eye irritation.
(d) Often there is difficulty with the use of an alum floc for sand and gravel filters.

If the total alkalinity is low, it can be adjusted merely by the addition of sodium bicarbonate to the water. This adjustment with sodium bicarbonate can be done at least once, since this is a mild type of chemical.

To raise total alkalinity by 50 ppm, add 9 Kgs of sodium bicarbonate for every 100 m3 of water volume. Whilst soda ash (sodium carbonate) also will also increase the alkalinity to some extent, it tends to increase the pH too much to be practical. It should be remembered that when you want to

raise the pH and not the total alkalinity use soda ash, but when you need to adjust total alkalinity use sodium bicarbonate.

9.8 High pH, Low Total Alkalinity Water

In still other areas around the Country, we find water with a high pH, but a low total alkalinity. Sometimes in such areas pH is greater than 9 - perhaps a high as 10.
When acid is added to this water to adjust the pH, it is found that often the pH will drop abruptly to below 7, even with only small additions of acid. As a result, plaster may be etched and or the metal fixtures in the system may be corroded.

These dissolved metals eventually stain the pool - green, blue or gray to almost black copper stains or yellowish brown to brown iron stains. The way to avoid this problem would be very simply to first test for total alkalinity and adjust it to the desirable 80 to 100 ppm range with sodium bicarbonate. Then, acid can be added to adjust the pH to the proper range. You will actually find that when the sodium bicarbonate is added to this high pH water there actually will be some decrease in pH since the sodium bicarbonate has a pH lower than that of fresh water.

9.9 High Total Alkalinity Water

In still other areas of the country we find that there is an excessive total alkalinity in the water. A high level as high as 300 - 400 ppm may be found. In such cases the pH may be considered to be over-stabilized so that it tends to remain at a level around 8.4. When acid is added to this type of water to drop the pH to 7.4 we find that after a very short period of time the pH will bounce back up to about 8.2- 8.4. This process must be repeated many times in order to eventually "stabilize" the pH at the more desirable range of approximately 8.4.

What happens is that every time acid is added, a small amount of the total alkalinity is destroyed or neutralized, carbon dioxide gas is formed, and in the process the pH is lowered to the 7.4 range. However, since there is still an excessive total alkalinity remaining, the pH will bounce back up to approximately 8.4. After a period of time when enough of the excess alkalinity has been destroyed to reduce the level to around 100 ppm, it is found that the pH does not bounce up nearly as rapidly or as high as it did when there was a large excess of total alkalinity present.

Also less acid will be required for each pH adjustment. That is, it takes less acid to go from, say, a pH of 8.0 to a pH of 7.4 as the total alkalinity is reduced.

It should be pointed out that even in areas of high total alkalinity you often have tap water with a pH of 7.2 - 7.4. This is of course, due to the fact that the supply water was treated and delivered from a treatment plant. When such water is added to the swimming pool, the pH of the water will very shortly rise to the 8.4 level (since the high carbon dioxide level of the water is lost to the air rather quickly) and since the total alkalinity is high, it will take many additions of acid before the pH will tend to remain at the 7.4 - 7.6 level.

Test for T.A. should be run approximately once a week until the proper range of 80 -100 ppm has been achieved. Then tests are run approximately once a month in order to determine if the desired

range is being maintained. It should be remembered the total alkalinity does not change abruptly as does pH but rather it will gradually, over a period of time, tend to rise due to the addition of refill water with a high total alkalinity count and decrease due to the additions of refill water with a low total alkalinity count.

There are a number of areas in the country where water systems with low total alkalinity are located very close to water systems with high total alkalinity. In these areas the swimming pool operators, pool service men and dealers can run into many problems unless they understand total alkalinity and test for it regularly. For example, in the area with the high total alkalinity it may take a ten litres of acid to drop the ph of the pool water from 8.0 to approximately the 7.4 - 7.6 range.

If total alkalinity is low, however, a litre of acid may be all that is needed to get the same effect. If more than this litre of acid is added the pH often will be dropped to the acid side and as a result there is corrosion of the metal pipes and the fixtures in the pool, etching of the plaster and the danger of eye irritation of the swimmers. These problems can be avoided very simply by testing the pool water for total alkalinity and adjusting to a desired range.

The total alkalinity test also is a very valuable tool for trouble shooting and solving of existing swimming pool problems. For example, if you analyse pool water for just pH it is often difficult to diagnose a pool problem, since the pH changes frequently and at the time you run the test is usually different from what it was at the time the problem was caused.

Total alkalinity, on the other hand, changes only gradually so that comparing the total alkalinity of the pool water with the total alkalinity of the pool water of an earlier pool water sample or a tap water sample you can often determine what happened to the pool since it was filled or last checked.

You can determine, for example, if excessive amounts of acid have been used in the pool to lower the total alkalinity to an undesirable low level. You also can determine if insufficient acid has been used to maintain proper pH, so that total alkalinity has either gone up with time or has not been reduced from what was initially an undesirable high level.

Some Pool Operators run into difficulty because they do not realise that although relatively large amounts of acid are needed fairly frequently with a pool that has been recently filled with high total alkalinity water, that after a period of time - as the alkalinity has been reduced less acid is needed with each adjustment and acid is needed less often. Such Operators fail to gradually reduce the amount and frequency of acid additions so that low pH, corrosion and eye irritation result.

9.10 Water Hardness

Water hardness is another property of swimming pool water that should be taken into consideration. Water hardness is the measure chiefly of the calcium and magnesium in the water. It tells how much there is present. Although the magnesium is of less concern, the calcium content of the water is very important, because it is the calcium content that combines with some of the total alkalinity to form scale.

You should never soften pool water to zero calcium hardness because then the water will be more corrosive to the plaster finish of a pool and to the metal pipes and fixtures. A water which has a high hardness content should be softened to approximately five grains minimum. If the water hardness is too low a chemical such as calcium chloride can be added to increase the hardness level. It should be kept in mind that this chemical is weakly acid and will tend to lower pH.

To increase calcium hardness by 10 ppm, add 15 grams of Calcium Chloride per 1m3 of pool water.

The test for total hardness is very simple and only takes a few minutes to run. Most test kits use a dye that changes color. Please follow the directions on your test kit as tests differ depending upon the test kit manufacturer.

In some cases you will find that the dye will change to a blue, go back to purple and then go back to blue as you add more drops of the test solution. This is an indication that there are certain metals ion in the pool which are interfering with the test. If this happens the test will not be valid unless you add a certain chemical called an inhibitor. Another caution which should be pointed out is the fact that occasionally some of the chemical solutions which are used will crystalize or settle out to some degree. If this happens the solutions should be discarded and fresh solution purchased. Otherwise, results may be considerably in error and have no value.

The test for total hardness measures both calcium and magnesium. Since only the calcium level in the water is really to concern the value for total hardness is usually multiplied by a factor such as 0.7 to give an average value for calcium in the water.
Since the calcium content of the water usually increases slowly due to evaporation of pool water and subsequent additions of raw water, the tests for total hardness usually run only about once or twice a year.

9.11 Water Balance Index

By knowing the calcium content of the water, the total alkalinity, pH and temperature of the water you can readily determine an overall water balance called the Langlier index. This Langlier index is an equation which totals up factors such as calcium hardness, total alkalinity, pH and temperature and only to a minor extent the total solids present in the water. This will tell you if the water is going to be corrosive to the tiles and grout of the pool or whether the water is saturated in respect to calcium and will deposit a calcium scale either on the tiles, in the filter or in the coils of the heater.

9.12 The Enigma of Total Dissolved Solids

Have you ever worked with a pool that just didn’t seem to respond to any treatment? One day the chlorine residual was high, the next day it was low without any apparent reason. Have you ever had a good free available chlorine residual but found that algae was growing and slime or mould had started to grow? Did you ever add large quantities of acid or soda ash without affecting a substantial change in pH?

Or how about coloured or murky water, when the filter was operating perfectly and superchlorination was regularly practised? How did you handle that one? Did you find scale in a pool, although everything was in its proper range and Langlier's formulae said it was in good balance? Or how about peculiar colours and stains forming on the surfaces of the pool? Eyes burn, but free chlorine and pH were right?

During this time you used the best test kits available and you replaced all the old reagents with fresh material. You tested for everything you could think of and bought every conceivable wonder cure that you could think of. Still, the problems persisted.

Then you checked the stabiliser level. Good heavens....it's 105 ppm or maybe even 200ppm of cyanuric acid and then you say, "now I've found the problem". So you drain the pool, or at least remove part of the water and surprise, surprise, all the problems magically disappeared. Cyanuric acid, you conclude is the culprit - the source of all your problems. The pool is "overstabilzed" because the algae and bacteria are growing, there's no more free chlorine, the pH is erratic, your pool ladder is rusting, and the tiles are falling off the wall. But, and this is a big "but", if the cyanuric level has increased in the pool, so too has the total dissolved solids. Although total dissolved solids is not a new concept, it is rarely managed and controlled in a professional manner.

Anyway, where does TDS come from? The mains water that is used to fill the pool, usually contains hardness such as calcium and alkalinity-like carbonates, as well as dissolved organic and inorganic materials such as sulphate or silicate. In addition the salts from the residual of active chlorine that has been used up to form chloride, swimmer sweat, urine waste, unsuperchlorinated solids such as creatine, soluble hair sprays and body lotions add to the total. Wait! There is still more, in an outdoor pool, the wind blows in leaves and grass clippings, as well as material contained in rain that has passed through polluted air. Once in the pool, all this stuff becomes more and more concentrated.

These solids can be further increased by the effects of evaporation. This could double or even triple the solids content with the pool in a single year.

Filter backwashing is often the only "management" tool that is ever used to control the build-up of a pool's total dissolved solids. But new technology and the ever increasing cost of raw water has resulted in the development of modern filters (both sand and media type) that provide longer filter cycles and have shorter backwash times. Such plants do not necessarily consume enough pool wash water to effectively control TDS.

Some European standards legislated that 30 litres of pool water be dumped for every bather that uses the pool. Whilst this may have the desired effect, it does not provide a very scientific or logical approach that can be sensibly managed and controlled by the Pool Operator.

TDS should be prevented from accumulating within a pool by following a proper maintenance program that includes periodic disposal of some water from the pool. Rather than being based on myths, old wives tales and generic rules of thumb, such a program should be based on actual measured values, albeit TDS or more convenient conductivity. It is important to realise that pool make up water will have a TDS reading (albeit substantially lower than what can found in most

swimming pools) and that proper controls are fundamental required. You wouldn't necessarily add chlorine according to the number of bathers in the pool. You would naturally test the water for free chlorine and add an appropriate dose. So to for TDS. It should be measured and controlled, before blindly dumping valuable pool water.

What possible benefits can be obtained by monitoring and controlling TDS. We already have enough things to worry about without adding yet another constraint! The answers simple; from a disaffection point of view, the steriliser that you are currently using will be infinitely more effective if the TDS readings are properly managed. In simple terms, imagine that you are at one end of a pool and you are trying to reach the other end. Nothing is in the water but you.

Pretty simple, isn't it? Now some other swimmers are added, which obviously get in your way. The greater the number of swimmers the more difficult it will be for you to get to the other end. Imagine that you are a chlorine molecule and the spot on the other end of the pool is bacteria; and the swimmers are dissolved solids. This may help to understand why a concentration of TDS can interfere with the bacteriocidal activity of chlorine; simply because of the crowding effect. Whilst this is a vast oversimplification, pool water chemistry can be quite complex and it is usually not, just a simple one on one relationships.

Given the ever increasing cost of incoming mains water and the outgoing cost (and all the regulations) that are associated with the discharge of pool water, numerous benefits can be obtained by monitoring and managing the progressive build-up of Total Dissolved Solids. Possibly the largest single benefit, is the potential for the beneficial re-use of wash water for irrigation purposes. Given that this re-use is entirely dependant upon the salinity of the waste water (and that it is subject to approval by the Environmental Protection Authority) the control of TDS can open up many opportunities. Without effective control of TDS, you can forget any chance of using pool water for irrigation.

9.13 General Notes and Comments

On no account must pool chemicals be mixed with each other in the dry state or in solution, except in the swimming pool itself. As mild as it may seem, Sodium or calcium Hypochlorite is an oxidizing compound and as such is incompatible with quaternary ammonia type algaecides any other organic substances such as wood, some packaging materials etc.,

Important Note:-

Disinfectants containing Phenols and or Ammonia should not be used at any stage to clean pool surrounds or fixtures.