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Controlling Chloramines with Proper Pool Water Chemistry

THE IMPORTANCE OF POOL WATER CHEMISTRY

An indoor swimming pool can be the source of income, family fun and healthy exercise. When the chemistry is properly balanced, the pool water will maintain a sparklingly clear appearance, remain free of odor and protect bathers from bacteria and germs. Chlorine, the primary pool treatment process, kills the germs and destroys the harmful organic contaminants introduced into the water by bathers.

In addition to the health concerns of the occupants, improperly balanced pool water chemistry can attack the indoor pool's HVAC system and the building's structural components. Airborne combined chlorine compounds along with condensate form a liquid that is very corrosive to ferrous metals and stainless steel due to chloride content and acidity. In addition, combined chlorine compounds cause eye irritation and the so called "chlorine odor" most noted by pool occupants. Combined chlorine compounds have a foul, irritating odor while free chlorine in water, in normal concentration, has no discernible odor.

A dehumidification system will remove the excess moisture from the pool enclosure but it will not eliminate the harmful chlorine compounds that cause the chlorine odor and metal corrosion. Additional ventilation can be used to dilute the odor, but the additional cost to condition the air makes it prohibitive. Only a comprehensive pool water chemistry program and continuous monitoring will keep your pool crystal clear and odor free.

HOW CHLORINE WORKS

Chlorine acts as a disinfectant that destroys harmful organisms such as bacteria, algae, fungi, viruses, etc. It also eliminates impurities that are not removed by filtration. These two processes are called sanitation and oxidation. This organic contamination must be destroyed by chlorination to avoid pungent, chlorine-like odors as well as eye and mucous membrane irritation in the pool area. Chlorine is introduced into the pool water by injection through the main water line supplying the pool. The chlorine immediately converts to its bacterial and virus killing form called free chlorine.

Free chlorine has no significant vapor pressure, meaning it cannot evaporate from the water in which it dissolves and carries out its disinfecting. Free chlorine consumption takes place as it reacts with organic matter, converting it to a volatile compound called combined chlorines or chloramines. As pool usage increases, more organic matter is introduced into the pool water and more of the free chlorine is converted to chloramines. The swimming pool's water treatment system automatically replenishes the free chlorine through the pool's automated chlorinator to maintain a recommended free chlorine level, which is typically in the 1.0 to 3.0 ppm range.

UNBALANCED CHLORINE

If left unchecked, the chloramine concentration will grow to unacceptable levels with potentially harmful effects. The Pool-Spa Operator's Handbook* recommends that the chloramine levels not exceed 0.2 ppm. If the level is above 0.2 ppm, the corrosion process caused by the chloramines in the air is accelerated. You can detect a high chloramine level when you smell a chlorine odor within the pool enclosure. It is the chloramines evaporating from the pool in large quantities that gives off the chlorine smell, and not that of the free chlorine. One way to accurately measure the chloramine level in your pool is to use a colorimeter, which shows the quantity of free and total chlorine in the water. Chloramine concentration is the difference between the total chlorine and free chlorine, as seen in the following formula:

Combined Chlorines= Total Chlorine — Free Chlorine
1.0ppm (chloramine) = 2.5ppm (total chlorine) — 1.5ppm (free chlorine)

*Pool-Spa Operator's Handbook by the National Swimming Pool Foundation, 10803 Gulfdale Suite 300, San Antonio, TX 78216

THE DANGERS OF HIGH COMBINED CHLORINES

The chloramines in the air can cause significant damage to anything metallic when condensed on metallic surfaces. These metal surfaces can be windows, doors and frames, ductwork and HVAC equipment.

The chloramines will condense along with moisture from the pool on cold surfaces forming a corrosive chloride-rich solution. The higher the concentration of chloramines in the air, the more corrosive the condensate will be. Such chloride solutions form a harmful substance that will corrode metals, including stainless steel where it forms a particularly serious stress corrosion cracking problem.

THE ART OF SUPERCHLORINATION

Superchlorination Brings Chemistry Back Into Balance

Ideally, the chloramine level in the pool should be kept below 0.2 ppm. This goal requires frequent pool water testing each day as the chemistry can change dramatically due to the variability in bather load. When the chloramine level exceeds 0.2 ppm, additional measures must be performed. The most common method to reducing chloramines is to "shock" the pool using superchlorination.

Superchlorination is raising the free chlorine level in the pool to a sufficient level to oxidize ("burn") out all the chloramines. According to the latest recommendation in the Certified Pool Operator (CPO) Handbook, a quantity of ten (10) times the measured combined chlorine level as the amount of free chlorine required to fully react all chloramines while leaving some free chlorine residual in the pool. As an example, if testing gives a combined chlorine level of 0.5ppm, chlorine compound is added to the pool to increase the free chlorine level to 5ppm. If 2ppm of free chlorine is already present, the amount added is the difference or 3ppm.

A successful shock treatment can depend on the accuracy of the water testing used. DPD tests determine combined chlorine indirectly by measuring both the total and free chlorine. These tests are typically accurate within +/- 0.2 ppm. However, it is important to remember that inaccuracies and false readings may occur if the total chlorine exceeds 5ppm.

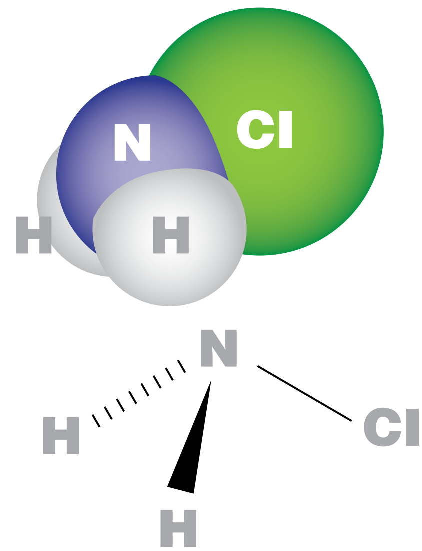
For help determining shock concentrations, the Pool-Spa Operators Handbook includes a chart to measure the quantity of chlorine compound required to acquire the necessary free chlorine concentration. This chart takes into account pool sizing (in gallons) and covers several common chlorine compounds used for shock treatments. While there is no magical concentration, the right measurement will optimize the shocking process.

Understanding Breakpoint Chlorination

In order to understand how breakpoint chlorination works, it is necessary to understand why chloramines accumulate to unhealthy levels. Unfortunately, chlorine's oxidation of nitrogenous wastes from bathers does not occur in a single step. The initial reaction forms incomplete oxidation products that are generally referred to as monochloramines. While monochloramines form rapidly, the secondary reactions forming dichloramines and trichloramines occur much slower. Over time, this results in a build-up of monochloramines assuming a constant addition of bather load.

At the higher level of free chlorine during superchlorination, these secondary reactions occur more frequently and at a quicker rate. Superchlorination allows the pool to return to 0 ppm combined chlorine much quicker. Keeping an elevated free chlorine level (above 3ppm) during normal operation will also oxidize wastes quicker. However, this approach has other complications. Bather wastes become more volatile as they become more chlorinated. As these reactions are sped up at higher chlorine levels, the off gassing of these compounds from the pool worsens at higher bather loads. Additionally, elevated levels of free chlorine could increase corrosion rates of metal surfaces both in the pool and in the building due to the extra chloramines in the air.

Because of this off gassing, good ventilation is recommended during shock treatment to remove these gaseous chloramines. If the ventilation system does not provide regular airflow at the water surface, it may be worthwhile to use fans during the shocking process to sweep away the blanket of gas that forms. This extra ventilation has been shown to improve results of shock treatment. Another useful tactic during shocking is to employ a 100% outside air purge cycle into the HVAC's control system. The purpose of the purge is to replace the air in the natatorium with fresh non-chloraminated air.



NH_2Cl - Monochloramine

Managing Free Chlorine

It is generally recommended that free chlorine quantities not exceed 10ppm for regular shock treatments. While the higher quantities will increase the rate of chloramine decomposition, the excess chlorine creates a highly corrosive condition over the duration of the treatment that can damage pool equipment and surfaces. In situations where combined chlorine exceeds 1ppm, the facility should prepare for a longer down time or employ supplemental measures to aid in the treatment process.

After shocking, the free chlorine level must be lowered to an acceptable level per local health codes. While this will occur eventually, an additive can be applied to the water to achieve this result. Shock treatment is not always successful. Some more complex organic chloramines may not volatize from the water nor oxidize fully during shocking due to the much lower reaction rates with chlorine. In this case, a non-chlorine shock such as Potassium Monopersulfate (MPS) may be more effective.

Periodic Shocking As Routine Maintenance

At a minimum, pool shocking should be done once per month as part of regular pool maintenance. This treatment may coincide with filter maintenance to make sure that the pool is properly maintaining a healthy pool environment. If shock treatments are required more than once per week, supplemental methods of chloramine reduction should be used such as supplementing shock treatments with MPS, adding a medium pressure UV, adding an ozone system, or diluting the pool with fresh water.

It has been reported that using a fan to sweep off the blanket of nitrogen gas that forms over the pool's surface during shocking has assisted in the shocking process. Another tactic used during the shocking process has been to incorporate a 100% outside air purge cycle into the HVAC's control system. The purpose of the purge cycle is to remove airborne gas by-products that may interfere with the shocking process.

Prevention Lowers Contamination Risk

The most effective treatment for reducing chloramines is prevention (ie. reducing the precursors to chloramines by cutting down on bather wastes). Promoting pre-swim showers, pre-swim bathroom use, don't swim sick, swimmer education brochures, and similar measures may help in this aspect. Also, instructing pool operators on how to run the filter properly and the proper use of non-chlorine shock are additional measures to prevent high levels of chloramines from forming.

Supplemental pool treatment is another way to control chloramines, especially Ozone and medium pressure UV. While free chlorine is still required, these supplemental systems are proven to regularly remove intermediate oxidation products from the water. When properly sized and maintained, these systems reduce or eliminate the need for excess shocking. In fact, future public health codes may require the use of such systems in commercial pools.

The last resort to troublesome pool chemistry is through dilution. The pool is partially drained and refilled with clean, treated fill water to reduce the chloramines to a manageable level. Dilution could also refer to the ventilation in the space if airflow is not properly designed for the pool. However, the problem with pool chemistry is derived from the wastes and chemicals in the pool.

UV LIGHT - SUPPLEMENTARY SWIMMING POOL TREATMENT

Maintaining Good Pool Water Chemistry

Swimming pool disinfection is necessary to create a healthy and safe environment for indoor pool recreation. The most common swimming pool treatments continue to revolve around chlorine. When most chlorine treatments are first added to pool water, they produce free chlorine as hypochlorous acid and hypochlorite ion residuals.

These chemicals react very quickly to both oxidize and disinfect the contaminants introduced by both swimmers and the environment. This residual mechanism is advantageous due to the continuous addition of debris and germs by patrons requiring immediate treatment. Due to its relative low cost and high effectiveness in this role, chlorine continues to be used prominently around the world.

Unfortunately, chlorine chemistry is often difficult to manage and can have undesirable effects on both swimmers and the environment. The addition of chlorine to pool water typically requires additional chemicals to maintain a comfortable pH around 7.4-7.6. Therefore, not only are more chemicals entering the pool but additional costs for the chemicals, storage, and maintenance are added. Improper management of pH can result in bleached swimming suits, skin and eye irritation, and pitting of pool surfaces.

Recent research has also discovered several microbes that are particularly resistant to chlorine disinfection. Two of these protozoan pathogens are Cryptosporidium and Giardia. Even with good maintenance of chlorine residual, cryptosporidium may remain active in pool water for more than a week. If an outbreak is expected, pools need to be closed for a day or two with excess levels of chlorine to kill off the germs. Prevention is often the best cure by scheduling periodic superchlorination of the pool. Obviously, this adds considerable cost for chemicals, maintenance, and pool down-time.

Managing the quantity of free chlorine residual in the pool is also difficult as chlorine is quickly depleted by reactions with contaminants in the pool. When chlorine reacts with organic compounds, it may only partially oxidize the compounds resulting in intermediate products known as disinfection by-products (DBPs). A very strong “chlorine” smell is caused by DBPs and may be indicative of poor pool water chemistry. Chloramines, the most common DBPs, are directly attributable to swimmers complaints of skin irritation and eye burn. The long term effect of chloramines can also have devastating effects to dehumidifying equipment and metallic supports as condensate laden with chloramines are extremely corrosive. There is a large demand for alternative disinfection methods to replace chlorine or at least minimize its deleterious effects, and UV treatment is a possible solution to this issue.

How UV Light is Generated, Delivered and Measured

UV light for disinfection involves generating UV light with the desired germicidal properties and delivering that light to the pathogens in the water. It is generated by applying a voltage through a gas mixture, resulting in a release of photons at a wavelength that is predetermined from the components of the gas mixture and the temperature and pressure of the vessel.

Most UV lamps use mercury as the primary component in the gas mixture although xenon is also known to release germicidal light. In order to understand how UV works, the method of how the light propagates from the lamp to the water needs to be discussed.

There are several obstacles in the vessel that the UV light contacts including the quartz sleeves, the pool water, and the contaminants in the water. When UV light hits an obstacle, it reacts by reflecting, refracting, scattering or absorption. Absorption involves the transformation of the light to other forms of energy. The amount of absorbance of a material depends on the materials composition. For example, a DNA molecule absorbs UV light.

One of these factors for UV light delivery is the measurement of the absorbance of a material. For water treatment applications, the absorbance of light is used to determine the amount light passing through the water and reaching target organisms.

Pool water flow rate through the UV reactor is a function of the pool size and required turnover rate of the pool water and is thus a determining factor in the residence time of the reactor. This residence time is defined as the time that a particle spends in the reactor while exposed to UV light. Therefore, it can be reasoned that a faster flow results in a decreased dose.

Another factor, UV intensity, is a fundamental property of the UV light being produced. Finally, UV dose is found by multiplying the UV intensity, the residence time in the reactor, and the UV transmittance of the water. This calculation provides units for UV dose.

UV Disinfection Equipment

UV reactors are designed for effective disinfection of the pool water. Equipment components of the typical UV system consist of the UV reactor, UV lamps, ballasts, lamp sleeves, cleaning systems, and UV sensors. An illustration of an LP system with labeled components is given in Figure 1 for reference.

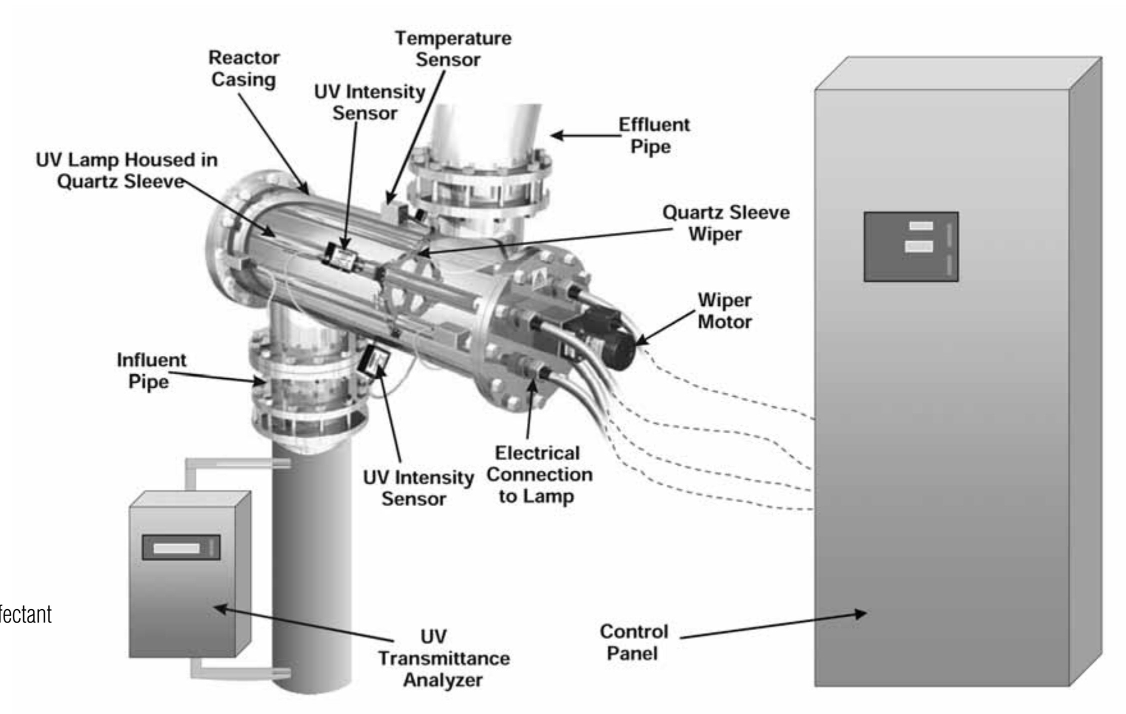


Fig. 1 — Example of UV disinfectant equipment (EPA Guide 2006)

UV Reactor

The UV reactor for swimming pool disinfection is classified as closed channel. Typically composed of 316 stainless steel, the reactor is designed to provide efficient and cost-effective dose delivery of the UV light. The flow through the chamber is turbulent to promote mixing while minimizing head loss. The lamp location, baffles, and inlet/outlet locations all affect mixing. Lamps are oriented to optimize dose delivery.

UV Lamps

There are several types of UV lamps but the most common are low-pressure (LP), low-pressure high-output (LPHO), and medium-pressure (MP). With use, UV lamps degrade over time resulting in a decreased output and thus lower UV dose. Fouling of the interior envelope is typical with electrode degradation. Exterior fouling from the water can also increase aging.

Lamp Sleeves

Lamp sleeves contain UV lamps to maintain the lamp's operating temperatures and prevent lamp breakage. Typically composed of a tube of quartz, lamp sleeves must be designed to withstand high temperatures, pressures, and ozone.

Cleaning Systems

There are three types of cleaning systems employed by manufacturers depending on the application. Manual chemical cleaning involves turning off the system, removing the lamps, and cleaning with a chemical solution of citric acid, phosphoric acid, or other manufacturer provided approved cleaning solution. Lamp sleeves can also be cleaned in place without removal by filling the chamber with the cleaning solution and allowing it to dissolve the fouling. This process typically takes about 3 hours from shutdown to startup. Manual cleaning varies in frequency from monthly to yearly depending on water quality and fouling frequency.

Alternatively, motor or magnetic powered wiper systems are used to clean the sleeves in place during operation. Mechanical wipers typically consist of stainless steel brush collars or teflon rings that move along the sleeve. Some wipers also contain cleaning solution to physically scrape and chemically dissolve the fouling during its sweep of the sleeve. MP lamps typically require wipers due to the increased temperatures causing more rapid fouling of the sleeves.

Sensors

UV sensors are used to monitor the intensity of the UV lamps at a certain point in the reactor. When used with flow rate sensors and possibly UVT sensors, it can determine the dose delivery of the system. This measurement correlates to changes due to aging, fouling, and power setting.

Measuring UVT is also important in determining dose delivery and so UVT analyzers are often employed. If UVT analyzers are not used, other sensors for determining water quality may be used. Several manufacturers use the measurement of UVT to vary the lamp output so that an appropriate cost-effective dose is being delivered.

UV System Sizing

Sizing of the UV system is most important for effective and efficient water treatment. A system that is too large will consume too much energy and burn free chlorine at a faster rate whereas a system that is too small will deliver insufficient UV dosage to treat the water. Most UV systems are designed to deliver a minimum 60mJ/cm2 as the UV design dosage required.

In order to accomplish this dosage, two primary components used to size a UV system are the UV transmittance (UVT) of the water and the flow rate. This flow rate is typically characterized as the design peak or average flow rate depending on the demand to turnover the water. While design peak flow rate depends on the peak bather load of the pool, a quick calculation for average flow rate can be done. Average flow rate is calculated by dividing the volume of the pool (in gallons) by the desired turnover rate of the water (typically 4 hours to accomplish six turnovers per day). Additional conversions may be needed to convert flow rate in gallons per hour to other units.

UV FOR WATER TREATMENT

Disinfection

UV light for water treatment has multiple purposes with the most typical application used for disinfection. UV light disinfection occurs by damaging the nucleic acid (RNA and/or DNA) of microbes. This action prevents them from replicating thereby eliminating their ability to infecting hosts. UV light disinfection is deemed especially effective in deactivating chlorine resistant microbes. Two especially chlorine resistant protozoan pathogens include Cryptosporidium and Giardia.

Chloramine Reduction

Another application of UV light is the reduction in chloramines. The phenomenon of photolysis is generally thought to be responsible. Photolysis is a chemical reaction in which a chemical compound is broken down by photons. UV lamps also degrade free chlorine residual depending on the dose delivered. With increasing UV dose, increasing amounts of residual are removed from the water.

Cost Recovery

The first costs of UV systems are high, but a return on investment can be realized in switching from chlorine to a UV system. The average pay back period is within three years of startup of the UV system. This cost is recovered in the following ways: reduced chemical costs, less makeup water, less out-side air heating costs.

Since UV systems clean the water and reduce the incidence of chloramines in the air, the demand for fresh outside air may be reduced. While ASHRAE 62-10 has a minimum amount of fresh air that is required for the space, excess fresh air is often needed for pools with chloramine problems in an attempt to dilute the air. The costs associated with conditioning this outside air are large. By using a medium pressure UV system, these costs can be reduced.

CONCLUSION

While UV systems can solve many of the issues with chlorine treatment, UV cannot replace chlorine entirely. An active residual disinfectant is still needed to combat the continuous addition of germs from bathers. Furthermore, most state regulations place this minimum chlorine residual at 1ppm or 1mg/L. However, UV, especially medium pressure UV, greatly alleviates the pool owner from the complexity of chlorine chemistry management by reducing corrosive chloramines and treating chlorine-resistant pathogens.

In fact, several studies have shown that a significant reduction in chlorine use and make-up water can be realized through the use of UV. Choosing the appropriate disinfection goals while designing the UV system is especially important in this regard. While the UV system is not maintenance free, the ease of installation and minimal maintenance are positive aspects compared to other more complicated systems and chlorine chemistry management in general. In addition to its efficiency in disinfection, these aspects make it a viable supplementary disinfection treatment for swimming pools.

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