UV for pools - Chloramines, Crypto, and Confusion

UV technology has become popular as a way to improve air and water quality within commercial aquatic venues. The benefits of UV are twofold; controlling chloramines (primarily a concern for indoor facilities) and, for all aquatic facilities, disinfecting pathogens which are resistant to chlorine treatment. Chlorine resistant pathogens are responsible for two-thirds of the Recreational Water Illness (RWI) outbreaks reported to the CDC. There are critical concerns in regards to water quality and equipment options to assure consistent performance of a UV system. This article will detail how UV works and review important distinctions in regards to lamp and equipment options. It will also review some misconceptions sometimes seen in the market.

Chloramine Control

For the uninitiated, chloramines are a by-product of chlorine disinfection. They are responsible for the odor, irritation, and enhanced corrosion associated with indoor aquatic facilities. UV systems are designed to expose all of the filtered water to UV "C" energy and naturally breakdown chloramines. Continually reducing chloramines in the filtered water, results in lower concentrations in the pool water and significantly improved air quality. Chloramines in the air increase the rate of corrosion to exposed metallic components. Air handler and dehumidification manufacturers are aware that UV can help reduce the rate of corrosion to their equipment and extend the life of critical components. Indoor competitive swim teams report a significant reduction in the incidence of "athletic asthma" after UV is added. The standard procedure of chemically "shocking" the pool to reduce chloramines is often eliminated after adding UV; although shocking is still necessary following a fecal accident.

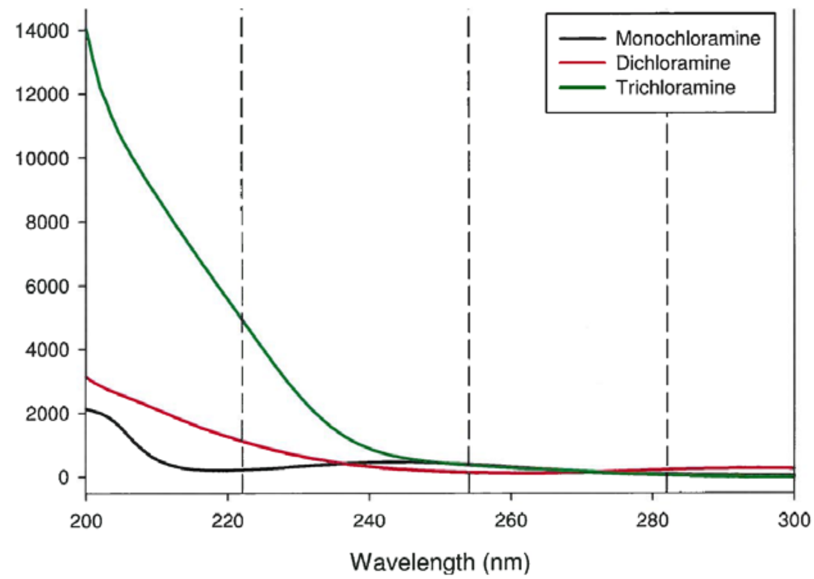
Disinfection

An increasing number of state health codes are relying on the germicidal properties of UV to address Cryptosporidium. "Crypto" is responsible for 2/3rds of the waterborne outbreaks reported to the CDC. These health codes require "validated" secondary disinfection equipment. Validation will be discussed later in this article.

UV "C" Energy

UV energy in the "C" range is defined between 200 and 280 nanometers (nm). We are more familiar with UVA and UVB energy for suntans & sunburns. UVC energy provides two benefits for commercial aquatics; disinfection and chloramine destruction. UV disinfects by attacking the DNA and RNA of bacteria, viruses, and protozoan cysts like Crypto. The ideal range for disinfection peaks between 260-265nm. The ideal range for the destruction of chloramines occurs within 200nm-240nm (Fig. 1)

Figure 1 UVC energy absorption of mono, di, and trichloramines.



There are two types of UV lamps used for industrial/commercial/municipal water treatment; low pressure and medium pressure lamps. The term "pressure" refers to the internal gas pressure of the lamp itself. Low pressure lamps use nominal energy to obtain exactly one wavelength within the UVC range; 254nm. 254nm is close to the peak germicidal (again, 260-265nm) and is considered efficient from an electrical standpoint for disinfecting water. Medium pressure lamps emit every wavelength from 200-280nm and are used for disinfection at all but the smallest flow rates. Medium pressure lamps are better suited for chloramine control due to the energy they emit at every wavelength from 200nm-240nm. Because medium pressure wavelengths are more effective on chloramines, the electrical efficiency of low pressure is less apparent when considering chloramine control. Table 1 illustrates that the 222nm wavelength is absorbed thirteen times as much by trichloramines as low pressure's 254nm. Again, medium pressure supplies every wavelength from 200nm-240nm. You can see why medium pressure is considered a more effective tool for breaking down chloramines.

Table 1. Molar Absorptivity Values ($M^{-1}cm^{-1}$) for volatile DBPs and free chlorine at different wavelength.

Li, Blatchley (2007)

Species	**λ=222 nm**	**λ=254 nm**	**λ=282 nm**
$CNCHCl_2$	25	< 1	< 1
CNCl	12	5	< 1
CH_3NCl_2	**1662**	**211**	**562**
NCl_3 (Trichloramine)	**4938**	**367**	**54**

NaOCl(HOCl) pH=7	71	64	71

Standard Systems

UV systems have two components, a treatment chamber and power control cabinet. The chamber contains one or more lamps. The chamber is plumbed in a bypass to treat 100% of the return water. The bypass allows for servicing while the pool remains open. The lamp(s) are surrounded by a quartz sleeve, so the lamps do not actually touch the water. Chambers for commercial aquatics should also contain two critical components: UV monitors and automatic internal wipers.

UV Monitors

The UV monitor measures the actual UV energy delivered to the water. The intensity of the lamp, thru the quartz sleeve, and thru the water is determined. If the lamp is old, the quartz sleeve is dirty, or the water quality suffers, the UV monitor will alert the owner (via a LED display on the power/control cabinet) that the specified level of energy is not being provided. An accurate UV monitor is the only way to know the actual energy provided. Sophisticated monitors which measure actual UVC energy should be used. Using the electrical draw of the lamp, or lamp hours used, to determine lamp intensity does not take into account fouling of the quartz sleeve.

Please note that the monitor can be programmed to cheat the operator; by recalibrating the monitor when a “low UV” alarm occurs. When a new lamp is installed, on a system with cleaned quartz sleeves, the UV monitor is calibrated at 100%. This is the ONLY time a UV monitor should be calibrated. Again, a UV monitor should NEVER be calibrated on a system which has a “low UV” alarm; this is giving a false positive reading, the specified level of energy is not being provided.

The UV monitor can assure the owner that the specified level of energy is being applied. It will also let the owner know when the sleeves need to be cleaned and/or the lamp needs to be replaced. In states which require UV in their commercial aquatic health code, a “low UV” alarm will automatically shut down the water feature and alert staff that the required lamp intensity is not being applied.

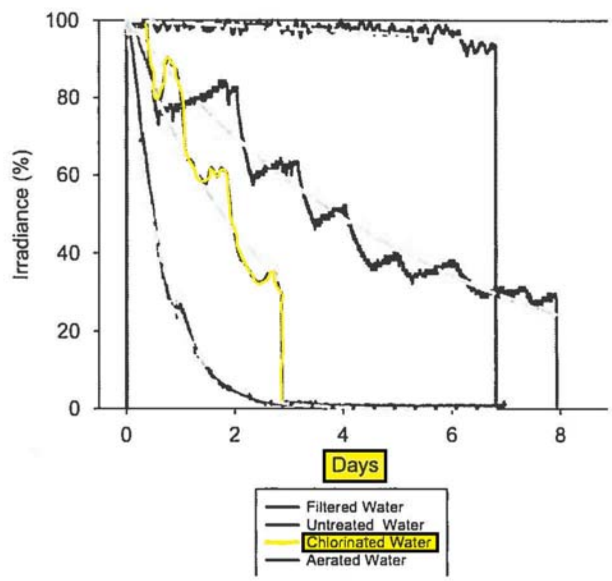
Automatic Internal Wipers

Industries which use UV after carbon filtration do not worry about fouling on the quartz sleeve. Almost every other commercial UV application, which has organics in the water, takes into account quartz sleeve fouling. Quartz sleeves or thimbles do not magically repel oils, cosmetics, or lotions. On the contrary, UV energy actually pulls fouling out of the dissolved state and attracts scaling on the quartz sleeves. Dissolved iron, manganese, and calcium are elements which UV causes to scale out of solution and accumulate on the quartz sleeve. Accumulations on the sleeves increasingly block the UV energy from being emitted into the water. And accurate UV monitor can alert you that critical germicidal UV energy is not being emitted into the water.

Science has shown that even a small amount of iron in the water causes significant levels of scaling on the quarts sleeve and dramatically reducing the UV energy applied to the water. Dissolved iron has shown to reduce the energy provided by as much as 50% in a single day (Wait, Blatchley 2010). Scaling on sleeves was shown to accelerate as the water's ORP increases (Collins and Malley 2005, Wait et al. 2005, Derrick 2005). This accumulation can occur within days (Wait, Johnston, Blatchley 2007) Fig. 2.

Figure 2 – Significant fouling can occur with days

Wait, Johnson, Blatchley (2007)



To combat fouling, UV systems have internal automatic wipers which act like a windshield wiper and squeegee across the sleeve multiple times per day.

Manual cleaning involves draining the chamber and removing the sleeves; which are then cleaned by hand. We recommend cleaning the sleeves every six to twelve months; an accurate UV monitor will also let you know when a servicing is required. For an NSF-50 listing, a limited number of UV manufactures, whose systems do not contain internal wipers, must include in place chemical cleaning systems; with no possibility of cleaning chemicals entering the pool. These systems must be mounted in a bypass and contain ports for chemical injection. It is recommended that the chemical cleaning procedure, and any ancillary equipment and chemicals, be clearly defined as a part of regular maintenance.

Costs – MP & LP

There is a significant cost in replacing low and medium pressure lamps; the reason for this is that they, along with the sleeves, are made of quartz. When considering low or medium pressure UV systems, one should consider all costs of ownership including electrical, spares, installation space, and service labor. A standard medium pressure system typically has one or two lamps and quartz sleeves. There are also associated O-rings to seal and wipe the sleeves. Medium pressure lamps are more expensive, at $400 -

$1,000 each, but you use significantly fewer of them. Relative to low pressure, medium pressure lamps can have shorter life for many industrial applications. However, in commercial aquatics, operating a medium pressure lamp fairly continuously will provide a lifespan similar to low pressure lamps. Medium pressure UV systems have a smaller physical footprint and require significantly less service area. The lamp lengths are usually 1.5 – 3 feet in length; requiring this length to service the system.

A typical low pressure system has 4, 6, 8, 12, 18, or 24 lamps, quartz sleeves and associated O-rings. Low pressure lamps typically cost $100 -$300 each. Most medium pressure lamps use chokes or transformers to power the lamps; these components are not considered expendable and should outlast the life of the system. Low pressure lamps, and some medium pressure systems, use ballasts to power the lamps. Ballasts are considered expendable. A single ballast to power two low pressure lamps can cost $300, this cost can add up when multiplied by twelve on a 24-lamp system. The number of spare parts for low pressure systems rises significantly with an increase in flow rate. The lamp lengths are usually 4-5 feet in length; requiring this length to install and service the system. Due to the increased number of lamps, the amount of mercury used in typically 3-4 times more when choosing low pressure.

Labor costs

Again, quartz sleeves, on chambers with functioning internal automatic wipers, should be removed and manually cleaned every 6-12 months. The spare quartz lamps and quartz sleeves are fragile and expensive. Care should be taken, and proper instruction from the manufacturer provided, to avoid having to purchase additional lamps & sleeves to replace any potentially broken during servicing. Labor costs for cleaning a five-foot long 12-lamp low pressure system is significantly greater than a medium pressure system containing two lamps which are two feet long. It is worth noting that increased lengths, number of lamps and sleeves adds to the risk of breakage during servicing. Proper service training will help reduce this risk.

Power Control

Medium pressure systems can be programmed to run at reduced power. The programming can be manually programmed or automated. A chemical controller, which can determine the chloramine level, can automatically adjust the power to a medium pressure UV system. Running at low power, when there is low demand, will save on energy costs and extend the life of the lamps. Low pressure lamps run at one power level.

Health Codes & Validation

Large scale outbreaks of RWI's blamed on Cryptosporidium are leading an increasing number of states to add requirements for UV as a secondary disinfectant into their aquatic health code. This trend is expected to continue as few technologies can address chlorine resistant pathogens in 100% of the return water. These health codes are not accepting manufacturer's claims of performance but require independent third-party validation testing. UV manufacturers ship a specific UV model to a lab which then uses testing based on U.S. EPA drinking water standards. The lab issues a report indicating the amount of water a system can treat to address Crypto. It is worth noting that while NSF-50 provides validation testing for Crypto, their Annex H is independent of this testing and does not provide the validation required by health codes. It may be wise to look at specifying validated units on future projects in case health codes eventually require UV. To confirm that the validated flow rate in the lab's report matches your facilities design flow rate; request a copy of the validation certificate.

Clarifications / corrections

There are several points promoted within the industry which either require further scientific study to be proven or are clearly inaccurate.

A study by Duke University compared the effect of medium and low pressure lamps at degrading free and one type of chloramine, monochloramine. The #1 conclusion from this study "1 - Chlorine and monochloramine in water decay steadily when exposed to monochromatic [low pressure] and polychromatic [medium pressure] UV light. However, total decay of chlorine and monochloramine are relatively small in the UV dose range that is generally applied for disinfection (15-130 mJ/cm2)." (Örmeci, Ishida, Linden 2005). Chlorine consumption should not rise, and often has been minimally reduced. Low pressure systems designed to control only monochloramines are missing the main problem. Research on UV and pool water has shown that many of the nitrogen compounds from swimmers are converted directly to trichloramines (which off-gas as a vapor) and precedes monochloramine formation (Blatchley, Cheng 2010).

Advanced Oxidation Process (AOP)

UV should not be considered as a way to oxidize organics in the water. UV can be used with other chemicals and equipment to produce hydroxyl radicals which oxidize organics; however, this technology is expensive, requires exacting design considerations, and could be detrimental to chemical levels, including free chlorine, in the water.

Claims of advanced oxidation with UV alone are derived from a very small amount of ozone which is generated from oxygen at the 185nm wavelength. Valid AOP claims can be made in air treatment and ultrapure water treatment where impurities in the water are measured in parts-per-billion; not pool water treatment. The percentage of energy emitted by UV lamps at 185nm is relatively small; additionally, this wavelength travels a fairly short distance and is readily absorbed. The actual amount of 185nm energy which leaves the lamp, travels the distance to the quartz sleeve, and transmits through the quartz sleeve into the water is minimal.

It is worth noting that the small amount of ozone generated in the dry area between the lamp and sleeve can be harmful to the equipment exposed. "Because ozone is corrosive, toxic, and absorbs UV light, LP [low pressure] and LPHO [low pressure high output] lamps used in water disinfection applications are manufactured to reduce output at 185nm." (US EPA LT2ESWTR, 2006). It is also well documented that the presence of ozone actually reduces the amount of germicidal UV emitted. Claims of advanced oxidation using UV in pool water should be verified with third party peer-reviewed science.

Overview

- Look at all costs when evaluating the best UV system
- Confirm an automatic internal wiper and true UV monitor are included with your system
- Give preference to medium pressure UV for chloramine control
- Consider using validated units to confirm manufacturer's claims and protect your investment from potential future health codes.
- Make sure there is a service schedule in place to clean the quartz sleeve; more often on systems without wipers.
- Confirm there is local technical support from the manufacturer, ask for local references

Don'ts

- Never reprogram the UV monitor in a "low-UV" event.
- Don't accept assertions that the quartz sleeves will remain clean in pool water.
- Don't accept claims that UV is outlawed in other countries, or that it increases the level of unhealthy disinfection by-products. Demand proof from third-party, peer-reviewed, science.

When properly designed, manufactured, installed, and serviced; UV systems can provide significant benefit over many years. Reduced corrosion to the facility, improved air quality, and a reduced risk of a large Crypto outbreak makes UV attractive for commercial aquatics.

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