UV in Swimming Pools and Water Parks

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Background

For both public and private pools and water parks, disinfection plays a key role as a required treatment step. Bathers cause many pollutants to enter the water, such as bacteria, urine, sweat and other excretion products of swimmers. Swimming pool water must undergo treatment in order to remain clear and clean, free from harmful substances (bacteria, viruses, algae and other pathogens) and suitable for use by swimmers. This creates the need for disinfectants, such as chlorine, to be added to the water to kill pathogenic microorganisms. Sweat and urine largely consist of water, ammonia and urea. When these products react with chlorine, unwanted reaction products can be formed that consist mainly of chloramines. Of particular concern in swimming pool waters are the formation of chloramines and chlorinated organic compounds that are known to give rise to swimming pool odor and eye, nose and throat irritation.

Disinfectants used for swimming pool water should be safe and non-irritating to swimmers and spectators alike. They must be active in small concentrations and retain their activity for a long time. Disinfectants for swimming pool treatment must be active in the pool itself, because pollutants and pathogenic microorganisms are constantly added to the water. Therefore, the water has to maintain a residual disinfectant concentration. The disinfectant must be easily traced and measured and should be safe to use. For most pool operators, chlorine is the disinfectant of choice, although there is growing awareness regarding the negative health impacts of chlorine and its byproducts.

Ultraviolet (UV) light represents a powerful technology that has been successfully deployed in diverse industries, such as life sciences (pharmaceuticals and biotechnology), microelectronics, power generation, food and beverage, aquaculture, marine, oil and gas, recreational water and industrial wastewater for several years. UV disinfection of pools is a chemical-free method for killing pathogens by ultraviolet light. UV does not add anything to the water stream, such as undesirable color, odor or chemicals, nor does it generate harmful byproducts. To ensure a safe and pleasant pool environment without using strong disinfection chemicals, UV water treatment disinfects and simultaneously destroys chloramines and chloro-organics instantly as the water passes through the treatment chamber. UV energy is imparted to the water stream to accomplish the process of disinfection and chloramine destruction in a fast, effective, efficient and environmentally friendly manner. The use of ultraviolet disinfection for pools is particularly suitable for bathers who are sensitive to the usual swimming pool disinfectants or allergic to chlorine. UV is not designed to completely replace chlorine, but well-maintained pools can see significant reductions in chlorine usage. This results in a greatly improved bathing environment, with many pool operators reporting increased bather usage and a higher number of regular bathers after switching to UV. In fact, many bathers returning to a pool following the installation of UV actually believe chlorine has been entirely removed.

UV has now taken over for ozone as the system of choice for chloramine removal in newly built pools. Significant numbers of existing pools are also switching to UV, driven principally by performance and economic factors.

Table 1. UV dose (mJ/cm^2) required for 3-log (99.9%) inactivation of various microorganisms.[2]

Microorganism	UV dose
Bacteria	
Aeromonas Hydrophilia	3.9
Campylobacter Jejuni	4
Legionella Pneumophila	6.9
Salmonella Anatum	15
Salmonella Enteritidis	9
Salmonella Typhi	6.4
Salmonella Typhimurium	5
Shigella Dysenteriae	2
Shigella Sonnei	6.5
Staphylococcus Aureus	6.5
Vibrio Cholerae	2.2
Yersinia Enterocolitica	3.7
Esherichia Coli	3.5-7.3
Streptococcus Faecalis	8-9.9
Protozoa	
Cryptosporidium Parvum	12
Giardia Lamblia	11
Spores	
Bacillis Subtilis	51-61
Virus	
Adenovirus Type 40	90
Adenovirus Type 41	80
Coxsackievirus B5	21
Hepatitis A	15
Hepatitis A HM175	12-22
Poliovirus Type 1	14-23
Rotavirus SA11	23-26
Phage	
MS-2	38-61
oX174	6.4-12
PRD-1	24
B-40	23

Disinfection

UV light inactivates a host of pathogenic microorganisms, encompassing bacteria, viruses and protozoans (*Cryptosporidium* and *Giardia*) at very low doses. Chlorine is totally ineffective in dealing with *Cryptosporidium* and high doses are needed for *Giardia* and *Legionella*, all of which are readily inactivated by UV and are a growing concern for swimming pool operators. Disinfection challenges include chlorine-resistant germs, poor maintenance, poor hygiene, increased numbers of swimmers (many of whom are young children, which can result in increased diarrhea and/or fecal accidents) and water swallowing. All of these factors increase the risk of outbreaks

Instances of recreational water illness (RWI) are increasing in the US. The Centers for Disease Control and Prevention (CDC) believes these numbers will only increase in the future. The leading cause of RWI outbreaks in the US is *Cryptosporidium*. The parasite,

Figure 1. Spray ground/interactive fountain anatomy

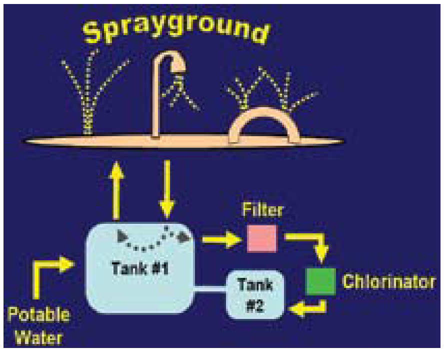


Figure 2. Disinfection and chloramine destruction

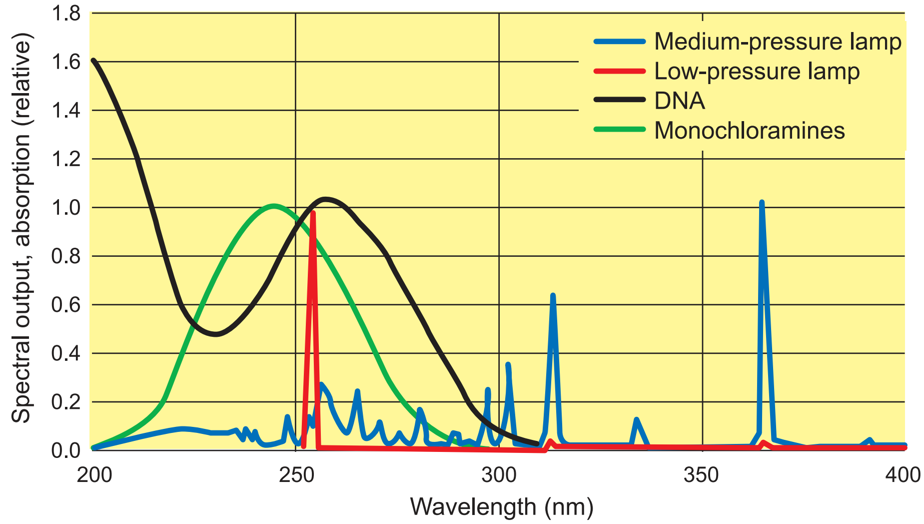


Figure 3. Chloramine destruction

$Cl_2 + H_2O \rightarrow HOCl + HCl$

$3\ NH_4^+ + 3\ HOCl \rightarrow 3\ NH_2Cl + 3\ H_3O^+$

UV

$2\ HOCl \rightarrow 2\ H^+ + 2\ Cl^- + O_2$

UV

$4\ NH_2Cl + 5\ H_2O \rightarrow 4\ Cl^- + 2\ H_3O^+ + NO_3^- + 3\ NH_4^+$

UV

$4\ NH_2Cl + 5\ H_2O + 3\ HOCl \rightarrow 4\ Cl^- + 5\ H_3O^+ + NO_3^- + 3\ NH_2Cl$

commonly called *Crypto*, is found in human and animal feces and is easily transmitted through water. When ingested, *Crypto* can cause an illness called Cryptosporidiosis that can last up to two weeks, with symptoms that include long bouts of diarrhea, vomiting, nausea, abdominal cramps, headaches and low-grade fevers. The oocysts are resistant to chlorine disinfection and can survive for days in treated recreational water venues, despite adherence to recommended residual chlorine levels (one to three ppm). Increased popularity of recreational water venues may also lead to an increase in the number of Cryptosporidiosis outbreaks. Interactive water fountains are established sources of gastrointestinal infections, yet most health codes fail to regulate their design and operation. Treatment strategies for recreational water facilities need to be improved.

Spray grounds, or interactive fountains, typically consist of water spray or jet devices located in an area accessible to the public (Figure 1). These venues are intended to provide individuals with a means to play in the water without going into a swimming pool. They are also ideal settings for *Cryptosporidium* outbreaks. Young children and diapered infants provide more opportunities for fecal incidents. The presence of spray increases the likelihood for water ingestion, which helps disseminate *Cryptosporidium*. Additionally, an open atmosphere creates opportunities for animal-related incidents. The risk is also magnified when water is recirculated.

Because of its resistance to chlorination, *Cryptosporidium* has become the leading cause of gastroenteritis outbreaks associated with treated recreational water venues, and accounted for 60 percent of the outbreaks reported to CDC during 1995-2004. Of the recreational water venues that were inspected for disinfection and chlorination, all but one had records indicating adherence to recommended residual chlorine levels.[1] These outbreaks underscore that conventional chlorination and filtration of swimming pools and water parks may be inadequate to control Cryptosporidiosis and transmission of recreational water disease.

UV disinfection as part of the conventional water treatment system, such as filtration and chlorination (multi-barrier approach), can prevent RWI outbreaks and protect the health and safety of swimmers in recreational water applications. UV water treatment systems designed for a typical UV dose of 30 mJ/cm^2 can provide sufficient disinfection since most pathogens require relatively low doses of UV energy for inactivation, as shown in Table 1.

Chloramines in pools

Bathers in pools may introduce several contaminants to the pool water, such as urine, sweat, mucus, skin, hair and sunblock. Urea from urine quickly converts to ammonia and chloramines that appear in swimming pools as a result of the reaction between ammonia and chlorine. Chloramines cause eye, nose, throat and skin irritation, chlorine odor and related coughs and corrosion of stainless steel structures in the presence of humidity. Chloramines are also linked to the development of asthma.

UV is extremely effective in breaking down chloramine compounds into chlorides and nitrogen compounds in swimming pools, specifically tri-chloramines, the culprit associated with the odor as well as eye, nose and throat irritation often found in pool environments.

Chloramine destruction

Monochloramine is normally the most commonly formed derivative in pool water, based on normal pool pH levels; with di- and trichloramine being secondary reaction products. If the level of monochloramine is controlled and kept low, the formation of di- and trichloramine is greatly reduced, since they are formed from the monochloramine precursor. Chlorine consumption will also occur by direct photolysis of chlorine at the same time that chloramine is being destroyed. The relative rate of monochloramine loss versus chlorine loss is important. Destroy monochloramines by UV light while it is low in concentration, before it results in considerable concurrent chlorine loss and before dichloramines are formed.

Efficacy of UV light for microbial disinfection (DNA) peaks at the wavelength of 260–265 nm. The peak wavelength for reducing monochloramines is 245 nm (Figure 2). Low-pressure lamp systems provide high output at 254 nm, which is very close to the optimum wavelengths for both disinfection and chloramine control. Medium-pressure lamp systems are also used. Chloramines can be broken apart by UV light. In simplistic terms, with an abundant supply of chlorine the UV destruction of one chloram-

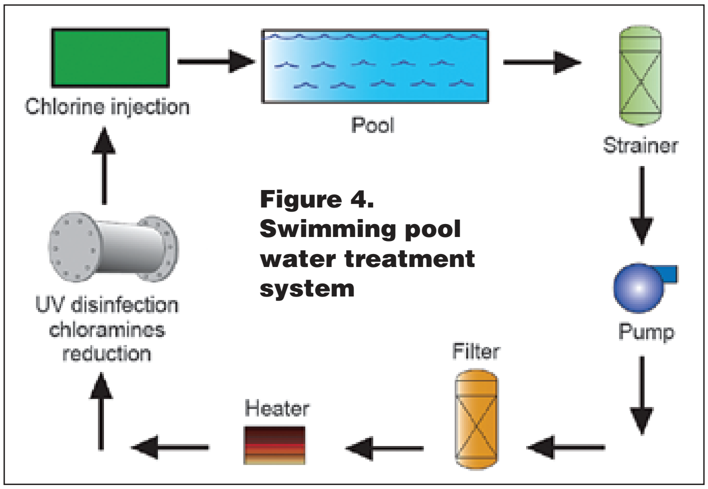


Figure 4. Swimming pool water treatment system

ine molecule occurs at the expense of one UV photon and three chlorine molecules (Figure 3).

It is important to recognize that if a pool has several turnovers per day through the treatment system (Figure 4), chloramines will be produced in the interval between passes through the UV unit. The UV system should be designed to bring the chloramine levels down with an adequate UV dose at each pass through the UV unit (Figure 5). Acceptable levels of chloramines are defined as 0.20 to 0.25 ppm. The optimum design UV dose for this application is 60 mJ/cm^2. Beside the direct reduction of chloramines due to UV light, the usage of free chlorine can in many cases be reduced. This stems from lowered frequency of pool water discharge and fresh water makeup and chlorination due to previously elevated chloramines levels.

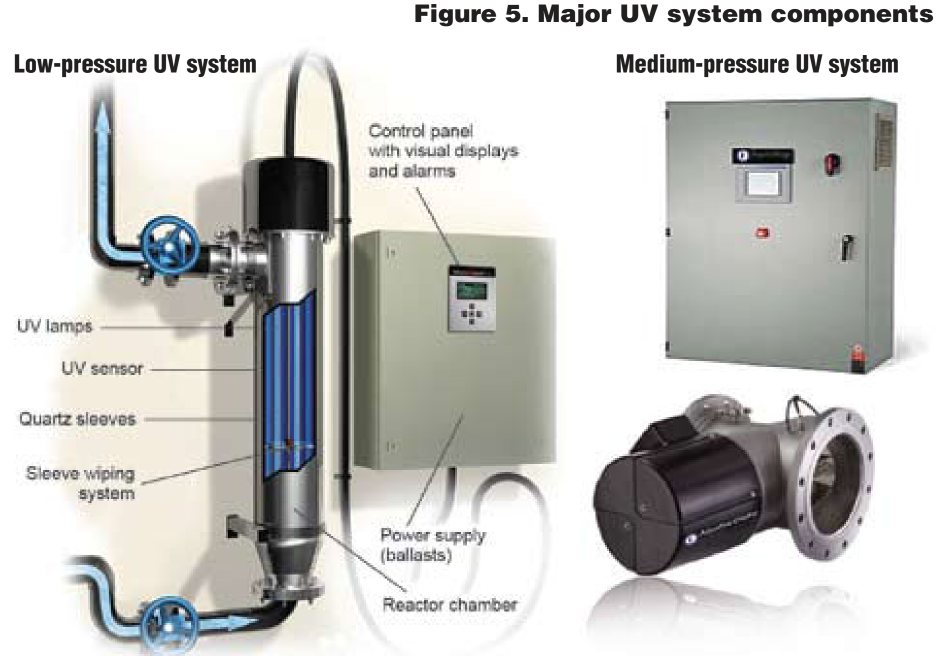
Conclusion

The treatment of swimming pool water by means of UV light effectively reduces the level of chloramines in the pool. Reducing the level of chloramines in the water, as well as in the air, greatly improves the environment for those swimming, as well as those observing within the enclosed pool area. While ultraviolet light has the added benefit of accomplishing disinfection in swimming pools and water parks, it should not be considered a replacement for chlorination or other types of chemical treatment. A properly sized UV system successfully controls chloramines; increases comfort and health for swimmers and staff; eliminates the need for dilution and super chlorination; reduces corrosion and, most importantly, protects against *Cryptosporidium* and *Giardia*.

Reference

1. "Cryptosporidiosis Outbreaks Associated with Recreational Water Use—Five States." 2006, *CDC MMWR Weekly*, July 27, 2007.
2. EPA 815-R-06-007—*Ultraviolet Disinfection Guidance Manual* November, 2006.

Figure 5. Major UV system components



About the author

Ismail Gobulukoglu joined Aquafine Corporation–A Trojan Technologies Company in 2002 as Chief Scientist. Previously, he served as Director of Research and as an Electron Microscopy Facility Manager. After completing his undergraduate degree in physics from Marmara University (Istanbul), Gobulukoglu earned a Master's Degree in physics and a Ph.D. Degree in chemical and materials engineering, both from the University of Nebraska-Lincoln. He has 13 years experience in technical engineering, applied research, business and product development, sales and customer support and more than eight years experience in UV water treatment applications. Gobulukoglu is the author/co-author of more than 15 publications and a member of IUVA, ISPE, AWWA, IWA, WEF and ASHRAE.