UV & Ozone: A Match Made in Heaven

Practical implementation & ROI of UV/ozone systems for recreational water applications

By Ray Denkewicz

The Centers for Disease Control & Prevention (CDC) has catalyzed renewed interest in both ultraviolet (UV) and ozone for recreational water treatment as a result of its recommendation, set forth in the Model Aquatic Health Code, to utilize these technologies as secondary disinfectants to combat outbreaks of recreational water illnesses in aquatic facilities.[1] In the May and June issues of WQP, I discussed the important role that both UV and ozone play as secondary disinfectants to chlorine.[2,3] I also discussed and highlighted the many benefits of UV and ozone when paired in a dual disinfection strategy for recreational water treatment (see Table 1). The net benefits of the UV/ozone combination are attributed to the formation of hydroxyl radicals, resulting in the "power of three" for increased disinfection and oxidation efficacy (see Figure 1).

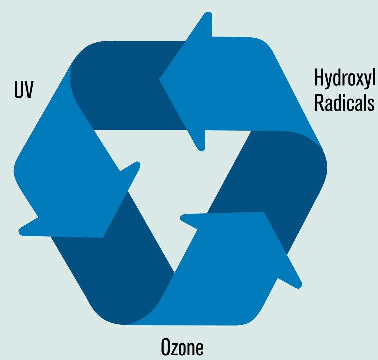
On the surface, then, it would seem as though UV and ozone are a match made in heaven—if the implementation of such a water treatment solution is both affordable and practical, that is.

UV and ozone have been documented to work together to create hydroxyl radicals. The combination is potent for both disinfection and oxidation.

Table 1. Benefits of a Combined UV/Ozone System

Synergistic disinfection efficacy against a wider range of microorganisms, particularly chlorine-resistant ones
Reduced chlorine demand
Destruction of chloramines, which eliminates odor and the corrosive nature of volatile components
Reduced overall chemical use
Environmental friendliness–no residual chemicals are placed in the water
Chemical-free
Oxidation of organic matter
Production of exceptional water quality

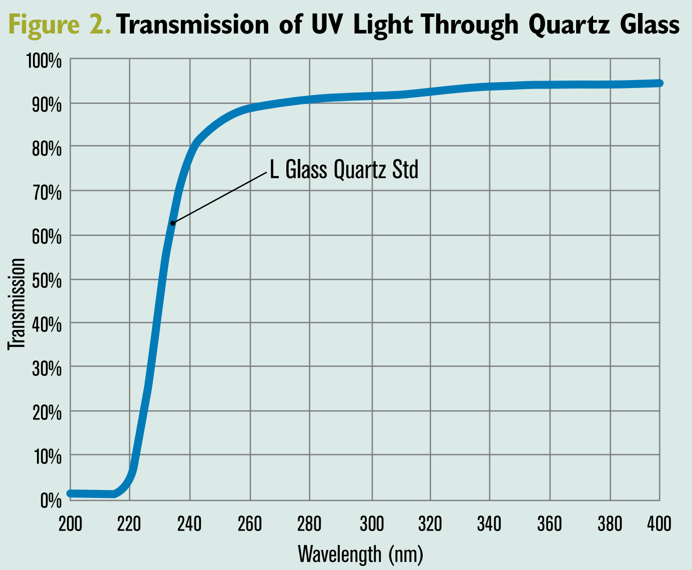
Figure 1. The Power of Three



UV & Ozone Technology Integration

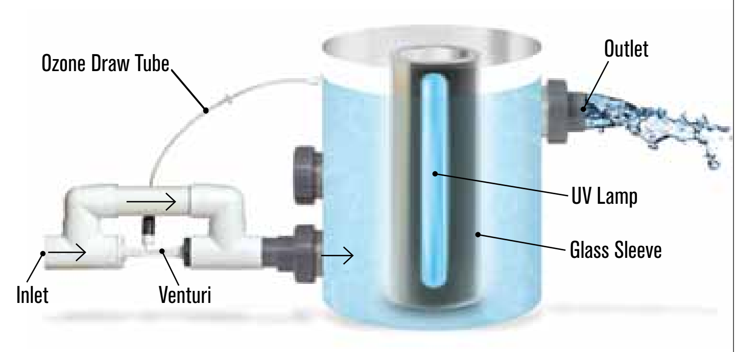
It is certainly possible to install a separate ozone system before or after a UV system to achieve a dual disinfection strategy. To do so, however, requires two separate systems and installations, which can be expensive. Fortunately, some low-pressure UV lamps can emit two wavelengths: 185-nm UV light for the generation of ozone and 254-nm UV light for inactivating microorganisms. These dual-wavelength lamps are available from most UV suppliers, cost about the same as single-wavelength UV lamps and can be engineered into a single system to deliver simultaneous UV and ozone water treatment.

Creating a UV/ozone combination system requires a fundamental understanding of how a conventional low-pressure UV system is configured. In such systems, UV lamps are housed in a vessel so that water passing through is exposed to the UV rays. To do this, each lamp (and there may be more than one) is surrounded with a quartz glass sleeve. This sleeve performs two key functions: It provides



Source: LightSources, Orange, Conn.

Figure 3. UV-Ozone Combination System



a physical barrier between the lamp and the water, and it allows the lamp's UV rays to be readily transmitted into the water phase (see Figure 2). If the UV lamps used in the vessel are single-wavelength lamps, also known as germicidal lamps (i.e., lamps that emit only 254-nm UV light), then the system is a conventional UV system.

To convert a conventional system into a combination UV/ozone system requires two key steps: replacing the lamp with a dual-wavelength model, and providing a means to remove the ozone created inside the quartz sleeve area and inject it into the water phase. While there are a variety of methods to extract ozone from the sleeve area, the simplest and most common is through the use of a venturi, a favored approach because venturis have no moving parts and can utilize the water flow in the piping to create a suction, or ozone draw.

Figure 3 provides a schematic of a UV/ozone combination system. As water passes through the plumbing, the venturi will draw air from the source to which it is connected. If the venturi is connected via tubing to the sleeve area around a lamp, the air it draws will contain ozone, as the UV light produces ozone from air using its 185-nm wavelength. When more than one lamp is used, a simple manifold can combine the air draw from all of the sleeves.

The ozonated water that enters the vessel is struck with the 254-nm UV light. As demonstrated in Figure 2, it is the 254-nm UV light, not the 185-nm UV light, that is transmitted through the glass sleeve surrounding a lamp. The 254-nm UV light converts the ozone into hydroxyl radicals, creating the one-two-three punch described in the June issue of WQP.[3]

While the quantity and concentration of ozone generated are small, we already have seen that this can be significant in contributing to the effects of both disinfection and oxidation.[3] The injection of ozone can be done before or after the UV light, but ozone must be injected before the UV vessel to take advantage of hydroxyl radical formation. When performed this way, no residual leaves the vessel, as the half-life of hydroxyl radicals is a fraction of a second.[4] As a result, no ozone degassing or destruction chamber is needed, as is the case when corona discharge ozone systems are used.

Table 2. Assumptions to Estimate ROI for UV/Ozone System on Outdoor Commercial Pool Operated 365 Days Per Year

CATEGORY	LIQUID CHLORINE	CALCIUM HYPOCHLORITE
Pool size (gallons)	100,000	100,000
Chlorine type used	Sodium hypochlorite (12.5%)	Calcium hypochlorite (65% available chlorine)
Chlorine demand (pounds per day chlorine gas per 10,000 gal water)	Varies from 0.5 to 3	Varies from 0.5 to 3
Approximate amount of chlorine required annually	Varies from 1,510 to 9,062 gal	Varies from 2,808 to 16,846 lb
Cost per unit of chlorine	Varies from $1 to $2 per gallon	Varies from $1.50 to $2.50 per pound
Acid consumption (assumed to be 1 gal acid for each 15 gal or 15 lb chlorine)	Varies from 101 to 604 gal	Varies from 187 to 1,123 gal
Cost per gallon of acid	$3	$3
Total annual chlorine & acid costs	Varies from $1,812 to $19,937	Varies from $4,773 to $45,485

ROI for Aquatic Facilities

Given its contribution to disinfection and oxidation, a UV/ozone system as a supplementary water treatment method to chlorine can be expected to reduce annual chlorine chemical costs. This was demonstrated at Hayward Industries' facilities using a 28,000-gal swimming pool operated at 60 gal per minute, configured with an oxidation reduction potential-controlled salt chlorination system and a single UV/ozone system comprising a stainless steel vessel (8 in. in diameter and 30 in. long) outfitted with one low-pressure, high-output lamp and a venturi injector system for the ozone.

Over a 27-day period, a 53% reduction in chlorine use was observed relative to the immediately prior 44-day period, in which the pool had been operated without a UV/ozone system. Note that the reduction in chlorine demand may vary for other pools depending on water volume, circulation, treatment method, bather load, geographical

Table 3. Assumptions Regarding Hypothetical UV/Ozone System for 100,000-gal Pool

Pool size (gallons)	100,000
Flow rate (gallons per minute)	Minimum 278 gpm for four turnovers per day
Equipment cost to end user (one-time purchase)	$8,000
Installation (one-time event)	$300
Replacement lamps (13,000-hour life) over three-year period	$1,500
Commercial electrical costs for 400-W system over three years at $0.11 per kilowatt-hour	$1,155
Total Three-Year Cost	$10,995

Table 4. Percent Chlorine Reduction Required to Achieve Three-Year ROI (Liquid Chlorine)

COST OF LIQUID CHLORINE PER GALLON	CHLORINE DEMAND IN POUNDS OF CHLORINE NEEDED PER 10,000 GPD					
	0.5	1	1.5	2	2.5	3
$1	–	–	67%	51%	40%	34%
$1.25	–	84%	56%	42%	33%	28%
$1.50	–	71%	48%	36%	29%	24%
$1.75	–	62%	41%	31%	25%	21%
$2	–	55%	37%	28%	22%	18%

Table 5. Percent Chlorine Reduction Required to Achieve Three-Year ROI (Calcium Hypochlorite)

COST OF CALCIUM HYPOCHLORITE PER POUND	CHLORINE DEMAND IN POUNDS OF CHLORINE NEEDED PER 10,000 GPD					
	0.5	1	1.5	2	2.5	3
$1	77%	38%	26%	19%	15%	13%
$1.25	67%	33%	22%	17%	13%	11%
$1.50	59%	30%	20%	15%	12%	10%
$1.75	53%	27%	18%	13%	11%	9%
$2	48%	24%	16%	12%	10%	8%

location, sunlight and other environmental factors.

With appropriate assumptions, the return on investment (ROI) for a supplementary UV/ozone system can be estimated for any pool size employing any chlorine sanitizer type. Let's look at two examples using the assumptions outlined in Table 2, for an outdoor pool operated 365 days per year, with nominal cyanuric acid of 30 to 50 ppm.

If we assume that a UV/ozone system sufficient for a 100,000-gal pool costs the end user $10,955 over a three-year period, then the requisite chlorine reduction needed to achieve a three-year ROI can be calculated (see Table 3). Paramount in these assumptions are the cost for the chlorine and the chlorine consumption of the pool, typically expressed in pounds of chlorine gas needed per 10,000 gal of pool water per day. Many local and state health regulations require that a chlorination system be sized to deliver up to 3 lb of chlorine gas per 10,000 gal per day. This is an extraordinary chlorine demand that is not commonly required in most pools, except in cases of high bather loads, which can occur at some aquatic venues for short durations of time. Therefore, in the ROI presented in Tables 4 and 5, a range of values for the chlorine demand, as well as a range of values for the cost of liquid chlorine and calcium hypochlorite, have been used to capture the range of operational conditions as they are likely to exist in real pools across the U.S.

Tables 4 and 5 summarize the percent reduction in chlorine needed to achieve a three-year ROI on a UV/ozone system for a hypothetical 100,000-gal outdoor pool operated with either liquid chlorine (12.5%) or calcium hypochlorite (65%), respectively. It is interesting to note that, in the majority of cases, a chlorine reduction of about 50% for liquid chlorine and 30% for calcium hypochlorite makes an investment in a UV/ozone system pay for itself in as little as three years. Beyond that time, the financial benefits accrue to the end user. This, however, is a strict financial exercise that does not account for other important benefits of a combination UV/ozone system, including:

- Safer water due to the killing power of UV and ozone for chlorine-resistant microorganisms;
- Potentially lower costs for "shocking" the pool with chlorine or potassium peroxymonosulfate due to the oxidation contribution of the UV/ozone system;
- Potentially lower capital costs of smaller chlorine feed equipment; and
- Fewer chloramines due to the destructive power of the UV/ozone system, resulting in less chlorine odor, less potential irritation to swimmers and less potential for corrosion in indoor pool environments.

The Future of UV & Ozone

Combining UV and ozone into a single system design for aquatic facilities appears to be both a practical and promising approach, particularly when viewed from an ROI standpoint. In addition, benefits from the implementation of both UV and ozone, such as chloramine reduction and oxidation, make an even more compelling case for UV/ozone implementation. In my opinion, the use of UV and ozone should garner attention in many water treatment applications, both as standalone technologies and as an intentionally paired disinfection duo, well into the future.[5] **WQP**

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