Bromine and Ozone:

Operational Challenges Encountered in the Treatment of Heavily Used Commercial Water Systems

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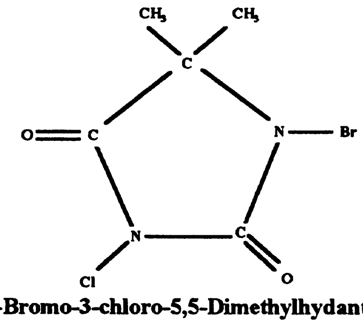
Commercial swimming pools and water systems present unique challenges to operators and aquatic directors. Bromine sanitation with 1–Bromo–3–Chloro–5,5–Dimethylhydantoin has been used successfully for over 40 years in commercial swimming pool disinfection. The history of BCDMH in commercial swimming pools stretches from the University of Michigan Women's Pool in 1952 to the Georgia Institute of Technology Aquatic Center, site of the 1996 Atlanta Olympic Aquatic events. The coupling of the powerful oxidation properties of ozone to this proven method of sanitation produces exceptional water quality.

The success of any water treatment system is dependent upon the proper operation of the circulation and filtration systems. Proper sizing and maintenance of these systems and the sanitation equipment is critical to achieving clean clear water.



1-Bromo-3-chloro-5,5-Dimethylhydantoin

Figure 1

The chemical compound 1–Bromo–3–chloro–5,5–Dimethylhydantoin is most commonly referred to as BCDMH. BCDMH is widely available and is the most common method of bromine sanitation throughout the pool industry.

The chemical structure of BCDMH is illustrated in Figure 1. The molecular weight of BCDMH is 241.5, and it is commercially available as 92.5% active strength. BCDMH is a stable compound which in one test exhibited an insignificant loss of available halogen content over a 32 year storage period.

BCDMH is distributed in the form of tablets that appear similar to Trichlorisocyanuric Acid tablets. Bromine tablets are significantly different from their chlorine counterparts in that BCDMH is eight times less soluble than trichloroisocyanurate. Due to the low solubility of BCDMH a chemical feeding device is necessary to deliver product to the pool. This soaking/erosion type of feeder is called a brominator. Brominators are sized according to the volume of outdoor swimming pools. In the case of indoor facilities, brominators are sized according to the daily bather load of the pool. As a general rule, the installation and sizing recommendations provided by the manufacturer should be followed when installing a brominator.

The hydrolysis of BCDMH generates hypobromous acid (HOBr) and hypochlorous acid (HOCl). Both of these species exhibit characteristics of oxidation and disinfection. The product of these chemical processes is primarily bromide ion (Br^-) and chloride ion (Cl^-), respectively. The bromide ion will further react with free hypochlorous acid to regenerate hypobromous acid (HOBr) while the inactive chloride ion remains in solution. Therefore, the primary chemical species performing oxidation and disinfection in a BCDMH treated swimming pool is hypobromous acid (HOBr). Scientific evidence also suggests that improved algicidal effectiveness is exhibited by a dual halogen system. One algae study (Knott and Edlis 1969) demonstrated rapid algae kill

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when exposed to a mixed system of bromine and chlorine. These traits, coupled with the improved microbiological efficacy of bromamines, provide the basic foundation for BCDMH's overall effectiveness.

Chemistry of Hypobromous Acid

The method of activity of hypobromous acid against microorganisms is similar to that of hypochlorous acid. HOBr and HOCl react to destroy bacterial organisms by disrupting the enzymatic activity that is crucial to the metabolism of the organism.

HOBr is a weak acid that exhibits a pH dependent acid dissociation. The equilibrium of the following reaction is dependent on pH:

$$\underset{\text{Hypobromous Acid}}{HOBr} \underset{\text{Increasing pH}}{\overset{\text{Decreasing pH}}{\rightleftharpoons}} \underset{\text{Hydrogen Ion}}{H^+} + \underset{\text{Hypobromite Ion}}{OBr^-}$$

As pH increases, the reaction shifts to the right toward the inactive hypobromite (OBr^-) species. As pH decreases, the reaction shifts to the left toward the active species, HOBr. At the pool pH of 7.5, the acid dissociation yields 94% active HOBr. In a chlorine system, the acid dissociation of hypochlorous acid is less desirable yielding only 48% active HOCl. Illustrated in Figure 2, in the normal pH range of a swimming pool, hypochlorous acid exhibits a far greater reduction in activity due to its acid dissociation than hypobromous acid.

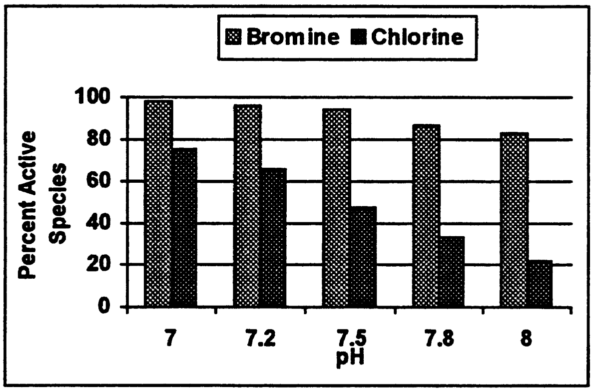

Figure 2

In the same manner that hypochlorous acid reacts with ammonia and other swimmer wastes to form chloramines, hypobromous acid reacts with these compounds to form bromamines. Bromamines have several unique and well documented characteristics. Bromamines, unlike chloramines, are excellent disinfectants. It has been established that bromamines exhibit disinfection properties superior to chloramines and approaching that of free bromine and free chlorine (Johnson 1977). Unlike chloramines, bromamines do not produce unpleasant odors and eye irritation. Studies conducted by the Illinois Department of Health indicated that reduced eye irritation and odors were characteristic of bromine treated pools in comparison to chlorinated systems (Lawrence and Block 1968). Bromamines are also more effective oxidants than chloramines at both neutral and alkaline pH values (Beckwith and Moses).

Disinfection and oxidation is accomplished by proper maintenance of a sanitizer residual. Table 1 illustrates the recommended bromine residual for specific applications.

Pool Type	Recommended Bromine Residual
Commercial Pools	3.0 – 5.0 ppm
Commercial Spas	4.0 – 6.0 ppm

Table 1

Ozone

Ozone, deriving it's name from the Greek word "ozein", meaning to smell, is a gaseous molecule of triatomic oxygen, O_3. It has a very noticeable odor, even at low concentrations. The coupling of ozone and bromine typically involves the continuous ozonation of a sidestream or slipstream equaling approximately 15–30% of the main circulation flow.

Because of ozone's instability, it must be produced on site at concentrations high enough to be effective. Effective ozonation of commercial pool waters requires the use of the corona discharge (CD) method of ozone generation. Corona discharge ozonators generate the 1 to 3 percent concentration of ozone necessary to effectively accomplish the required oxidation of bromide ion to HOBr and associated oxidation and microflocculation of organic compounds. As a result of this preferential ozone/bromide ion reaction, bromine/ozone systems do not typically require granular activated carbon (GAC) filters to remove excess and unreacted ozone. Of course, all equipment installed on commercial swimming pools should meet all specifications outlined by the National Sanitation Foundation Standard 50.

When properly injected and dissolved into water, ozone provides excellent oxidative properties. Of crucial importance to the synergistic benefits derived from an ozone/bromine system is the ability of ozone to regenerate hypobromous acid from inactive bromide ion.

$$\underset{\text{Bromide Ion}}{Br^-} + \underset{\text{Ozone}}{O_3} + \underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Hypobromous Acid}}{HOBr} + \underset{\text{Hydroxide Ion}}{OH^-} + \underset{\text{Oxygen}}{O_2}$$

This preferred reaction combines ozone's superior oxidation properties with bromine's recognized sanitation and aesthetic qualities. The result is, among other things, an improved level of water quality.

Operational Challenges

The operational parameters of a water system's circulation and filtration systems must meet the demands placed on the system by bathers and other environmental factors.

A pool's daily bather load is defined simply as the number of bathers entering the pool in a single day. A pool's bather load can be usefully characterized by the ratio of the pool volume in gallons to the average daily bather load.

Use Pattern Category	Ratio
Light	2000
Medium	1000
Heavy	400
Extreme	< 400

The lower this ratio the higher the bather load and the more challenging the task of maintaining clean clear water.

Proper circulation and filtration are critical to the successful operation of any aquatic facility. Circulation refers to the physical movement of water throughout the pool and related pool components and is characterized by the pool's turnover rate. The current ANSI–NSPI standard for turnover rate is 8 hours. It is important to recognize that pools with heavy bather loads require faster turnover times in order to remove pollutants introduced by swimmers. Many health departments are now requiring a maximum six hour turnover in commercial pools. It is also common to find water parks and other extreme bather load facilities which operate on turnover rates of 1–2 hours or less. The following is a guideline of turnover rates for specific bather loads.

Bather Load Category	Turnover Rate
Light	6 Hours
Medium	4 – 6 Hours
Heavy	3 – 4 Hours
Extreme	3 Hours Or Less

The Georgia Tech Aquatic Center, which most of the year can be described as having a medium bather load, is sized to a 5.5 hour turnover rate. The turnover rate is not the only important aspect of circulation. Good circulation is also dependent upon the number and location of pool returns and drains. These features ensure adequate distribution of water throughout the pool and eliminate 'dead spots' which can collect dirt and encourage algae growth.

Filtration

The physical removal of particulate matter from the water as it passes through porous filter media is referred to as filtration. The flow rate established by the circulation system is crucial to this process. A flow rate through a filter media that is too rapid or too slow creates inefficiencies in the filter that can reduce overall water quality. Filtration and circulation are the most significant factors affecting water clarity and overall water quality. The following table describes the optimum flow rate in gallons per minute per square foot of filter area for the three different filter types.

Filter Type	NSF STD	Optimum
High Rate Sand	5 – 20	10 – 15
DE w/ slurry	2.5	2.0
DE w/o slurry	2.0	1.5
Cartridge	0.375	0.375

Recommended Flow Rate in gpm per square feet

The Georgia Tech Aquatic Center competition pool operates at a filtration rate of 12 gpm per sq. ft. through six high rate sand filters.

Summary

Bromine and ozone systems are a proven and successful method for treatment of commercial swimming pools. Bromine and ozone systems have demonstrated the ability to provide clear high quality water under the most demanding situations like the Georgia Tech Aquatic Center in 1996. BCDMH is viewed as a more desirable option for sanitation. Bromine will continue to be regarded positively by swimmers pleased by the reduction in pool odors and eye irritation that are characteristic of bromine systems. Bromine is a proven and economical method for maintaining exceptional water quality in commercial swimming pools.

The operation of a commercial aquatic facility presents unique operational challenges due to heavy bather loads and other environmental factors. The proper application of circulation and filtration fundamentals, the use of a proven method of sanitation, and the utilization of good maintenance practices, create a sparkling clear and enjoyable environment for swimmers.

References

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