CASE STUDY

PROFILE OF OZONE/BROMINE SANITATION SYSTEMS CITY OF TUCSON MUNICIPAL POOLS

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Due to the inherent risks associated with the use of chlorine gas as a sanitizer for the City of Tucson's twenty-six municipal swimming pool sites, I found myself in search of an alternative water sanitation method. The challenge was clear; find a system that would be safer to manage than gas chlorine, yet yield the same favorable sanitation and water quality results. Since all the sites are located in close proximity to residential neighborhoods and public schools, safety was the most important consideration.

In my preliminary investigation, I found there were very few commercial swimming pool installations using the type of system I was researching - the combination of ozone, bromine and CO_2. Two pools, one in California and the other in Texas, matched the profile I had developed. Despite the fact that neither pool had heavy bather loads, safety issues were minimized and both water clarity and composition (chemical makeup) were excellent. Our use of chlorine gas had proven to be the least expensive sanitation method, but its continued use was ruled out due to safety concerns. Other chlorine-based alternatives such as sodium hypochlorite, calcium hypochlorite and di-chlor were also deemed unacceptable alternatives because it was believed that water quality – and in particular water clarity – would be significantly compromised.

At my request, The City of Tucson's Risk Management Division funded a study of the ozone/bromine/CO_2 system. It began in August of 1995 at one of the city's year-round pools and in 1997, the city purchased the equipment. The test site continues to be a heavily-used facility and the study has evolved into an ongoing research program, where I track chemical usage, equipment maintenance costs, man-hour requirements, etc.

The System

The installation is a 300,000 gallon outdoor pool with a consistently high bather load. Twin 7.5 hp circulation pumps operate 24 hours a day and turn the water over every five to six hours. After the main water flow passes through the EPD high rate sand filters, approximately 25% of the water is diverted into an ozone sidestream loop. Sidestream water is driven by two 1 hp booster pumps. A 52 gram per hour, air-cooled ozone generator manufactured by ClearWater Tech delivers an ozone dosage of approximately 0.27 ppm (dosage based on main flow gpm). Sidestream water then flows into a pair of contact vessels (plumbed in parallel), then joins the main flow returning to the pool. A separate sidestream is plumbed off the ozone sidestream loop for the flow cell (location of ORP and pH probes for the chemical controller) and bromine feeders.

How The System Works

In contrast to chlorine systems, the ozone, bromine and CO_2 work synergistically to provide effective sanitation/disinfection and promote proper water chemistry. A correctly-sized ozone subsystem functions in two distinct ways – first, it acts as a powerful primary oxidizer of swimming pool contaminants, including soaps, body oils and perspiration. Ozone is also extremely effective for inactivating bacteria, viruses, spores and cysts. In the presence of halogen-type oxidizers (bromine in this case), ozone will also oxidize ammonia, urea and amino acids (however slowly).

Second, ozone increases the efficiency of bromine by regenerating "spent" bromine into "active" bromine. As a result of the oxidation process, the active oxidizing agent in bromine - hypobromous acid - becomes inactive bromide ion. Ozone oxidizes the bromide ion back to hypobromous acid, making it available once again to act as a disinfectant. Below is how this nearly instantaneous process looks chemically; it shows that bromide ion plus ozone plus water yields hypobromous acid, hydroxide ion and oxygen.

Br- + O3 + H2O HOBr + OH- + O2

This reaction does not occur with chlorine compounds, where the chloride ion is the by-product of the oxidation process. In the City of Tucson pools that have yet to be converted to ozone/bromine/CO_2, chlorine gas must act as both the primary oxidizer and residual sanitizer. In the ten converted pools, ozone and bromine work together to provide primary oxidation and residual sanitation.

Also critical is the use of CO_2 for pH control, primarily because it meets the safety criteria I had established for the system by eliminating the strong acid or base chemicals (muriatic acid, sodium hydroxide, etc.) used for pH control. Also, there is a synergy between hypobromous acid and and CO2; the two can work together to help stabilize the alkalinity of the water (hypobromous acid lowers alkalinity, while

CO_2 raises it). While we have not noticed the effects of this synergy in our converted pools, a genuine problem we do face in the desert Southwest is evaporation, which has a tendency to erode alkalinity. Consequently, we often need to raise the alkalinity, which we do by adding food grade sodium bicarbonate.

With all subsystems functioning together, we find it easier to maintain our converted pools within recommended guidelines for major chemical parameters. We like to keep our bromine residual at 6 ppm, but may let it go as high as 8 ppm during periods of excessively high bather loads. While watching our bromine levels, we pay particular attention to the ORP (Oxidation Reduction Potential) readings. An Oregon State Health Department study on thirty public spas suggests that there is a clear relationship between ORP and the presence of waterborne pathogens. Zero plate counts were found in all spas that maintained ORP levels above about 630 millivolts (mV). We maintain our ORP levels at 685 to 725 mV.

We also keep the pH between 7.3 and 7.5, alkalinity at 100 to 130 ppm and calcium hardness between 300 and 400 ppm. I have found that maintaining the alkalinity at 100 to 130 ppm and calcium hardness at 3 times alkalinity can help keep the pH in balance. Finally, we try to keep total dissolved solids (TDS) at or below 1,200 ppm. Maintaining proper alkalinity and TDS levels is an ongoing challenge with some of our pools because makeup water comes from wells, the water from which can vary significantly in composition.

A few final suggestions that we find helpful in making an ozone/bromine system work – use a flocculant for water clarity, follow a regular make-up water program and shock the pool periodically. We use poly-aluminum sulfate for flocculation and granular chlorine to shock our test pool twice a year. Each application has different requirements, but one thing remains common to any commercial pool installation – strict attention to water chemistry and regular maintenance is essential. I am aware of no sanitation system that is maintenance free.

Ozone Generator Sizing

Correctly sizing the ozone subsystem is critical to the overall success of the system. Matching the amount of ozone output to the application allows it to provide primary oxidiation and convert bromide ion back to hypobromous acid. An undersized ozone generator will limit ozone's ability to function as the primary oxidizer, which will adversely affect ORP readings.

The ozone subsystems on our converted pools are sized based on a number of factors, including total gallonage, the pool's recirculation rate, bather load, physical surroundings, filtration capacity, etc. Ozone dosing guidelines suggest that outdoor pools with high bather loads be dosed at about 0.3 ppm (based on full flow), and our 300,000 gallon test site pool is at 0.27 ppm. The generally accepted sizing formula (used to determine the amount of ozone required) shows that the 52 gram-per-hour ozone generator is correctly matched to the application.

833 gpm (flow rate @ 6-hour turnover)
X 0.3 (dosage rate) X .227
= 56 grams/hour

Swimming pools with extremely high bather loads, poor filtration systems or particularly dirty physical surroundings will require higher ozone dosage rates.

Advantages

1. Safety – Needless to say, handling bromine and CO_2 is much safer than chlorine gas cylinders and caustic soda. Since ozone is generated on-site from oxygen, it does not need to be transported, stored or re-filled. Ozone is a powerful oxidizer and is therefore a potentially dangerous gas, but it is drawn into the water under vacuum and the ozone generator shuts down automatically if vacuum is interrupted. Also, with a very short half-life, ozone quickly reverts back to oxygen.

2. Not as pH-dependent - system effectiveness is not as pH-dependent as chlorine. The amount of hypochlorous acid (HOCL) – the most efficient oxidizer in chlorine compounds - begins to drop significantly as the pH rises above 7.4. In fact, 70.7% of chlorine is HOCL when the water is at a pH of 7.2. However, if the pH is allowed to drift as high as 7.8, the percentage of HOCL is cut nearly in half to 37.8%. In contrast, pH has very little influence on the ability of ozone to oxidize waterborne contaminants.

3. System synergy – Ozone is the most powerful oxidizer commercially available and is able to regenerate the bromide ion back to hypobromous acid. This adds efficiency to the system and allows us to use less bromine to achieve the desired residual in the water.

4. Size of contact vessels – Because the ozone/bromide ion reaction is so rapid, ozone contact vessels can be much smaller in an ozone/bromine system than in an ozone/chlorine system. This is often an important issue due to space limitations in the equipment area. Also, larger tanks are comparatively expensive.

5. Bromamines – Bromamines are formed when bromine can only partially oxidize a particular contaminant in the water. Unlike chloramines ("bound up" chlorine, caused by partial oxidation of a contaminant), bromamines can actually work as an algaecide and be reused. Chloramines are quite ineffective sanitizers in swimming pool applications.

6. Reduced maintenance costs – Maintenance man-hours for converted pools is a fraction of what our chlorine gas systems require. Refilling the bromine feeders is quick and simple, and the ozone subsystem only requires an inexpensive check valve rebuild or replacement three to four times a year. The ozone generators and air preparation systems are modular in construction, so they can continue to operate without interruption until a component is repaired or replaced.

7. Reduced skin irritation – I am aware of dozens of individuals who are swimming in our converted pools because of allergic reactions to chlorine products, primarily in the form of skin rashes. While some people react adversely to bromine, I know of just

one such instance since installing our first ozone/bromine/CO_2 system in 1995.

Conclusion

Since the original study began in 1995, ten of the forty-eight total swimming pools operated by the City of Tucson have been converted from gas chlorine to the ozone/bromine/CO_2 system. While bromine costs more than gas chlorine, the 44-pound pails can be handled easily by our regular maintenance personnel. The one-ton and 150 lb. chlorine gas cylinders are obviously much more difficult to handle and require that trained, certified handlers deliver them in a placarded vehicle. We safely and legally maintain up to 500 lbs. of bromine at each of our sites. In fact, the National Fire Protection Association recently adopted revised guidelines (NFPA 430) for the storage of liquid and solid oxidizers. Under these new regulations, bromine (BCDMH) has been downgraded to a Class 2 oxidizer, so up to 2,250 lbs. may be stored in a certain type of non-sprinklered facility.

Despite a few disadvantages to the ozone/bromine system – the initial capital cost and space requirements of the ozone subsystem and the comparatively high cost of bromine – there are many advantages, including the synergies that can lead to reduced chemical use. We have noticed that once “dynamic equilibrium” is reached in a particular pool, bromine consumption drops substantially. After the first five to six months of initial operation, weekly reductions of 12-16% are not uncommon.

Also, ozone is generated on-site, which reduces recurring chemical costs. Ozone is a superior oxidizer; in fact, ozone is the only oxidizer that can meet drinking water standards by eliminating such contaminants as cryptosporidium. Finally, ozone acts as microflocculant, enhancing the performance of the filtration system and poly-aluminum sulfate. The result is exceptional water quality and clarity. By effectively managing the strengths of both ozone and bromine, aesthetically pleasing water can be maintained for the pleasure of all.

I still receive regular inquiries about the City of Tucson’s ozone/bromine/CO_2 systems. Everyone from interested parks and recreation departments, pool operators, builders, architects, and health department officials ask about water quality, differences in maintenance requirements, how to retrofit existing pools, etc. The information I am pleased to provide is extremely favorable toward the system as a safe, effective swimming pool water sanitation alternative.

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