Study of Source/Capture of Airborne Chloramines

written & distributed by Paddock Pool Equipment Company, Inc.
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Introduction

It is all too common to walk into an indoor pool facility and smell "chlorine". The layman's typical reaction is that there is too much chlorine in the pool. However, this chlorine odor is not caused by excess chlorine but rather by a chlorine compound called chloramine that is being created in the water and off-gassing from the surface of the pool. The industry has known about chloramine formation for many years, but in recent years it has become more apparent that the tell-tale odor is also the primary cause of facility corrosion and has proven to be a considerable health risk to the pool patrons, lifeguards, coaches and observers. Paddock Pool Equipment Company (PPEC) has designed a system to minimize the level of airborne chloramines which in turn, provides excellent air quality in natatoriums. This report details the processes used in documenting the improvement in air quality at a local Charlotte, NC area natatorium before and after the installation of the Paddock Evacuator™ system.

Defining Chloramine Formation

The chloramine compound is formed in the pool as a chemical reaction between the free chlorine in the pool and nitrogen-containing compounds brought into the pool by bathers. These naturally-occurring nitrogen compounds are contained in sweat, urine, body oils and other proteins released by all users of the pool. As more nitrogen is released into the pool, the waterborne chloramine levels increase, resulting in an increase in chloramine off-gassing, thus creating the odor of chlorine in the room. Additionally, three different chloramines can be created - monochloramine, dichloramine and trichloramine. Trichloramine is the most volatile and will off-gas most quickly.

Over the years, the pool industry's reaction and recommendations have focused on trying to eliminate chloramines in the water in order to eliminate the off-gassing of these volatile compounds. The most common approach involves "shocking" the pool with high levels of chlorine in an attempt to oxidize the chloramine compounds. Shocking pools has limited success in that adequate oxidation levels are difficult to achieve, and air removal during the process is vital. Secondary "on-stream" chloramine treatment systems installed in the recirculation piping in the filter room are also common. These include Ozone systems that oxidize the compounds and UV systems that break apart the compounds as the pool water is recirculated. Both of these approaches can be effective; however, their limitations are 1) they only see the water four to six times a day; 2) the chloramine levels in the water are, in effect, reduced by dilution; 3) if the chloramine formation is substantial, off-gassing takes place before treatment can occur. Eliminating chloramines in the water is difficult if not impossible, and chloramine off-gassing occurs even with correct pool water chemistry and properly operating water treatment systems. Once chloramines become airborne, water treatment systems are ineffective.

Additional efforts have been made by facility management to minimize the introduction of nitrogen compounds by mandating swimmers bathing before entering the pool and requiring bathers to get out of the pool for bathroom breaks.

Even with these measures in place, chloramine formation cannot be prevented and still presents a difficult challenge.

Industry Research of Chloramines

A number of studies have documented the amount of nitrogen in sweat and urine and what quantities are released into pools. One study reports that roughly 40% of swimmers will release urine into a swimming pool at an average rate of 25 to 30 ml each. Another shows active swimmers produce large amounts of sweat which contains about 1 gram of nitrogen per liter of sweat.

While it is impossible to predict the level of urine and sweat introduced into pools, practical experience has shown that high bather loads produce high chloramine levels.

The trichloramine mentioned above is very volatile and vaporizes easily at the water's surface, especially when it is agitated by swimmer activity such as splashing and kicking or where spray features are

installed. It is known to be a strong mucous membrane irritant, and it is the primary chloramine compound associated with upper respiratory tract irritation and "Lifeguard Lung". These trichloramines are heavier than air and hover at the pool surface where swimmers and patrons are exposed to the highest levels of irritants.

Current air handling systems are designed to provide specific volumes of fresh air and evacuate specific amounts of natatorium air. However, most HVAC designs do not specifically address the chloramine problem. At best, most systems merely attempt to mix fresh air in the room and dilute the airborne chloramines to the point where they are tolerable.

The obvious benefits of improved air quality might include:

1. Improved air quality for lifeguards and other employees and patrons
2. Increased oxygen levels available to swimmers
3. Reduced chloramine-associated deterioration of HVAC systems
4. Reduced chloramine-associated deterioration of pool deck equipment
5. Reduced humidity load on HVAC system
6. Reduced energy requirements due to reduced tonnage demand

Source/Capture System Design

The approach PPEC has taken to address the problem of airborne chloramines is unique in the industry. As demonstrated above, it is impossible to prevent chloramine formation, so the focus needs to be in effective airborne chloramine removal. To successfully remove airborne chloramines, they must be captured and removed at their source, the water surface, or, to use an HVAC term, "source/capture".

A system designed to remove airborne chloramines at, or very near, the water surface should effectively reduce the level of airborne chloramines, thereby improving air quality in the natatorium.

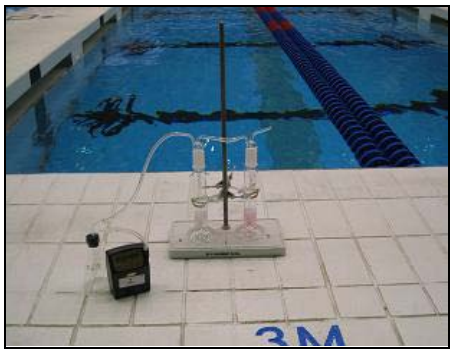
Test Protocol Design

After repeated reports of high chloramine levels, PPEC began making visits to a local Charlotte, NC area natatorium to study the environment at the pool and provide a solution to the chloramine issue. PPEC interviewed swimmers, pool managers, lifeguards, swim team coaches, aerobics instructors, even parents of swim team members. It was immediately apparent that there was a chloramine problem at the facility. Beyond the physical discomfort factor associated with chloramines, PPEC also discovered accelerated aging of pool and deck equipment, building structure and HVAC system components.

The owner agreed to have this pool be the site for a well-documented study of the source/capture system. It was decided that detailed testing of existing conditions needed to be performed; the Paddock Evacuator™ system would be installed, and then the same testing would be performed.

In order to provide an unbiased analysis, PPEC solicited the help of a respected Environmental Engineering professor at a well-known University to help with designing the test protocol. They enlisted PhD candidates to do the actual testing. A test procedure using gas-phase-transfer of chloramine molecules was agreed upon, and a testing protocol of one test per hour at two predetermined locations in the natatorium was designed.

In addition, one observation was made in the pool gutter itself to give a representative view of the chloramine concentration at the water's surface. This proved to be rather difficult due to the splashing of swimmers as they made turns in the vicinity of the testing apparatus.



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Samples were collected hourly at the pool deck level and on a table 40 inches above deck level. Both apparatus were located 54 inches from the pool gutter.

Once baseline data was accumulated, a prototype version of the Paddock Evacuator™ system was installed and activated. After a short period of adjustments, a second series of data was collected to determine chloramine concentration levels after evacuation. A second sample was also collected at the gutter level to serve as a comparison with the initial gutter sample.

Baseline Data

Chart 1 shows the observed levels of airborne chloramines in mg/m³ in the air around the pool deck during a normal period of pool activity.

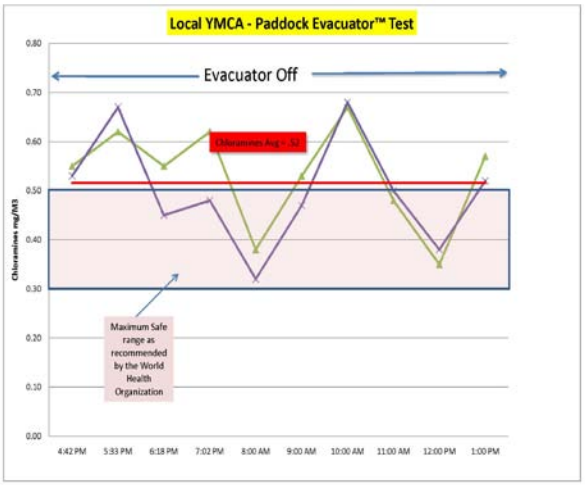

Chart 1

The average level of airborne chloramines observed was .52 mg/m³ with a minimum of .32 mg/m³ and a maximum of .67mg/m³. Chloramines measured in the gutter were .68mg/m³. The World Health Organization recognizes .30 mg/m³ as the minimum "detectable" concentration and .50 mg/m³ as the maximum comfortable concentration before irritation symptoms are documented.

Test Results

After baseline data were collected, the Paddock Evacuator™ system was activated and initial adjustments made. Hourly data samples were again collected. Chart 2 shows the observed levels of airborne chloramines in mg/m³ after turning on the Evacuator system.

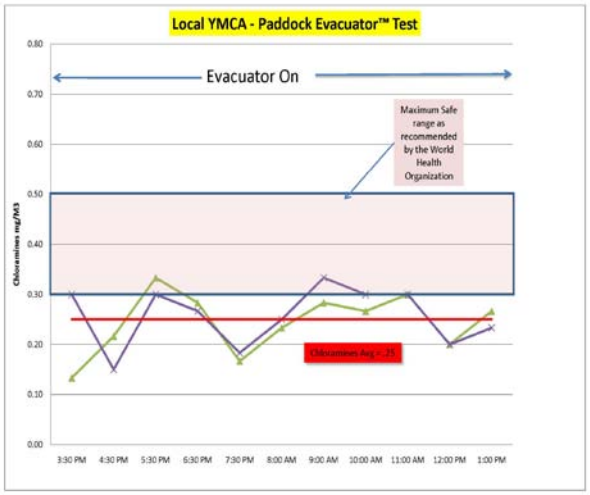

Chart 2

The average level of airborne chloramines observed was .25 mg/m³ with a minimum of .13mg/m³ and a maximum of .33mg/m³ . Chloramines measured at the gutter were .66mg/m³.

Temperature, humidity and CO_2 data in the natatorium were also monitored during the duration of the testing.

	Evacuator Off			Evacuator On		
	Mean	Std Dev	Var.	Mean	Std Dev	Var.
Temp	83.10	1.12	1.25	82.60	1.07	1.15
RH	54.41	6.63	43.94	38.04	4.16	17.31
CO_2	524	130	16800	494	51	2558

If baseline data and test period data are compared, one can readily conclude that the Evacuator system effectively removed a majority of airborne chloramines during the testing period. Test results from the pool gutter confirm that the chloramines at the water surface were similar (.68 and .66mg/m^3) during the two test periods.

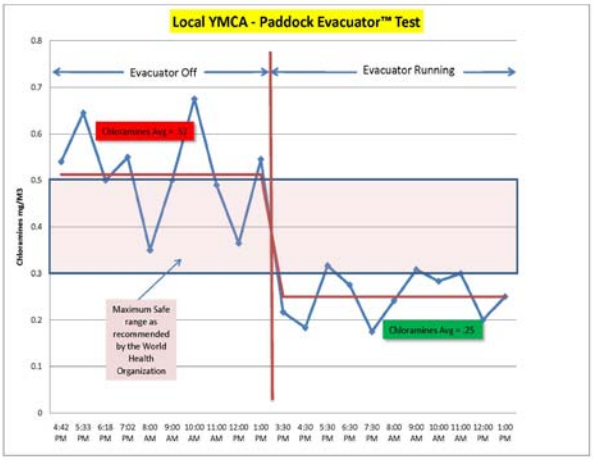

Chart 3

Chloramines and Bather Load

It is commonly assumed that airborne chloramine concentrations are directly related to number of swimmers in a pool. The more swimmers, the higher the chloramine concentration. Observations during the test periods covered by this paper indicate that the activity level of the swimmers has more effect upon airborne chloramines than absolute number of swimmers in the pool.

A small group of very active swim team members created a high level of chloramines, while a very large group of senior aerobics exercisers created a comparatively smaller reading. More testing needs to be conducted to develop a better understanding of the relationships between bather load and airborne chloramine concentrations.

Anecdotal Feedback from Employees and Patrons

Pool employees and patrons were asked to describe, in their own words, how they felt the air quality in the natatorium changed after the installation of the Paddock Evacuator™.

One lifeguard reponded, “Since the installation of the Evacuator, the air quality of our pool has improved a lot. It is easier to breathe, and the humidity is less than half what it used to be. The windows are not as foggy, and our eyes are not watering!”

Another lifeguard responded, “I feel that since the Evacuator has been installed, the air doesn’t seem as thick, and the chlorine smell has steadily been dwindling.”

“Some of the patrons at the Y have commented on the chlorine being less strong, and it being easier to breathe. They actually questioned if we have been using less chemicals.”

“Before the Evacuator, I could smell the chlorine as soon as I reached the door to the pool. Now the smell is gone; my eyes are clear, and I don’t get nearly as hot as I used to.”

“When I’m here everyday I’m used to the smell, but when I’m not here on the weekend and come in on Monday, I can smell it. But this last week, I made it a point to pay attention to the smell and could really tell a difference. The smell was not there when I was coming down the hall to my office.”

Conclusions

In this swimming pool facility, high concentrations of airborne chloramines were measured during a controlled test period. These high levels of chloramines were above the safe levels recommended by the World Health Organization. Lifeguards and swimmers regularly commented about the poor air quality contributing to breathing issues.

After installation of the Paddock Evacuator™ system, significantly lower levels of airborne chloramines were measured during another controlled testing period. Lifeguards and swimmers commented

that air quality was much improved after the installation of the Evacuator system.

The relationship of bather load to airborne chloramine concentrations was observed, and it was theorized that the bather activity levels are more responsible for chloramine concentrations than actual numbers of bathers. This relationship needs further study.

Path Forward

Much was learned during this controlled test concerning how chloramines are formed in a swimming pool environment and how they may be controlled. To effectively control chloramines in an indoor swimming pool facility, four primary areas must be focussed upon.

1. Pool water chemistry – Free chlorine concentration in pool water should be accurately measured and controlled within the recommended levels of between 1 and 3 mg/l. High levels of free chlorine are directly related to the formation of chloramines in the water.
2. Air handling system – HVAC systems must be sized correctly and balanced to effectively control temperature and humidity.
3. Airborne chloramine evacuation – Once airborne chloramines are formed, a system such as the Paddock Evacuator™ chloramine removal system should be installed to remove them.
4. Waterborne chloramine control – Once chloramines are formed in pool water, they should be removed by the most efficient manner. Further testing will be conducted to determine the effects of UV photodegradation upon waterborne chloramine concentrations.

Visit our website, www.paddockindustries.com for more information.