Published in *ByDesign,* the Technical Publication of the Engineering Practice Specialty, Vol. 7, No. 2 by the American Society of Safety Engineers.

Indoor Air Quality in Natatoriums

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Cella natatoriua is Latin for "a swimming pool in its own building." Residential, commercial, institutional and theme pools located indoors are, therefore, natatoriums. Swimming and water sports are generally considered to be fun, healthy activities for all ages. But what if the air in a natatorium caused serious health problems?

As few as 5 years ago, patrons at indoor pools would say, "I do not smell any chlorine. Is this pool safe to swim in?" Thanks to the work of agencies such as Centers for Disease Control and Prevention, National Swimming Pool Foundation and National Recreation and Park Association, the public is learning that the smell of chlorine actually signals a serious problem with the pool water chemistry.

Pool Water Chemistry

Chlorine serves two purposes in pool water. It sanitizes, which is the process of killing germs, and it oxidizes, which is the process of burning out organic contaminants. Organic contaminants include hair gel, body lotion and ammonia from sweat or urine excreted into the pool. Sanitizing is the easier of the two jobs and many germs, including E. coli, are killed almost instantly in properly sanitized water. Oxidation is much more difficult to achieve, especially oxidation of ammonia. This leads many to believe that clear water is safe water, but this is not always so.

To properly oxidize ammonia in pool water, eight chlorine molecules are required for every one ammonia molecule. When there is not enough chlorine in the water to react with ammonia excreted into a pool, available chlorine in the water forms a chemical bond with the ammonia. As more chlorine is pumped into the pool, more complex chemical bonds form. The result of these chemical bonds is a byproduct called trichloramine or nitrogen trichloride. Agitation of the pool water results in the release of nitrogen trichloride into the air, a process called off-gassing. Prolonged exposure to nitrogen trichloride can seriously affect the respiratory system.

There are complex and expensive processes for breaking apart the chemical bonds formed by ammonia and chlorine in water and also for removing the resulting nitrogen trichloride from the air, but when done incorrectly, they can result in more harm than good.

Health Effects of Pool Off-Gassing

"Lifeguard lung," a form of sick building syndrome (SBS), has been associated with poor indoor air quality in aquatic facilities. It is medically referred to as hypersensitivity pneumonitis (HP), which is an inflammation of the lungs caused by overstimulation of the immune system from the inhalation of viable and nonviable Gram negative bacteria and their endotoxins. These endotoxins come from bodily wastes of patrons (sweat, urine, feces) and active chemicals in the pool waters of aquatic facilities.

Symptoms of lifeguard lung may include wheezing, coughing, shortness of breath, problems concentrating, muscle aches, fever/chills, headache and eye irritation. The onset of symptoms usually occurs more than 24 hours after exposure. Repeated exposure may lead to the development of granulomateous pneumonitis, which involves irreversible scarring of the respiratory tract. In fact, epidemiological studies have shown a direct and increasing correlation between indoor chlorinated pools and the prevalence of asthma among both children and adults (Yu, 2006, p. 26).

All aquatic staff and patrons are potentially susceptible with the severity of symptoms directly related to the duration, concentration and frequency of exposure. A dose-response has shown that lifeguards who work longer hours are more susceptible to lifeguard lung and granulomateous pneumonitis than lifeguards who work shorter hours.

The number, types and designs of spray devices found in aquatic facilities play a significant role in the illness. A facility may have one or more bubblers, fan sprays, fountains, geysers, hot tubs/spas, slides/flumes, wall spouts or waterfalls. Aerosolization of water droplets and mist from these devices and patron splashing is often captured by the heating, ventilation and air conditioning (HVAC) system and recirculated into the facility's enclosed environment.

Additionally, biofilms may form on filters, in the piping of the water recirculation system and in pumps. These biofilms are breeding grounds for pathogenic bacteria. The bacteria release endotoxins, which are then inhaled. Pool sanitation and oxidation systems, water temperature, patron density, energy conservation measures and improper pool water maintenance contribute to the indoor air quality problem.

Studies have shown a direct correlation between the concentration of respirable aerosol particles and the types of spray devices used in aquatic facilities (Rose, 1998). Compared to background levels in air, fountains and waterfalls, a 1.4-fold increase in respirable aerosol particles occurs. Add a slide or flume and a 2.3-fold increase occurs. The use of multiple spray devices in a facility can result in a 5.2-fold increase in respirable particle levels and an 8-fold or greater increase in endotoxin levels.

Pool Operation Solutions

A heavily used pool will likely need the higher flow rate to keep up with organic loading caused by patrons, but the initial cost of building a pool to these specifications is extremely high. Tight budgets and value-engineering often result in pools designed to create rather than prevent poor indoor air quality. After a pool has been built and indoor air quality problems develop, many pool operators rely on chemicals and the HVAC system to help them manage problems that were designed into the circulation system.

Chemical Solutions

Manual and mechanical systems exist for chemically destroying nitrogen trichloride, but both have their drawbacks. The manual systems consist of complicated mathematical computations and chemical testing procedures that if performed improperly result in the release of more noxious gases into an indoor pool environment. Mechanical systems are available to test and treat pools containing chlorine and ammonia. These systems are expensive, labor-intensive,

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sometimes inadequate and can create chemical byproducts that have other detrimental effects on swimmers.

Filter media that can remove ammonia from pool water is available, but it is expensive and has limited receptors for ammonia. When those receptors are loaded to capacity, excess ammonia remains in the pool water. The overloaded filter media must be replaced or cleaned to remove ammonia from the pool water.

A more recent development in the pool industry is the use of ultraviolet (UV) light to kill germs and to break apart the chemical bonds chlorine and ammonia form. UV systems are available in both low- and medium-intensity with the former being less expensive but unable to break the chlorine-ammonia bond.

The latter, while capable of breaking the bond, also destroys chlorine. This results in increased costs for chlorine replacement. Even though UV kills germs, it eliminates only those germs that the light directly contacts. The UV equipment is installed in the circulation line rather than in the pool itself, so residual chlorine must be maintained in the pool to kill germs as they are introduced into the water.

HVAC System Solutions

HVAC systems for natatoriums must be designed to control temperature and humidity and to provide ventilation for air quality. Air distribution, evaporation rates, pool water chemistry and operating costs must all be considered and balanced for a successful system design.

One source of design criteria for natatoriums is the American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE). ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality, prescribes ventilation rates for average pools using chlorine as the primary disinfectant (ASHRAE, 2003, p. 4.6).

ASHRAE also provides guidelines for total air movement within the natatorium. The recommended rates range from four air changes per hour (ACH) to eight ACH. However, for high-occupancy public pools or when pool water chemistry is out of balance, the prescribed rates are often insufficient to keep air contaminants at a safe level. For these facilities, calculations should be performed to determine the airflow rates required to remove contaminants that are released from the pool surface.

The most efficient natatorium HVAC system is one that can balance the temperature, humidity and air quality requirements with the least amount of outdoor air. However, even in the most well-maintained pool, harmful air contaminants can be released from the pool surface from time to time.

Therefore, the HVAC system must be designed to handle these upset conditions. Since ventilation rates high enough to achieve good air quality—even when water quality is poor—will result in high energy costs, the system should be designed to minimize the ventilation rates during times when the water quality is good and when harmful air contaminant release is minimal. One solution is to provide a manual switch that allows the system to provide a higher rate of airflow during periods of high occupancy or when pool upset conditions exist.

To minimize air contamination (and to help reduce airflow rates), returns should be located to collect warm humid air as close to the water surface as possible. Additionally, pool areas should be maintained at a negative pressure relative to other areas of the building to prevent the escape of chloramine-laden air emissions. ASHRAE suggests active means of pressure control with openings to adjacent areas minimized and automatic closers on doors.

Conclusion

Improperly operated, maintained or ventilated natatoriums can result in long-term damage to the respiratory system of both patrons and staff. Despite these serious health effects, a lack of awareness exists regarding the cause of this illness and how to prevent it. Furthermore, many facility operators are not properly equipped or do not fully understand how to prevent the release of these endotoxins.

Multiple factors must be considered when evaluating a natatorium for indoor air quality. The chemicals used to treat the water must be properly regulated and consistently monitored. The HVAC system must be able to properly process the air on the highest occupancy days, yet still be cost-effective enough to meet the requirements for standard daily operations.

Because the off-gassing of a pool changes from day-to-day and even from hour-to-hour and because each facility's design and usage vary so greatly, there is no one uniform solution to this problem. Each facility must be examined to determine the most reasonable way to ensure the health and safety of its staff and guests. ■

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