Ventilation and air distribution in indoor aquatic facilities

Optimize outdoor air to create healthy and durable pool spaces

by Gary Lochner, Innovent

Healthy and durable indoor pool spaces require a well-designed air distribution system with enough ventilation to exhaust toxic chloramines and protect the building structure and materials from harmful condensation and corrosion.

Imagine yourself at your favorite swimming pool. Take a deep breath. If you are outside, that's a breath of fresh air. But if you're inside, you might breathe in a strong swimming-pool odor. Given that both pools are sanitized with chlorine, why does one have an odor and the other not? The answer is: Outdoor air. Outdoor pools have plenty and indoor pools, frequently, do not.

Most swimming pools are treated with chlorine. When chlorine binds to water contaminants it forms chemicals such as dichloramine and trichloramine. These chloramines irritate skin and eyes and off-gas into pool space air where they are toxic to breathe and corrode building materials.

Chloramines are a known respiratory health hazard for swimmers, lifeguards, and other pool occupants. Chloramines can fill an entire pool space but tend to concentrate directly above the pool water surface, right where swimmers breathe.

> ***"Chloramines can build up in the water, which means they can build up in the air if there is not enough fresh air surrounding pools and other places people swim in chlorinated water. This is particularly true for indoor aquatic facilities where air handling systems are not bringing in enough fresh air and exhausting enough chloramine-polluted air, which is common during winter months when heating costs increase. Chloramines that off gas from the water are heavier than air. This means they settle on top of the water's surface where they can cause negative health effects in swimmers and spectators."*** *— The Centers for Disease Control*[1]

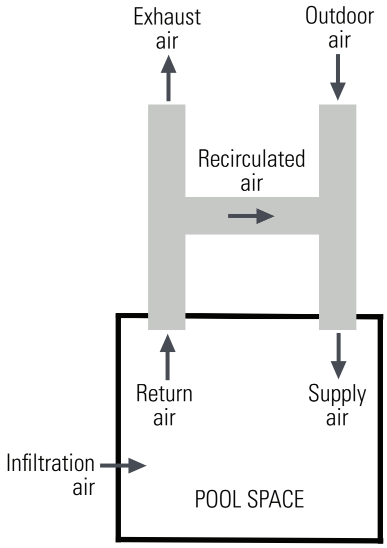
When chloramines concentrate above the water surface it can be challenging to maintain proper water chemistry. Chloramine-polluted air is also acidic and corrodes stainless and carbon steel, which can cause structural deterioration.

Healthy and durable pool spaces require proper air distribution to all space micro-zones. Zones shown here include swimming, deck, and elevated spectator areas, and exterior-facing glass, wall, and roof areas.

For a pool environment to be healthy and durable, chloramines must be removed by a well-designed ventilation system that has proper air distribution and enough circulating outdoor air to exhaust chloramines from the space.

A typical indoor pool space has several micro-zones that include areas with swimmers, people on the deck, spectator areas, and exterior walls and roofs that require condensation and corrosion prevention. Pool spaces are often quite tall (from 15–50 ft [4.5–15.2 m]) and require the air distribution system to provide good mixing throughout the space to prevent stratification and dead spots that can lead to corrosion.

This guide provides recommendations on calculating supply and return airflows, locations of supply diffusers, possible return and exhaust points, and the amount of outdoor air required for effective chloramine removal to create a healthy and durable pool space.



Definitions

Supply air. Total airflow delivered to the pool space. Includes outdoor air and recirculated air

Outdoor air. Ventilation air; also called fresh air before it is treated

Return air. Air delivered to the air handling equipment through return ducts from the pool space. Includes both air to be recirculated and exhausted

Air changes per hour, ACH. Describes the number of times the total volume of air in the space is replaced. Includes outdoor air and recirculated air when discussing indoor pools

Exhaust air. Air removed from the pool space and exhausted to atmosphere

Infiltration air. Outdoor air or conditioned air entering the pool space through the pool space enclosure due to pressure differential

Enclosures with very high sensible loads, or single-story spaces with high dehumidification loads or air volume (such as therapy pools), can require more air changes to provide an acceptable supply air temperature.

DETERMINING THE SUPPLY AIR DELIVERY RATE

The supply air delivery rate that provides the ventilation, air distribution, dehumidification, and heating and cooling requirements of these spaces is defined by ASHRAE in air changes per hour (ACH), which can also be converted to cubic feet per minute (cfm).

Supply air delivery rate in cfm = (Room volume in ft^3 × Number of air changes/hr)/60 min/hr)

The total amount of supply air delivered to a pool space includes outdoor air and recirculated air.

Supply air delivery rate = Outdoor air + Recirculated air

Note: The amount of outdoor air required to maintain a healthy and non-corrosive indoor environment is explained starting on page 8.

Start with a supply air delivery rate of 6 air changes per hour

To meet air distribution requirements, ASHRAE recommends a supply air delivery rate of 4-6 ACH for recreational pools and 6-8 ACH for competition pools with spectators. Innovent recommends starting with a supply air delivery rate of 6 ACH. If you are confident that the air distribution requirements can be met with less than 6 ACH, this amount can be reduced to a minimum of 4 ACH for recreational pools.

Adjust supply air delivery rate to meet temperature requirements

Enclosures with very high sensible loads (such as facilities with large amounts of glass in the enclosure), or single-story spaces with high dehumidification loads or air volume (such as therapy pools) can require more air changes to provide an acceptable supply air temperature. This is especially important for occupants wearing wet bathing suits who could become chilled when out of the water.

Therapy pool water temperatures are often above 90 °F (32.2 °C), which normally requires a high space temperature (max. 86 °F [30 °C]) to keep swimmers comfortable and reduce water heating and chemical treatment costs. However, there are often clothed occupants in pool therapy spaces that would be too warm in an 86 °F (30 °C) space. A compromise is designing for a space temperature of 84 °F (28.8 °C) with a higher air change rate to help keep clothed occupants more comfortable.

In very tall pool spaces, consider using HVLS fans to provide mixing and prevent stratification and corrosion rather than sizing the air handler and duct system for air changes based on total space volume.

Supply air delivery rates in very tall spaces

Some recreation centers with water slides, and aquatic centers designed for large competitions, have very high ceilings (35–50+ ft [10.6–15.2+ m]). However, other than a water slide there are usually no people or water at the upper heights in these facilities. It may be more economical to use high-volume low-speed (HVLS) fans to provide mixing and prevent stratification and corrosion at the upper heights, and design the ducted air system for 6 ACH based on a 30-35 ft (9.1–10.6 m) pool space height rather than size the air handler and duct system for air changes based on the total space volume. This can provide significant savings in duct and fan motor costs. It is important to provide safe maintenance access to HVLS fans if they are used in the design.

Supply air delivery rate to spectator areas

Spectator seating areas in competition pools are often elevated, beginning about 10–15 ft (3–4.5 m) above the pool deck. The best practice for providing maximum comfort in spectator areas is to physically separate them from pool areas with glass and use a dedicated air handling unit to deliver conditioned air and proper ventilation to that area. However, this method often proves too costly, and spectator areas are often located within the pool space.

For large competition pools, a good option is to have a dedicated air handling unit for the spectator area that is incorporated into the total supply delivery rate of the pool air distribution system. This provides the capability of meeting spectator area ventilation and air distribution requirements while providing a slightly more comfortable supply air temperature.

Due to budgetary concerns the most common design for supplying air to spectator areas utilizes the main pool air handler to ventilate and condition both pool and spectator areas. In this case, the air volume of spectator areas must be included when sizing the main pool air handler and the minimum supply air delivery rate must be 6 air changes per hour, as recommended by ASHRAE. This strategy usually requires a higher percentage of outdoor air to meet system ventilation efficiency requirements. For more information about system ventilation efficiency requirements, see *ASHRAE Standard 62.1-2016*.[3]

Air returned from a pool space to air handling equipment is contaminated with chloramines. Before resupplying to the space, the air handling unit must introduce enough outdoor air to create a healthy space and durable enclosure.

Return airflow rate

ASHRAE recommends keeping pool spaces at a negative pressure of 0.05 to 0.15 inches of water relative to the outdoors and adjacent areas of the building to keep humidity, chemicals, and odors confined to the pool space. To maintain negative pressure in the pool space, the exhaust air rate must exceed the outdoor air supply rate by a margin defined as the excess exhaust air rate. The excess exhaust air rate accounts for infiltration air due to pressure control, which will vary depending on enclosure tightness and doors opening. Because of this variability, negative pressure should be actively controlled, if possible.

Return airflow rate = Supply air delivery rate + Excess exhaust air rate

Innovent recommends designing the excess exhaust air rate at 10% of the supply air delivery rate. When systems are commissioned, we've found that the average excess exhaust resulting from pressure control for a typical pool ranges from 2–10% of supply air volume.

Design for return airflow rate = 1.1 × Supply air delivery rate

Excess exhaust air rate affects pressurization, fan and duct sizes

Some manufacturers recommend the excess exhaust air rate be 10% of outdoor air volume, and they also typically rely on only the "Area Outdoor Air Rate" for calculating outdoor air (see Table 1 and the section starting on page 8, "Determining the outdoor air portion of the supply air"). This approach often results in only 1-2% excess exhaust air, which is only sufficient for extremely tight enclosures. Since exhaust fans and ducts are often sized for this airflow, Innovent believes it is prudent to design the excess exhaust air rate at 10% of the supply air delivery rate.

AIR DISTRIBUTION

Now that the total supply and return air volume to be ducted is determined, the air distribution system can be designed. Proper air distribution in an indoor aquatic facility:

- Prevents condensation
- Prevents corrosion
- Prevents temperature and humidity stratification
- Removes airborne disinfectant by-products such as chloramines
- Provides effective mixing throughout the space
- Delivers fresh, outdoor air to the swimmers' breathing zone (right above the water), to the breathing zone of people on the deck, and to spectators
- Helps maintain the pool space at a slight negative pressure relative to adjacent spaces in the building and outdoor ambient pressure. This prevents exfiltration of chloramines and moisture through openings and leaks in the enclosure.

Supply air distribution

The design of the supply air distribution system for an indoor pool is complex because a typical space has several micro-zones with specific needs for total and outdoor airflow.

Supply air volume directed at exterior wall and roof surfaces must be sized to wash the surfaces with enough air to prevent condensation, especially on glass surfaces.

Air movement over pool surfaces

In the past, HVAC designers limited air movement over pool surfaces to reduce pool water evaporation and the corresponding costs of heating and adding chemicals to pool water. Return air grilles were only placed high in the space, away from the water. This practice resulted in poor removal of chloramines, supply air short-circuiting, and an unhealthy space with a shortened useful life. Since 1999, ASHRAE has recommended directing a portion of the supply air across the pool surface to displace and direct chloramines to a lower level return/exhaust point.

Supply air to the breathing zone over pool and up to 72" above the deck

Some supply air must be directed toward the pool surface to move chloramines away from the swimmer's breathing zone just above the water surface (ASHRAE recommends limiting air velocity at the pool surface to 30 fpm [0.15 m/s]). Some supply air also must be directed toward deck areas (for swim teams, lifeguards, people on the deck), toward the spectator seating area (if a separate unit is not provided for this area), and toward the lower level exterior-facing walls and windows to prevent condensation and corrosion. It may be possible to use a common supply duct with directed nozzles or diffusers for the lower level supply requirements (air to the pool surface, air to the deck breathing zone, and lower level condensation prevention).

Supply air to exterior glass, walls, and roof

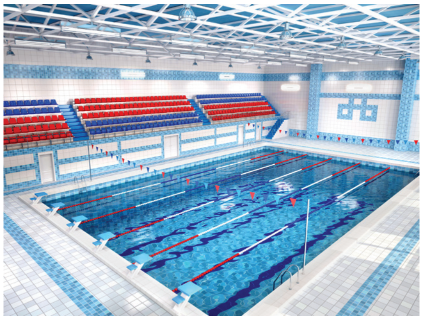
Supply air volume directed at exterior wall and roof surfaces must be sized to wash the surfaces with enough air to prevent condensation, especially on glass surfaces. To meet swimmer comfort and energy efficiency requirements, the ideal pool space relative humidity is 60% RH, which results in a high dew point of typically 67–70 °F (19.4–21.1 °C) and a high potential for condensation. In winter, the dry outdoor air introduced to improve indoor air quality forces the relative humidity down (typically to the 40-50% RH range), but the space dew point typically remains high at 55–65 °F (12.7–18.3 °C). Interior surfaces should be kept 5 °F (2.7 °C) above the space dew point by washing entire surfaces with supply air to prevent condensation.

Supply air to spectator areas

If the spectator area is located within the pool space, supply air directed to this area must deliver the design minimum outdoor air amount for a swim meet (7.5 cfm/spectator + 0.06 cfm/sq ft of area, as described in Table 1).

Depending on the amount of supply airflow needed for spectator areas and enclosure condensation/corrosion prevention above the breathing zone, the ratio of air delivered high in the space vs. low in the space may vary from 30% high/70% low for a lower height facility with few windows, to 60% high/40% low for a tall facility with a large spectator space and significant potential for condensation on the exterior surfaces. The effectiveness of the supply distribution required to meet the ventilation requirements of each zone will have an impact on the amount of outdoor air required to be included in the supply air delivery rate. Refer to guidelines for outdoor air beginning on page 8.

It may be possible to use a common supply duct, with properly sized and directed nozzles or diffusers, to deliver air to spectators and upper-level areas requiring condensation prevention and mixing, with exhaust air collection at a high return point.



The chlorides in chloramines attack building materials exposed to pool air and cause corrosion and early component failure.

Location of return air inlets

A combination of low and high return air grilles promotes chloramine removal, good mixing throughout the space, and prevents stratification and corrosion.

At the low return level there are three strategies for removing chloramines that concentrate over the pool:

1. Low-level deck return, with grille(s) located a few feet above deck level that mix with upper level return air prior to the air handling unit
2. Low-level deck exhaust, with grille(s) located a few feet above deck level connected to a dedicated exhaust duct to avoid mixing with return air
3. Source capture, a system that has multiple exhaust points in the water level pool gutter that are manifolded into one exhaust duct

Source capture systems are most effective at removing chloramines when water is undisturbed (unoccupied). Systems with low level deck return or exhaust may be better for swimmer health because chloramines are displaced and moved away from where swimmers breathe. Source capture systems and dedicated low level deck exhaust ducts should theoretically remove a higher concentration of chloramines. They often can be incorporated into the pool air handler for additional first cost. A low level deck return (Strategy 1 above) that mixes with upper level return air before connection to the air handling unit has the lowest first cost of these three strategies and is very effective at chloramine removal when combined with proper ventilation air.

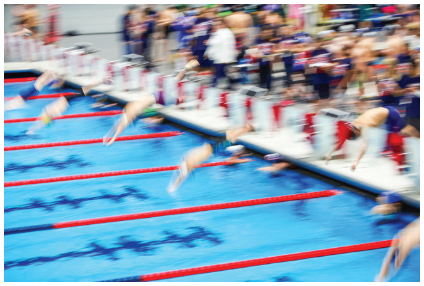
At the high return level, locate the return point(s) to promote mixing by capturing air supplied to spectator areas and to the upper level for preventing condensation and corrosion. Care must be taken to avoid locating the return point(s) immediately adjacent to supply diffusers to prevent short-circuiting of the supply air.

Air distribution system materials and construction

The chlorides in chloramines attack building materials exposed to pool air (especially carbon steel, and also stainless steel), and cause unsightly corrosion and early component failure.

Coated steel can be used successfully as long as the coating is intact, but any scratches or poorly coated areas will result in corrosion that can reduce the useful life of the pool enclosure, air distribution, and air handling equipment and, in the extreme case, cause structural failure.

Aluminum is the preferred material for ducting if metal duct is desired. Fabric duct is also commonly used. Air handler interior walls, floors (including drain pans), and components such as dampers, fan wheels, and heat



Depending on climate, the outdoor air introduced to improve indoor air quality, which is drier than the warm humid return/exhaust air it replaces for most of the year, can reduce or completely eliminate the dehumidification load.

exchangers should be made of aluminum, and coils should be completely coated with an elastic baked epoxy or phenolic coating. Components that must be made of steel for strength, such as fan isolation bases, should have an epoxy or phenolic coating. Use of coated steel inner walls and floors in air handlers should be avoided because the coatings are easily scratched during servicing no matter what type of coating process is used, and the underlying steel corrodes, shortening the life of the unit.

DETERMINING THE OUTDOOR AIR PORTION OF THE SUPPLY AIR

Air returned from a pool space to air handling equipment is contaminated with chloramines. Before resupplying to the space, the air handling unit must replace enough of the return air with outdoor air to create a healthy space and durable enclosure.

The moisture level of the return air must also be reduced before resupplying the space so that it can absorb evaporated pool water and other moisture from spectators or outdoor air on very humid summer days to maintain the space humidity set point. Depending on climate, the outdoor air introduced to improve indoor air quality, which is drier than the warm humid return/exhaust air it replaces for most of the year, can reduce or completely eliminate the dehumidification load. For more information about using outdoor air to dehumidify pool environments see our white paper, Energy efficiency in indoor aquatic facilities.

Note: Outdoor air is not a replacement for proper water treatment. The sizing recommendations made here assume an effective water treatment system.

Start with ASHRAE guidelines

ASHRAE minimum ventilation rate

ASHRAE Standard 62.1 prescribes an amount of outdoor air that, according to the ASHRAE Applications Handbook section on natatoriums,[4] is intended to provide acceptable air quality for an average pool using chlorine as the primary disinfectant (see Table 1). Based on this table, the minimum ventilation rate required to be delivered to the breathing zone (minimum amount of outdoor air) is 0.48 cfm/ft^2 for swimming pool and deck areas. The breathing zone is the area between 3" and 72" (7.6–183 cm) above the floor.

Table 1's Note C defines the deck area as “the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied.” Wetted deck areas and the pool itself can off-gas chloramines, which must be removed with ventilation. Any deck areas not capable of being wetted must be designated as another occupancy category (such as spectator space). Since deck areas for competition pools are not typically

Table 1: Minimum Ventilation Rates in Breathing Zone[1]

	People Outdoor Air Rate		Area Outdoor Air Rate			Default Values			
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
Occupancy Category: Sports and Entertainment	cfm/person	L/s•person	cfm/ft^2	L/s•m^2	**Notes**	#/1000 ft^2 or #/100 m^2	cfm/person	L/s•person	Air Class
Spectator areas	7.5	3.8	0.06	0.3	H	150	8	4.0	1
Swimming (pool & deck)	—	—	0.48	2.4	C	—			2

Notes
1 From Table 6.2.2.1, *ANSI/ASHRAE Standard 62.1-2016. Ventilation for Acceptable Indoor Air Quality.*
4 Default occupant density: The default occupant density shall be used where the actual occupant density is not known.
5 Default combined outdoor air rate (per person): Rate is based on the default occupant density.
C Rate does not allow for humidity control. "Deck area" refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.
H Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode.

large, and the layout of most recreational pools has minimal possibility of dry surface, the conservative approach for the designer is to include all pool and deck areas in the calculation.

For spectator areas (and any deck area the designer determines is not capable of being wetted during pool use), the minimum ventilation rate is calculated using both the "Area Outdoor Air Rate" and "People Outdoor Air Rate" for the applicable occupancy category (other areas might include hotel recreation spaces). For spectator areas this is 0.06 cfm/ft^2 plus an additional 7.5 cfm/person when spectators are present. Table 1's Note H allows outdoor air to be reduced to zero in spectator areas when no people are present.

Regarding the minimum ventilation rates in Table 1, the ASHRAE Applications Handbook on natatoriums states:

> ***"The ventilation requirement may be excessive for private pools and installations with low use, and may also prove inadequate for high-occupancy public or water park installations."***[4]

Since most public pools are intended to be high occupancy and used heavily, it follows that designing based on the ASHRAE 62.1 ventilation rates prescribed in Table 1 may be inadequate at providing an owner a healthy facility with acceptable air quality. In fact, this has proven to be the case in many installations across the country over the last 20 years.[1] Innovent's experience has supported the conclusion that one ventilation rate cannot meet the requirements of a wide variety of pool types and spaces.

The following affects the amount of outdoor air needed in pool spaces:

1. Facility type and associated swimmer activity level, water agitation, and water features

Pool water evaporation increases with swimming, diving, and splashing. Activity factors modify the estimated evaporation rate based on pool activity.

Table 2: ASHRAE natatorium activity factors[1]

Type of Pool	Typical Activity Factor
Baseline (pool unoccupied)	0.5
Residential pool	0.5
Condominium	0.65
Therapy	0.65
Hotel	0.8
Public schools	1.0
Whirlpools, spas	1.0
Wavepools, water slides	1.5 (minimum)

Notes
1 From "Places of Assembly: Natatoriums," *2015 ASHRAE Handbook: Applications.* ASHRAE.

2. Air distribution complexity, as discussed in the previous section, and the effectiveness of air distribution at providing outdoor air to each micro-climate within the space

ASHRAE activity factors

ASHRAE defines a pool evaporation rate equation that is valid for pools at normal activity levels, allowing for splashing and a limited area of wetted deck.[4] For pools with more or less evaporation, activity factors have been defined that modify the estimated evaporation rate based on pool activity (Table 2).

Pool water evaporation increases when water/air surface area increases with swimming, diving, splashing, and water features such as slides, sprays, fountains, dump buckets, etc. The off-gassing of chloramines also increases with the increased surface area, and more water treatment is necessary with higher activity and agitation. A community recreation center with some water features may have two to three times more evaporation than a hotel pool; and a public school pool may have 50% more evaporation than a pool with little agitation like a therapy pool.

System Ventilation Efficiency and Zone Air Distribution Effectiveness

ASHRAE 62.1 describes two concepts regarding the ability of an air distribution system to effectively provide outdoor air to spaces with multiple zones served by the same air distribution system (System Ventilation Efficiency) and with various configurations of supply and return points in the same space (Zone Air Distribution Effectiveness).[3] These two concepts describe the air distribution requirements of most indoor pools.

For example, if ASHRAE 62.1 (Table 1) requires 0.48 cfm/sq ft outdoor air to be delivered to the breathing zone, but 50% of the supply airflow (and, therefore, 50% of the outdoor air) is required to be distributed/utilized above the breathing zone to provide proper mixing, prevent condensation and corrosion, and provide fresh air for spectators, then the minimum outdoor air in the supply air from the air handling unit would need to be doubled.

In another example, if 30% of the supply airflow is delivered to the spectator area, then 40-50% of the supply air might need to be outdoor air to deliver the required 7.5 cfm/spectator of outdoor air. These situations might result in a System Ventilation Efficiency of 65–85%. In addition, the Zone Air Distribution Effectiveness for an air distribution configuration that has supply air points on the opposite side of a room from exhaust/return air points, which is often the case in pools, is 80%.

Adjust ASHRAE guidelines for activity and air distribution requirements

ASHRAE pool activity factors and air distribution factors can be used to modify the minimum ventilation rates prescribed in Table 1 to more

Innovent's minimum outdoor air multipliers (Table 3) account for pool activity and ceiling height and, therefore, achieve more accurate outdoor air calculations.

accurately meet the ventilation requirements of a variety of pool types and spaces.

Ventilation efficiency decreases as ceiling height increases and the distance of the supply points from the deck increases. Air distribution requirements to prevent condensation on walls, roofs, and skylights; to supply spectator areas; and to provide good mixing to prevent corrosion and stratification dictate that a significant amount of the supply air (and therefore outdoor air) be delivered to areas above the breathing zone. As a result, the space height may be used as a reasonable proxy for the air distribution factor.

Innovent's experience has shown that the formula in Table 1 provides successful results for low-height pool spaces (15' [4.5 m]) with relatively low activity. For pools with greater activity and higher ceilings, the minimum outdoor air rate needs to be increased. This means that for most public pool spaces the minimum amount of outdoor air required to provide a healthy and non-corrosive environment can be significantly more than what ASHRAE prescribes in Table 1. This is in keeping with the ASHRAE Applications Handbook's statement that the ventilation requirement prescribed in Table 1 "may prove inadequate for high-occupancy public or water park installations."[4]

Building upon ASHRAE's recommendations and statements, and relying on our experience gained from designing over 1,000 HVAC systems for a variety of indoor aquatic facility types, Innovent has created minimum outdoor air multipliers that modify ASHRAE's swimming pool and deck ventilation rates to achieve a more accurate minimum outdoor air calculation based on pool activity and ceiling height. See Table 3.

Table 3:
Minimum ventilation rate (outdoor air amount) multipliers for indoor aquatic facility pool and deck areas

Pool type	Residential	Therapy/condo	Hotel	Public/school	Community rec	Rec plus	Small hotel water park
Activity factor	0.50	0.65	0.80	1.00	1.25	1.5	2.0
Pool height	MINIMUM OUTDOOR AIR MULTIPLIER						
15 ft	0.85	1.00	1.19	1.39	1.59	1.75	2.06
20 ft	0.89	1.04	1.24	1.45	1.65	1.82	2.14
25 ft	0.92	1.08	1.29	1.50	1.71	1.89	2.23
30 ft	0.96	1.12	1.34	1.56	1.78	1.96	2.31
35 ft	0.99	1.16	1.38	1.62	1.84	2.03	2.39
40 ft	1.03	1.20	1.43	1.67	1.90	2.10	2.47
45 ft	1.07	1.24	1.48	1.73	1.96	2.17	2.55
50 ft	1.10	1.28	1.52	1.78	2.03	2.24	2.63

Note
The minimum ventilation rate (amount of outdoor air required) for an indoor aquatic facility pool and deck area = 0.48 cfm/sq ft of pool and deck × Minimum outdoor air multiplier.

Incorporating the minimum outdoor air multiplier from Table 3, the minimum ventilation rate calculation becomes (for pool and deck areas during normal operating mode, not during a swim meet):

Minimum ventilation rate = 0.48 cfm/sq ft of pool & deck × Minimum outdoor air multiplier

Note: If the pool has a spectator space, the designer should verify that the outdoor air required for swim meet spectators (7.5 cfm/spectator + 0.06 cfm/sq ft) will be provided by the supply air directed at the spectator area. For example, if 30% of the supply air is directed at the spectator area, then multiply the minimum ventilation rate calculated above by 30%, and verify that the result is greater than the outdoor air required for spectators, adjusting the minimum ventilation rate up as necessary.

In Innovent's experience, using the minimum outdoor air multiplier has proven very effective at creating healthy indoor pool environments. The best news for owners is that a pool air handling system designed to embrace the health and economic advantages of outdoor air can provide a healthier space at a lower total operating cost than a mechanical dehumidification system. We discuss the pros and cons of these two approaches in detail in our guide, Energy efficiency in indoor aquatic facilities.

Exhaust airflow rate

The exhaust airflow rate required is equal to the design outdoor airflow rate plus the excess exhaust airflow rate discussed earlier. Note that modes of operation such as purge modes for super-chlorination, swimming meet modes requiring additional outside air for spectators, or systems using more outdoor air for efficient dehumidification result in a higher exhaust airflow rate.

Detecting and removing chloramines from a pool space

Recently there has been discussion in the industry on the identification and monitoring of chloramine levels in pool spaces. In particular, volatile organic compound (VOC) sensors have been proposed as a way to evaluate chloramine levels and adjust the amount of outdoor air introduced into the space. Per The Centers for Disease Control,

> ***"No rapid, simple, and commercially available tests for di- and tri-chloramine exist at the current time. However, monitoring for trichloramines can also be effectively accomplished by training pool operators to be on alert for the distinctive chloramine odor and eye and lung irritation it causes. The odor threshold for trichloramine is 0.1 mg/m^3 and health symptoms start happening around 0.3-0.5 mg/m^3, so odor monitoring generally works well as an early warning system."*** [2]

VOC sensors do not measure chloramines because chloramines are not VOCs (they are inorganic). In addition, there are currently no recognized safe levels for chloramine concentration. Attempting to measure a known health hazard with an inapplicable sensor to make pool space ventilation decisions when there is no accepted safe chloramine level is not advisable. Currently, the only reliable way to detect chloramines is with your nose.

SUMMARY

Healthy and durable indoor pool environments require a well-designed ventilation system with effective air distribution and enough outdoor and exhaust air to remove toxic and corrosive chloramines from the space. The key question becomes: How much outdoor air is required? The answer is that it varies depending on a number of factors, including pool type, pool activity, ceiling height, and air distribution complexity and effectiveness. Innovent's outdoor air multiplier, described in Table 3, builds upon the foundation of ASHRAE's minimum ventilation formulas by taking these factors into account and providing a method to accurately calculate outdoor air requirements for a wide variety of indoor aquatic facilities.

About the author

Gary Lochner is Senior Director, Application Engineering, Sales at Innovent. He holds a Mechanical Engineering Degree with heat transfer emphasis from the University of Minnesota. His background includes technical and leadership positions at a major HVAC manufacturer and a succession of roles at Heatex and Innovent. For nearly twenty-five years Gary has helped design over 1000 HVAC units serving indoor aquatic facilities, ranging from high school pools to community rec centers to major water parks. Gary has spoken on design considerations for these spaces at many ASHRAE chapter meetings. This broad experience has uniquely equipped him with a deep understanding of the many complex factors at play in natatoriums.

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www.innoventair.com/applications-expertise/natatoriums
Innovent's online resource for healthy and energy efficient indoor aquatic facilities

Design Guide
Energy efficiency in indoor aquatic facilities: Thoughtful choices yield significant energy savings. Gary Lochner.

Chloramines & Pool Operation
Website from The Centers for Disease Control and Prevention
www.cdc.gov/healthywater/swimming/aquatics-professionals/chloramines.html

REFERENCES	
1	“Chloramines and Pool Operation,” The Centers for Disease Control and Prevention’s Healthy Swimming Website, www.cdc.gov/healthywater/swimming/aquatics-professionals/chloramines.html
2	Section 4.6.2.7.12, Air Handling System Filters/Air Quality—Health, *2016 Annex to the Model Aquatic Health Code,* 2nd Edition, July 2016. The Centers for Disease Control and Prevention.
3	*ANSI/ASHRAE Standard 62.1-2016. Ventilation for Acceptable Indoor Air Quality.* ASHRAE.
4	“Places of Assembly: Natatoriums.” *2015 ASHRAE Handbook: Fundamentals.* ASHRAE.

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