Model Aquatic Health Code

Draft Ventilation and Air Quality Module ANNEX Section Modified After the First 60-day Review that Closed on 6/12/2011

Informational Copy: NOT Currently Open for Public Comment

This version of the MAHC Ventilation Module has been modified based on the first round of public comments received. It is being re-posted so users can view how it was modified but is not currently open to public comment. The complete draft MAHC, with all of the individual module review comments addressed will be posted again for a final review and comment before MAHC publication. This will enable reviewers to review modules in the context of other modules and sections that may not have been possible during the initial individual module review. The public comments and MAHC responses can be viewed on the web at http://www.cdc.gov/healthywater/swimming/pools/mahc/structure-content/index.html

The MAHC committees appreciate your patience with the review process and commitment to this endeavor as we all seek to produce the best aquatic health code possible.

This information is distributed solely for the purpose of pre dissemination public viewing under applicable information quality guidelines. It has not been formally disseminated by the Centers for Disease Control and Prevention. It does not represent and should not be construed to represent any agency determination or policy.

MAHC Ventilation and Air Quality Module Abstract

Health issues related to indoor pool use and associated poor water and air quality are increasingly being documented. The Ventilation and Air Quality Module is a first step towards improving air quality at indoor aquatic facilities and reducing associated health effects. The Ventilation and Air Quality Module contains requirements for new or substantially altered construction that include:

1) Reliance on ASHRAE 62.1 for determining the amount of outdoor air required.
2) Discussion in Appendix 1 of an alternative way to determine the extra make-up air needed based on the indoor venue water use type (e.g., flat water, agitated water, or hot water) and venue or deck patron density (square feet/person).
3) Outlining of air handling system performance criteria
4) Outlining of operator maintenance, recordkeeping, and operational requirements.
5) Development and implementation of plans to reduce combined chlorine compounds in indoor aquatic facilities and inform facility patrons of their impact on building air quality.

The Ventilation and Air Quality CODE Module shows a Table of Contents giving the context of the Ventilation Design, Construction, Operation and Maintenance in the overall Model Aquatic Health Code's Strawman Outline (http://www.cdc.gov/healthywater/pdf/swimming/pools/mahc/structure-content/mahc-strawman.pdf).

Note on the MAHC Annex

Rationale

The annex is provided to:

(a) Give explanations, data, and references to support why specific recommendations are made;
(b) Discuss the rationale for making the code content decisions;
(c) Provide a discussion of the scientific basis for selecting certain criteria, as well as discuss why other scientific data may not have been selected, e.g. due to data inconsistencies;
(d) State areas where additional research may be needed;
(e) Discuss and explain terminology used; and
(f) Provide additional material that may not have been appropriately placed in the main body of the model code language. This could include summaries of scientific studies, charts, graphs, or other illustrative materials.

Content

The annexes accompanying the code sections are intended to provide support and assistance to those charged with applying and using Model Aquatic Health Code provisions. No reference is made in the text of a code provision to the annexes which support its requirements. This is necessary in order to keep future laws or other requirements based on the Model Aquatic Health Code straightforward. However, the annexes are provided specifically to assist users in understanding and applying the provisions uniformly and effectively. They are not intended to be exhaustive reviews of the scientific or other literature but should contain enough information and references to guide the reader to more extensive information and review.

It is, therefore, important for reviewers and users to preview the subject and essence of each of the annexes before using the document. Some of the annexes (e.g., References, Public Health Rationale) are structured to present the information in a column format similar to the code section to which they apply. Other annexes or appendices provide information and materials intended to be helpful to the user such as model forms that can be used, recreational water illness outbreak response guidelines, and guidelines for facility inspection.

Appendices

Additional information that falls outside the flow of the annex may be included in the Model Aquatic Health Code Annex

Acronyms and Initialisms in this Module: See the Ventilation and Air Quality Module, Code Section

Glossary Terms in this Module: See the Ventilation and Air Quality Module, Code Section

Preface: *This document does not address all health and safety concerns, if any, associated with its use. It is the responsibility of the user of this document to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to each use.*

Model Aquatic Health Code
Ventilation ANNEX

Keyword	Section	Annex
	4.0	**Design Standards and Construction**
	4.1	**Plan Submittal**
	4.2	**Materials**
	4.3	**Equipment Standards**
	4.4	**Pool Operation and Facility Maintenance**
	4.5	**Pool Structure**
	4.6	**Indoor/Outdoor Environment**
	4.6.1	**Lighting**
Ventilation	**4.6.2**	**Indoor Aquatic Facility Ventilation**

Background of Ventilation and Air Quality Technical Committee Work on the MAHC:

Numerous local and state health CODEs (N=28) plus the National Environmental Health Association (NEHA) recommendations regarding ventilation were reviewed. The Committee found that:

- Most addressed only moisture control
- The terms used were sometimes vague with 11 of the 28 CODEs having very general language typically stating "adequate" or "proper" ventilation without clear definitions of these terms.
- Only three CODEs and NEHA specify compliance w/ASHRAE standards.
- Most refer to their state and/or local ventilation and/or mechanical CODE for compliance requirements.
- Only five have developed other state-specific criteria for air turnover and exchange.

As a result of this varied and sometimes vague approach to defining “proper” ventilation, it is critical that the MAHC begins to better define AIR HANDLING SYSTEMS and establish parameters for air quality that reduces the risk of potential health effects. The aquatic industry has always had a challenge with indoor air quality. With the relatively recent increases in building of large indoor waterparks, which have high BATHER loads and a contamination burden unseen before, indoor air quality is an increasingly important health concern. The media focus in recent years has highlighted this challenge. Although the AIR HANDLING

Keyword	Section	Annex
		SYSTEMS of these AQUATIC FACILITIES are quite sophisticated, there are many variables to consider. In addition, much research is still needed in water chemistry and the use of other technologies to improve indoor air quality. The MAHC outlines the design, performance, and operational parameters that can be detailed using data available at the current time. The Annex information provides insight into the Ventilation and Air Quality Technical Committee's rationale and also identifies areas where more research is needed before additional parameters can be set. It was the intent of the Technical Committee to require the design of an INDOOR AQUATIC FACILITY to be conducted by a licensed professional engineer with experience in the design of mechanical systems. The Technical Committee approached this section assuming designs will be evaluated by the AHJ in the location in which the system is to be installed.
Purpose	4.6.2.1	The purpose of the AIR HANDLING SYSTEM is to assure the health and comfort of the users of the AQUATIC FACILITY. A variety of health effects can occur as a result of poor ventilation that leads to accumulation of chemical and biological products in the air. The following section reviews some of the issues of concern for INDOOR AQUATIC FACILITIES. <u>Chemical by-products:</u> The oxidation of waterborne organic and inorganic compounds by CHLORINE- or other halogen-based products is a complex process leading to creation of a large number of oxidation and DISINFECTION BY-PRODUCTS (DBPs) during the drinking water and aquatic water treatment processes. The source of these compounds is variable but includes source water CONTAMINANTS, BATHER waste (e.g., feces, urine, sweat, skin cells), and environmental introductions (e.g., dirt). Although the identity of many of these compounds is known, many others are uncharacterized and the health effects associated with short and long-term exposure to these compounds are only just starting to be characterized for the aquatic environment. Several of these compounds are known to be volatile and can accumulate in the air surrounding an INDOOR AQUATIC VENUE. Multiple publications discuss the acute and potentially long-term health effects of exposure to these

Keyword Section Annex

compounds in the aquatic setting.[1,2,3]

The nitrogenous oxidation by-products DICHLORAMINE and trichloramine (e.g., chloramines) are known to be irritants that cause acute eye and lung distress. Accumulation of these compounds in indoor settings has been previously documented in several occupational settings where workers routinely use chlorinated solutions to rinse organic products such as poultry[4,5] and uncooked produce.[6] Similar symptoms of ocular and respiratory distress have been documented in outbreaks associated with use of indoor aquatic settings.[7,8,9,10,11,12] Other suspected chloramine-associated outbreaks are listed in past issues of CDC's Waterborne Disease and Outbreak Surveillance Summaries that can be viewed at http://www.cdc.gov/healthywater/surveillance/surveillance-reports.html

Other DISINFECTION BY-PRODUCTS (DBPs) such as the trihalomethanes have been studied extensively due to their production during treatment of drinking water. These investigations have greatly impacted U.S.EPA water treatment regulations, so there is now a major emphasis on reducing production of DBPs. The effects of these compounds in model systems show long-term exposure associated with chronic

---

[1] LaKind JS, et al. The good, the bad, and the volatile: can we have both healthy pools and healthy people? Environ Sci Technol. 2010;44(9):3205-10.
[2] Zwiener C, et al. Drowning in disinfection byproducts? Assessing swimming pool water. Environ Sci Technol. 2007;41(2):363-72.
[3] Weisel CP, et al. Childhood asthma and environmental exposures at swimming pools: state of the science and research recommendations. Environ Health Perspect. 2009;117(4):500-7.
[4] King BS et al. Eye and respiratory symptoms in poultry processing workers exposed to chlorine by-products. Am J Ind Med. 2006;49(2):119-26.
[5] Sanderson W et al. Case reports: epidemic eye and upper respiratory irritation in poultry processing plants. Appl Occup Environ Hyg 1995;10:43–49.
[6] Hery M et al. Exposure to chloramines in a green salad processing plant. Ann Occup Hyg 1998;42:437–451.
[7] CDC. Ocular and respiratory illness associated with an indoor swimming pool — Nebraska, 2006. MMWR Morb Mortal Wkly Rep 2007;56;929-932.
[8] Kaydos-Daniels SC et al. Health effects associated with indoor swimming pools: a suspected toxic chloramine exposure. Public Health 2008;122:195-200.
[9] Bowen A et al. Outbreaks of short-incubation illness following exposure to indoor swimming pools. Environ Health Perspect 2007;115:267-271.
[10] CDC. Respiratory and ocular symptoms among employees of a hotel indoor waterpark resort --- Ohio, 2007 MMWR Morb Mortal Wkly Rep 2009;58;81-85
[11] Dang B et al. Ocular and respiratory symptoms among lifeguards at a hotel indoor waterpark resort. J Occup Environ Med. 2010;52(2):207-13.
[12] Hlavsa MC et al. Recreational water–associated disease outbreaks — United States, 2009–2010. MMWR Morb Mortal Wkly Rep. 2014;63(1):6-10.

Keyword Section Annex

health effects such as bladder cancer.[13,14]

Investigators are beginning to examine the long term health effects of exposure to DBPs during swimming. Although limited, some data suggests the potential for increased risk of asthma[15,16] and bladder cancer. [17] However, many of these studies are ecologic in design, which makes it difficult to definitively link exposures, actual exposure levels, and, swimming. [18,19,20]

Biological by-products: A variety of biological organisms that grow naturally in the environment (e.g., *Legionella*, *Mycobacterium avium* complex and other non-tuberculous mycobacteria, gram negative bacteria) or their constituents (e.g., proteins, lipo-polysaccharides, endotoxin) can be spread in the indoor pool environment and cause infections[21,22] and hypersensitivity/allergic reactions (e.g., "Hot tub lung"; "Lifeguard lung", Pontiac fever).[23,24,25,26,27] The levels of pathogens and

---

[13] Villanueva CM, et al. Disinfection byproducts and bladder cancer: a pooled analysis. Epidemiology. 2004;15(3):357-67.
[14] Cantor KP. Carcinogens in drinking water: the epidemiologic evidence. Rev Environ Health. 2010;25(1):9-16.
[15] Bernard A, et al. Impact of chlorinated swimming pool attendance on the respiratory health of adolescents. Pediatrics 2009;124(4):1110-8.
[16] Bernard A, et al. Infant swimming practice, pulmonary epithelium integrity, and the risk of allergic and respiratory diseases later in childhood. Pediatrics 2007;119(6):1095-103.
[17] Villanueva CM et al. Disinfection byproducts and bladder cancer: a pooled analysis. Epidemiology. 2004;15(3):357-67.
[18] Font-Ribera L, et al. Swimming pool attendance, asthma, allergies and lung function in the Avon Longitudinal Study of Parents and Children (ALSPAC) Cohort. Am J Respir Crit Care Med. 2011;183:582-8.
[19] Cantor KP. Carcinogens in drinking water: the epidemiologic evidence. Rev Environ Health. 2010;25(1):9-16.
[20] Weisel CP et al. Childhood asthma and environmental exposures at swimming pools: state of the science and research recommendations. Environ Health Perspect. 2009;117(4):500-7.
[21] Fields BS et al. *Legionella* and Legionnaires' disease: 25 years of investigation. Clin Microbiol Rev. 2002;15(3):506-26
[22] Falkinham JO 3rd. Mycobacterial aerosols and respiratory disease. Emerg Infect Dis. 2003;9(7):763-7.
[23] Hanak V et al. Causes and presenting features in 85 consecutive patients with hypersensitivity pneumonitis. Mayo Clin Proc. 2007;82(7):812-6.
[24] Sood A et al. Hypersensitivity pneumonitis-like granulomatous lung disease with nontuberculous mycobacteria from exposure to hot water aerosols. Environ Health Perspect. 2007;115(2):262-6.
[25] Rose CS et al. "Lifeguard lung": endemic granulomatous pneumonitis in an indoor swimming pool. American J Public Health. 1998;88(12):1795-800.
[26] Burnsed LJ et al. Legionellosis Outbreak Investigation Team. A large, travel-associated outbreak of legionellosis among hotel guests: utility of the urine antigen assay in confirming Pontiac fever. Clin Infect Dis. 2007;44(2):222-8.
[27] Tossa P et al. Pontiac fever: an operational definition for epidemiological studies. BMC Public Health. 2006;6:112.

Keyword	Section	Annex
		their constituents can be minimized with adequate AQUATIC FACILITY ventilation, maintenance, and required water quality.
Exemptions	4.6.2.2	The Technical Committee decided that only "buildings" as defined in the building code would be included in the scope of the INDOOR AQUATIC FACILITY definition since there are many variables to consider for places like open buildings (may not have a roof or missing sides) such as variations in weather, geographic zone, etc that would impact AIR HANDLING SYSTEM design even if one was needed. The guidelines in this module are meant to address the safety and health of users in environments in which air quality is managed by mechanical means due to the "closed" environment since fresh air is not able to freely flow through the building.
ASHRAE 62.1	4.6.2.5	The hierarchy of design was important in deciding what priorities were taken in the development of the design section. The following hierarchy was determined by the Technical Committee.

1) Indoor air quality - chemical, biological, and physical CONTAMINANT load
2) Moisture removal – humidity and temperature
3) Cost of energy – important to larger sites

When determining the factors a design professional considers, much discussion centered around ASHRAE 62 and the parts of design not specifically listed in ASHRAE 62 as it applies to INDOOR AQUATIC FACILITIES.

- There are two safety functions of the AIR HANDLING SYSTEM: to bring in fresh air and to protect the building and users, which requires movement of air. The current standard states 0.48 cfm/ft^2 fresh air is the minimum but still requires turnover. The CODE needs to consider turnover of air like turnover for AQUATIC VENUES; it should be based on BATHER load and the size and use of the building.
- The current standards approach to ventilation is based on square footage of the facility and yet AQUATIC FACILITIES vary in size. Some facilities have a 20 foot (6m) ceiling and in the case of indoor waterparks and stadium-style natatoriums, the ceiling heights can reach 60+ feet (18m). However, the water surface area has a great deal to do with the amount of CONTAMINANTS released into the air.
- There are many microclimates in larger AQUATIC FACILITIES with varied AQUATIC VENUES AND AQUATIC FEATURES. Air movement will need to be targeted within these

Keyword | Section | Annex

microclimates.

- The challenge is that ASHRAE 62 takes into account the number of users, not the building size.
- ASHRAE fundamentals require turnover of the volume of air. Designers felt water chemistry, fresh air, BATHER load, water surface area, and distribution of air (barring condensation) are more important than volume turnover.

System Design

4.6.2.6 Air Handling System Design

Design Factors and Performance Requirements

4.6.2.6.2 **Design Factors and Performance Requirements**

Known chemical, biological, and physical CONTAMINANTS.

The Technical Committee discussed the various chemical and biological CONTAMINANTS, the availability of testing protocols, and data to support developing health effect thresholds.

Chemical	**Biological**
Trichloramines	*Mycobacterium avium* complex
Trihalomethanes	*Legionella* spp. (primarily *L. pneumophila*)
Other chlorinated compounds	Endotoxin

The researchers on the committee were able to provide a list of research regarding the thresholds of such CONTAMINANTS that produced symptoms in users of INDOOR AQUATIC FACILITIES. More detailed summaries of these data can be found in Appendix 2: Summary of Health and Exposure Data for Chemical and Biological Contaminants.

After evaluating possible CONTAMINANTS, the committee felt the most frequently detected adverse health symptoms associated with indoor air quality were related to chemical CONTAMINANTS. In evaluating the various chemical CONTAMINANTS, it was found that

Keyword Section Annex

trichloramine was the most prevalent CONTAMINANT reported[28]. Therefore, this section of the MAHC focused on trichloramine as the major chemical CONTAMINANT for design considerations.

The table below summarizes findings on the threshold amounts that produced adverse health symptoms.

- Gagniere 1994[29] 0.5 mg/m^3
- Levesque 2006[30] 0.37 mg/m^3
- Hery 1995[31] 0.5 - 0.7 mg/m^3
- Massin 1998[32] 0.5 mg/m^3
- Jacobs 2007[33] 0.56 mg/m^3 (average)
- Thickett 2002[34] 0.5 mg/m^3

In evaluating the trichloramine research, it was apparent there is not a single test method used throughout the research. Without a validated test method, it is difficult to compare and benchmark the data from the various studies. As a result, a firm threshold could not be determined solely on the published research to date. Also, without a validated and simple test method, there is not an easy way for health departments or owner/operator to test routinely or with any consistency. For these two reasons, the Technical Committee felt it could not establish a threshold to be enforced by this section of the MAHC at this time. More research using a validated test method may lead to determination of a threshold level in the future. To enforce such a threshold level, the test also needs to be commercially available and easily performed by aquatics staff and health officials.

Therefore, the performance requirements for the AIR HANDLING SYSTEM have parameters for fresh air and dew point/humidity. To accomplish this, several design criteria were kept in mind.

---

[28] Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. Eur Respir J. 2002;19(5):827-32.
[29] Gagnaire F, et al. Comparison of the sensory irritation response in mice to chlorine and nitrogen trichloride. J Appl Toxicol. 1994;14(6):405-9.
[30] Lévesque B, et al. The determinants of prevalence of health complaints among young competitive swimmers. Int Arch Occup Environ Health. 2006;80(1):32-9.
[31] Hery M, et al. Exposure to chloramines in the atmosphere of indoor swimming pools. Ann Occup Hyg 1995;39(4):427-439.
[32] Massin N, et al. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. Occup Environ Med. 1998;55(4):258-63.
[33] Jacobs JH, et al. Exposure to trichloramine and respiratory symptoms in indoor swimming pool workers. Eur Respir J. 2007;29(4):690-8.
[34] Thickett KM et al. Occupational asthma caused by chloramines in indoor swimming-pool air. Eur Respir J. 2002;19(5):827-32.

Keyword Section Annex

1) Fresh air requirements are established to specific levels. The theory is that if the building mechanical system is able to evacuate enough air to remove trichloramine, then by default the other airborne CONTAMINANTS would also be evacuated.
2) Dew point/humidity levels are set to avoid mold growth and damage to the building structure.

In the future, if a readily available, standard air testing method for trichloramine is developed and a trichloramine or other CONTAMINANT threshold can be determined, then it is the recommendation of the Technical Committee that the MAHC adopt such an action threshold for air quality. Additionally, based on the air data threshold set, a threshold should also be re-evaluated and/or revised for combined CHLORINE compounds in water to minimize production and off-gassing of the volatile chloramines.

It was recognized by the Technical Committee that secondary disinfection systems (e.g., ozone, U.V.) could help to reduce the amount of off-gassing of DBPs and therefore would need less volumes of outside air to dilute the concentration of these chemicals in the air.

- Basic treatment includes the use of CHLORINE or bromine and standard filtration and will require a certain amount of outside air per AQUATIC VENUE type.
- UV/Ozone or other technology that is used to aid in the reduction of DBPs could reduce the amount of outside air required.
  - The efficacy of UV and ozone are well documented for their effect on biological CONTAMINANTS but the photochemistry taking place is a different reaction for DISINFECTION vs. controlling combined CHLORINE levels. Further research is needed to determine the effectiveness of UV and ozone on destroying DBPs before they can be considered in the design of an AIR HANDLING SYSTEM. Guidance will be included in the MAHC for the use of UV and ozone for DISINFECTION. It is unknown at this time if the parameters for the equipment to achieve DISINFECTION will also result in the reduction of DBPs.
  - The initial draft of the Ventilation and Air Quality Module included discussion of fresh air requirements for facilities utilizing UV and ozone, which allowed for a reduction in the amount of fresh air required for ventilation compared to basic water treatment. However, until the efficacy of

Keyword | Section | Annex

these technologies in reducing DBP formation can be established and parameters can be set in which any installation of these technologies can meet minimum requirements, we cannot include these technologies as a method to reduce fresh air requirements. Such information should be considered when efficacy data become available.

- For future development of minimum performance requirements for UV and ozone, one should consider dose as a function of concentration and contact time. Many systems are designed for full flow treatment but contact time is very limited. These minimum parameters may help to attain efficacy, but as noted, more research is required. Below are some proposed statements for use once system efficacy can be determined.
    - *The Design Professional may reduce the amount of fresh air with the use of UV and/or ozone if the Design Professional can demonstrate the efficacy of the system and have it validated by a third party. The system must achieve a xxx% reduction of trichloramine in a single pass.*
    - *The system must be designed to achieve at minimum, a dose of XXX at the highest and lowest flow rate the system would normally operate in.*
    - *UV systems must have a wavelength of 254 and/or 282 nm to reduce monochloramine, DICHLORAMINE, and trichloramine.*

- Another concern is that although it is believed UV and ozone are effective on breaking down trichloramine, we do not know its effect on the other CONTAMINANTS such as trihalomethanes. If one uses the assumption that using fresh air to evacuate trichloramine will result in removing other airborne CONTAMINANTS, then one must also consider other chemical CONTAMINANTS. If one reduces the amount of fresh air because a secondary technology is used to break down trichloramine, it does not mean the other airborne CONTAMINANTS are also destroyed by secondary technology. The photochemistry may be different so efficacy may have to be determined for other compounds.

Chemical Storage Rooms and other Spaces

4.6.2.6.3 Ventilation in Chemical Storage Rooms

The design for chemical storage rooms was included in the initial version of the MAHC Ventilation and Air Quality module posted

Keyword Section Annex

for public comment. It has, however been removed in the revised code as part of revising the definition of an indoor aquatic facility for which the air handling system does not include chemical storage rooms (they would be covered under other codes). The following annex information was retained as good information.

Chemicals are typically stored in AQUATIC FACILITIES for the purpose of maintenance and water treatment. They can create ventilation hazards for patrons and staff. International Mechanical Code and International Fire Code provide very specific guidance on the construction and air handling system design of these areas. Often AQUATIC FACILITIES store chemicals in the pump room, but the operational storage of these chemicals should be limited to what is necessary for immediate use. Back up supplies should be appropriately stored and maintained in a separate area designed according to the above standards.

Other key areas to consider for proper chemical storage would include:

- Follow local building codes and/or American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standards.
  - Separate the AIR HANDLING SYSTEMS for the chemical storage area and pump room from the rest of the building.
  - Separate the AIR HANDLING SYSTEM for the AQUATIC VENUE area from the rest of the building.
  - If an older AQUATIC FACILITY does not have separate AIR HANDLING SYSTEMS for the chemical storage area and pump room as well as the AQUATIC VENUE area, consider installing emergency heating, ventilating, and air conditioning (HVAC) cutoffs in these areas.
- Ensure that the chemical storage area, pump room, and AQUATIC VENUE area are well-ventilated.
- Ventilate the chemical storage area, pump room, and AQUATIC VENUE area to the outside.

Keyword	Section	Annex
Performance Requirements	***4.6.2.7***	***Performance Requirements for Air Handling Systems***
Minimum Outdoor Air	4.6.2.7.1	Significant numbers of public comments were received regarding the proposed increase, above ASHRAE 62 standards of required outdoor air. The commenters noted that the requirements will result in increased costs for equipment and operation while lacking adequate data to support the increase. Based on the potential negative impact and the need for additional research and data to differentiate the causes and sources of indoor air quality problems on design criteria (e.g., design, inappropriate operation, inadequate maintenance), the Steering Committee decided to defer to ASHRAE outdoor air requirements in this version of the MAHC. The Steering Committee thought it important to preserve the work done by the Technical Committee, so the proposed code language for additional outdoor air has been moved to Appendix 1 in the MAHC along with preserving the corresponding annex discussion. A research agenda should be developed and should be a priority to better address the contributing factors to indoor air quality problems and the appropriate design and operational requirements needed to address those factors.
System Alarm	4.6.2.7.2	There are several methods to add a monitoring station to the outside air portion of the air handler to establish the volume of exhaust air leaving the aquatic facility. Since a negative pressure must be maintained, by measuring the exhaust, the volume of outdoor air entering through the combination of the outside air vents, doors, and other infiltration methods must be equal to the measured exhaust.
Relative Humidity/Dew Point	4.6.2.7.6	Maintaining relative humidity within acceptable levels, below 60%, in the INDOOR AQUATIC FACILITY environment is important for a variety of reasons. Research has shown elevated relative humidity levels often coincide with mold growth, damage to building structures, bather discomfort, and inadequate ventilation. The engineer should pay particular attention when designing the AIR HANDLING SYSTEM to ensure relative humidity levels can be maintained below the recommended 60% when the INDOOR AQUATIC FACILITY is occupied. It may also be necessary to install properly calibrated and maintained, real-time, relative humidity monitoring devices inside the air handling system to ensure the mechanical system can react to changing conditions inside the indoor aquatic facility. Relative humidity can fluctuate based upon a variety of factors, including occupancy and use of the facility, but a range of 45% to 60% can be accepted.

Keyword	Section	Annex
		Additionally, OWNER/OPERATOR and inspection personnel should routinely monitor the relative humidity inside the INDOOR AQUATIC FACILITY. Relative humidity is a ratio, expressed in percent, of the amount of atmospheric moisture present relative to the amount that would be present if the air were saturated. Since the later amount is dependent on temperature, relative humidity is a function of both moisture content and temperature. For consideration in designing the facilities structure, dew point is a better measure of absolute moisture levels. Dew point has a relationship with relative humidity. A high relative humidity indicates that the dew point is closer to the current air temperature. Relative humidity of 100% indicates the dew point is equal to the current temperature and that the air is maximally saturated with water. For human comfort factors the maximum relative humidity has been specified for a very narrow range of indoor temperatures and thus is an easily measured and understood metric by users and owners of an aquatic facility. For the building design, dew point is a more important metric because the outdoor conditions can be over a very wide temperature range. The design professional must be able to calculate the internal dew point for all building structure components to avoid condensation. Condensation occurs when the inside surface temperatures equal the dew point of the space. Using a properly calibrated instrument designed to measure relative humidity eliminates the complexity of calculating relative humidity by hand. It is important to collect a series of representative relative humidity measurements inside the indoor aquatic facility. The building should be divided into representative areas if necessary, depending upon size and various AQUATIC FEATURES. Measurements should be taken from each occupied area. Measurements should be taken at deck level and recorded. Arithmetic average of measurements will provide an estimation of the relative humidity in the INDOOR AQUATIC FACILITY. This may require consultation with design professionals.
Remove Disinfection byproducts	4.6.2.7.8	It is the Technical Committee's intent not to limit the development of new technologies. Although the efficacy of these technologies are not readily apparent, in the future there is a hope that the CODE will allow for the design professional to decrease the outside air requirements when secondary technology is used and the design professional can prove the

Keyword	Section	Annex
		efficacy of the added technology. Other methods and technology for decreasing DBPs include: • Ventilating surge tanks to remove off-gassing trichloramine before the water re-enters the pool area • Use of a cooling tower to force water to off-gas trichloramine before reintroducing water to the pool area
Purge	4.6.2.7.11	When an AQUATIC FACILITY has an event (e.g. pool is shocked) that requires the introduction of a larger volume of outdoor air, the purge mode can be manual triggered to provide a flush of the interior space. Since the outdoor air is not tempered or conditioned in this mode, the length of operating time is limited to provide one air change of the space { (60 *cfm) / (cu ft) }.
Air handling system Filters	4.6.2.7.12	Manufacturers/designers could consider developing/incorporating specialized solid phase (e.g., activated carbon or other media) chloramine removal air filtration as another means to sequester chloramines and potentially reduce fresh air requirements. Such systems need to show proven efficacy. With new methods development, such systems could eventually be designed with sensors confirming that the combined chlorine levels are at an acceptable level (when such air measurement methods become available). If levels increased then the air handling system could proportionally increase the amount of outside air.

4.6.2.8 Air Handling System Installation

4.6.2.9 Air Handling System Commissioning

Model Aquatic Health Code
Ventilation Module
5.0 Operation and Maintenance

Keyword	Section	Annex
	5.0	**Operation and Maintenance**
	5.1	**Plan Submittal**
	5.2	**Materials**
	5.3	**Equipment Standards**
	5.4	**Pool Operation and Facility Maintenance**
	5.5	**Pool Structure**
	5.6	**Indoor/Outdoor Environment**
	5.6.1	**Lighting**
	5.6.2	**Indoor Aquatic Facility Ventilation**

Combined Chlorine Reduction

5.6.2.8 Water chemistry affects air quality

- The amount of disinfectant in the water should always be at sufficient level to disinfect properly, but high residual levels in an indoor environment contribute to the development of DBPs. A higher ratio of CHLORINE to nitrogen content in the water results in the formation of trichloramine. Lower levels of CHLORINE/bromine in the pool results in lower levels of DBPs in the presence of organic and inorganic CONTAMINANTS.
- High residual levels have been a requirement for outdoor pools that have sunlight exposure, but that requirement may not be necessary for indoor AQUATIC FACILITIES.
- Free CHLORINE levels could likely be maintained at a lower level due to the absence of dechlorination due to sunlight.
- Lower pH levels increase the effectiveness of CHLORINE and by maintaining pH less than 7.5, less CHLORINE is required to achieve effective DISINFECTION.[35]

The water quality will affect the air quality in INDOOR AQUATIC FACILITIES. Also bather practices will determine not only the water quality but also the air quality. Therefore, if air handling equipment is installed, INDOOR AQUATIC FACILITY operators should develop and implement a program to operate, monitor and maintain the equipment as designed to reduce combined CHLORINE compounds introduced into

[35] White GC. Handbook of Chlorination and Alternative Disinfectants 4th edition. John Wiley and Sons, Inc. Hoboken New Jersey 1999.

Keyword	Section	Annex
		the building from the AQUATIC FEATURES in accordance with the INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM design engineer's and/or the AIR HANDLING SYSTEM equipment manufacturer's recommendations.

Model Aquatic Health Code
Ventilation Module
6.0 Policies and Management

Keyword	Section	Annex
	6.0	**Policies and Management**
	6.1	**Operator Training**
	6.2	**Lifeguard Training**
	6.3	**Facility Staffing**
	6.4	**Facility Management**
	6.4.1	**Operations**
	6.4.2	**Patron-Related Management Aspects**
	6.4.2.1	***Bather Load***
	6.4.2.2	***Signage***
	6.4.2.3	***User Guidelines***
	6.4.2.4	***Swimmer Empowerment Methods***
Public Information and Health Messaging	6.4.2.4.1	The Technical Committee felt strongly that public education and health communication with users should be required at any INDOOR AQUATIC FACILITY. This messaging should make clear the responsibility of the user to shower before entering the pool and that they should not urinate in the pool. It is known that urine and sweat contribute nitrogen to the pool resulting in chloramines. By actively limiting the introduction of urine and sweat, the result should be fewer chloramines in the pool and the air. A summary of health and exposure data can be found Appendix 2.

A Note about Resources:

The resources used in all MAHC modules come from peer-reviewed journals and government publications. No company-endorsed publications have been permitted to be used as a basis for writing code or annex materials.

Bibliography

Codes Referenced

- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 62, Ventilation for Acceptable Indoor Air Quality
- International Building Code. "Open Building" definition
- International Code Council (ICC) International Mechanical Code, Chapter 4, and/or applicable local codes.
- Oklahoma pool code

References Cited in Module

Aggazzotti G, Fantuzzi G, Righi E, Predieri G. Blood and breath analyses as biological indicators of exposure to trihalomethanes in indoor swimming pools. Sci Total Environ. 1998;217(1-2):155-63.

Angenent LT, Kelley ST, St Amand A, Pace NR, Hernandez MT. Molecular identification of potential pathogens in water and air of a hospital therapy pool. PNAS 2005;102(13):4860-5.

Barbee SJ, Thackara JW, Rinehart WE. Acute inhalation toxicology of nitrogen trichloride. Am Ind Hyg Assoc J. 1983;44(2):145-6.

Bernard A, Carbonnelle S, Dumont X, Nickmilder M. Infant swimming practice, pulmonary epithelium integrity, and the risk of allergic and respiratory diseases later in childhood. Pediatrics 2007;119(6):1095-103.

Bernard A, Nickmilder M, Voisin C, Sardella A. Impact of chlorinated swimming pool attendance on the respiratory health of adolescents. Pediatrics 2009;124(4):1110-8.

Bowen A, Kile J, Austin C, Otto C, Blount B, Kazerouni N, Wong H-N, Mainzer H, Mott J, Beach MJ, Fry AM (2007) Outbreaks of short-incubation illness following exposure to indoor swimming pools. Environ Health Perspect 115:267-271.

Burnsed LJ, Hicks LA, Smithee LM, Fields BS, Bradley KK, Pascoe N, Richards SM, Mallonee S, Littrell L, Benson RF, Moore MR; Legionellosis Outbreak Investigation

Team. A large, travel-associated outbreak of legionellosis among hotel guests: utility of the urine antigen assay in confirming Pontiac fever. Clin Infect Dis. 2007;44(2):222-8.

Cantor KP. Carcinogens in drinking water: the epidemiologic evidence. Rev Environ Health. 2010;25(1):9-16.

Castellan RM, Olenchock SA, Kinsley KB, Hankinson JL. Inhaled endotoxin and decreased spirometric values. An exposure-response relation for cotton dust. N Engl J Med. 1987;317(10):605-10.

Cavestri, RC, Seeger-Clevenger, D. Chemical off-gassing from indoor swimming pools [Internet]. Dublin (OH): American Society of Heating, Refrigerating, and Air Conditioning Engineers; 2008 Ju [cited 2011 Mar 3]. 40 p. Available from: http://rp.ashrae.biz/page/RP1083.pdf.

CDC, Respiratory and ocular symptoms among employees of a hotel indoor waterpark resort --- Ohio, 2007 (2009) MMWR Morb Mortal Wkly Rep 58;81-85.

CDC. Ocular and respiratory illness associated with an indoor swimming pool — Nebraska, 2006. (2007) MMWR Morb Mortal Wkly Rep 56;929-932.

Dang B, Chen L, Mueller C, Dunn KH, Almaguer D, Roberts JL, Otto CS. Ocular and respiratory symptoms among lifeguards at a hotel indoor waterpark resort. J Occup Environ Med. 2010;52(2):207-13.

Falkinham JO 3rd. Mycobacterial aerosols and respiratory disease. Emerg Infect Dis. 2003;9(7):763-7.

Fields BS, Benson RF, Besser RE. *Legionella* and Legionnaires' disease: 25 years of investigation. Clin Microbiol Rev. 2002;15(3):506-26.

Fields BS, Haupt T, Davis JP, Arduino MJ, Miller PH, Butler JC. Pontiac fever due to *Legionella micdadei* from a whirlpool spa: possible role of bacterial endotoxin. J Infect Dis 2001:184(10):1289-92.

Font-Ribera L, Villanueva CM, Nieuwenhuijsen MJ, Zock JP, Kogevinas M, Henderson. Swimming pool attendance, asthma, allergies and lung function in the Avon Longitudinal Study of Parents and Children (ALSPAC) Cohort. Am J Respir Crit Care Med. 2011;183:582-8.

Gagnaire F, Azim S, Bonnet P, Hecht G, Hery M. Comparison of the sensory irritation response in mice to chlorine and nitrogen trichloride. J Appl Toxicol. 1994;14(6):405-9.

Glazer CS, Martyny JW, Lee B, Sanchez TL, Sells TM, Newman LS, Murphy J, Heifets L, Rose CS. Nontuberculous mycobacteria in aerosol droplets and bulk water samples from therapy pools and hot tubs. J of Occup Environ Hyg. 2007;4(11):831-40.

Goutziana G, Mouchtouri VA, Karanika M, Kavagias A, Stathakis NE, Gourgoulianis K, Kremastinou J, Hadjichristodoulou C. *Legionella* species colonization of water distribution systems, pools and air conditioning systems in cruise ships and ferries. BMC Public Health. 2008;8:390.

Hanak V, Golbin JM, Ryu JH. Causes and presenting features in 85 consecutive patients with hypersensitivity pneumonitis. Mayo Clin Proc. 2007;82(7):812-6.

Hery M, Gerber J, Hect G, Subra I, Possoz C, Aubert S, Dieudonne M, Andre JC. 1998. Exposure to chloramines in a green salad processing plant. Ann Occup Hyg 42:437–451.

Hery M, Hecht G, Gerber JM, Gendre JC, Hubert G, Rebuffaud J. Exposure to chloramines in the atmosphere of indoor swimming pools. Ann Occup Hyg 1995;39(4):427-439.

Hlavsa MC, Roberts VA, Kahler AM, Hilborn ED, Wade TJ, Backer LC, Yoder JS.. CDC. Recreational water–associated disease outbreaks — United States, 2009–2010. MMWR Morb Mortal Wkly Rep. 2014;63(1):6-10.

Jacobs JH, Spaan S, van Rooy GB, Meliefste C, Zaat VA, Rooyackers JM, Heederik D. Exposure to trichloramine and respiratory symptoms in indoor swimming pool workers. Eur Respir J. 2007;29(4):690-8.

Kaydos-Daniels SC, Beach MJ, Shwe T, Bixler D, Magri J. (2008) Health effects associated with indoor swimming pools: a suspected toxic chloramine exposure. Public Health 122:195-200.

King BS, Page EH, Mueller CA, Dollberg DD, Gomez KE, Warren AM. Eye and respiratory symptoms in poultry processing workers exposed to chlorine by-products. Am J Ind Med. 2006;49(2):119-26.

LaKind JS, Richardson SD, Blount BC. The good, the bad, and the volatile: can we have both healthy pools and healthy people? Environ Sci Technol. 2010;44(9):3205-10.

Leoni E, Legnani PP, Bucci Sabattini MA, Righi F. Prevalence of Legionella spp. in swimming pool environment. Water Res. 2001;35(15):3749-53.

Lévesque B, Duchesne JF, Gingras S, Lavoie R, Prud'Homme D, Bernard E, Boulet LP, Ernst P. The determinants of prevalence of health complaints among young competitive swimmers. Int Arch Occup Environ Health. 2006;80(1):32-9.

Li J, Blatchley ER 3rd. Volatile disinfection byproduct formation resulting from chlorination of organic-nitrogen precursors in swimming pools. Environ Sci Technol. 2007;41(19):6732-9.

Lilly PD, Ross TM, Pegram RA. Trihalomethane comparative toxicity: acute renal and hepatic toxicity of chloroform and bromodichloromethane following aqueous gavage. Fundam Appl Toxicol. 1997;40(1):101-10.

Massin N, Bohadana AB, Wild P, Héry M, Toamain JP, Hubert G. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. Occup Environ Med. 1998;55(4):258-63.

Milton DK, Walters MD, Hammond K, Evans JS. Worker exposure to endotoxin, phenolic compounds, and formaldehyde in a fiberglass insulation manufacturing plant. Am Ind Hyg Assoc J. 1996;57(10):889-96.

Milton DK, Wypij D, Kriebel D, Walters MD, Hammond SK, Evans JS. Endotoxin exposure-response in a fiberglass manufacturing facility. Am J Ind Med. 1996;29(1):3-13.

Panyakapo M, Soontornchai S, Paopuree P. Cancer risk assessment from exposure to trihalomethanes in tap water and swimming pool water. J Environ Sci (China). 2008;20(3):372-8.

Rose CS, Martyny JW, Newman LS, Milton DK, King TE Jr, Beebe JL, McCammon JB, Hoffman RE, Kreiss K. "Lifeguard lung": endemic granulomatous pneumonitis in an indoor swimming pool. Am J Public Health. 1998;88(12):1795-800.

Sanderson W, Weber A, Echt A. 1995. Case reports: epidemic eye and upper respiratory irritation in poultry processing plants. Appl Occup Environ Hyg 10:43–49.

Smid T, Heederik D, Houba R, Quanjer PH. Dust- and endotoxin-related acute lung function changes and work-related symptoms in workers in the animal feed industry. Am J Ind Med. 1994;25(6):877-88.

Sood A, Sreedhar R, Kulkarni P, Nawoor AR. Hypersensitivity pneumonitis-like granulomatous lung disease with nontuberculous mycobacteria from exposure to hot water aerosols. Environ Health Perspect. 2007;115(2):262-6.

Thickett KM, McCoach JS, Gerber JM, Sadhra S, Burge PS. Occupational asthma caused by chloramines in indoor swimming-pool air. Eur Respir J. 2002;19(5):827-32.

Tossa P, Deloge-Abarkan M, Zmirou-Navier D, Hartemann P, Mathieu L. Pontiac fever: an operational definition for epidemiological studies. BMC Public Health. 2006;6:112.

Villanueva CM, Cantor KP, Cordier S, Jaakkola JJ, King WD, Lynch CF, Porru S, Kogevinas M. Disinfection byproducts and bladder cancer: a pooled analysis. Epidemiology. 2004;15(3):357-67.

Weisel CP, Richardson SD, Nemery B, Aggazzotti G, Baraldi E, Blatchley ER 3rd, Blount BC, Carlsen KH, Eggleston PA, Frimmel FH, Goodman M, Gordon G, Grinshpun SA, Heederik D, Kogevinas M, LaKind JS, Nieuwenhuijsen MJ, Piper FC, Sattar SA. Childhood asthma and environmental exposures at swimming pools: state of the science and research recommendations. Environ Health Perspect. 2009;117(4):500-7.

White GC. Handbook of Chlorination and Alternative Disinfectants 4th edition. John Wiley and Sons, Inc. Hoboken, NJ. 1999.

World Health Organization. Guidelines for safe recreational water environments. Volume 2: Swimming pools and similar recreational-water environments 2006.

Zwiener C, Richardson SD, DeMarini DM, Grummt T, Glauner T, Frimmel FH. Drowning in disinfection byproducts? Assessing swimming pool water. Environ Sci Technol. 2007;41(2):363-72.

Appendices

- **Appendix 1: Air Quality Formula**
- **Appendix 2: Summary of Health and Exposure Data for Chemical and Biological Contaminants**

Appendix 1: Air Quality Formula

NOTE: *Significant numbers of public comments were received regarding the proposed increase, above ASHRAE 62 standards of required outdoor air. The commenters noted that the requirements will result in increased costs for equipment and operation while lacking adequate data to support the increase. Based on the potential negative impact and the need for additional research and data to differentiate the causes and sources of indoor air quality problems on design criteria (e.g., design, inappropriate operation, inadequate maintenance), the Steering Committee decided to defer to ASHRAE outdoor air requirements in this version of the MAHC. The Steering Committee thought it important to preserve the work done by the Technical Committee, so the proposed code language for additional outdoor air has been moved to Appendix 1 in the MAHC along with preserving the corresponding annex discussion. A research agenda should be developed and should be a priority to better address the contributing factors to indoor air quality problems and the appropriate design and operational requirements needed to address those factors*

INDOOR AQUATIC FACILITY AIR HANDLING SYSTEM should have a design capability to supply the minimum outdoor air requirements using MAHC Table 4.6.2.7.1 below in addition to ASHRAE 62.1:

$$R_{MAHC} = R_a + \frac{R_p}{\text{Density (ft}^2\text{ / person)}}$$

Table 4.6.2.7.1: Factors for Calculating Outdoor Air Requirements for Indoor Aquatic Facilities

Factors	**Flat Water**	**Agitated Water**	**Hot Water**	**Deck**	**Stadium Seating**	**Modifier**
ASHRAE R_a	0.48	0.48	0.48	0.48	0.06	None
Additional CFM per person (R_p)	10	25	60	10	7.5	None
Average density in the pool (sq ft/person)	20	15	10	50	6.6	Based on designer /engineer rationale
cfm/person/ft2	.5	1.67	6	.2	1.14	
R_{MAHC} (Total cfm per sq ft)	**.98**	**2.15**	**6.48**	**.68**	**1.2**	

R_a = ASHRAE 62.1 Equivalent (cubic feet per minute / square foot)

R_p = Occupant driven cfm/person

R_{MAHC} is the number of cubic feet per minute (cfm) of outdoor air required for the area.

For Example:

$$R_{MAHC} = R_a + \frac{R_p}{\text{Density (ft}^2\text{ / person)}}$$

$$R_{MAHC} \text{ (Flat Water)} = .48 + \frac{\text{(10 cfm/person)}}{\text{20 ft}^2\text{/person}} = .98 \text{ cfm/ft}^2$$

The additional cfm per person addresses the contaminants contributed to the air from the individuals in the pool. This number varies based on the release of contaminants to the air, which is dependent upon the agitation of the pool surface and the occupant density of the various locations within the INDOOR AQUATIC FACILITY as described below and the in Figure 1.

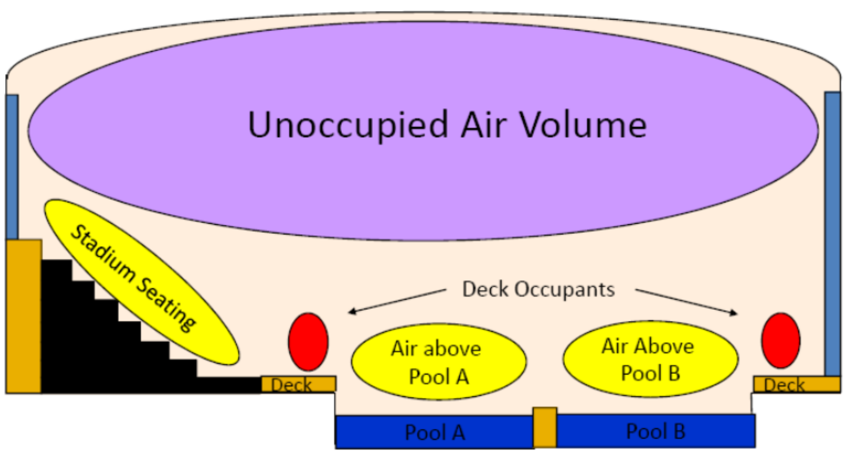

Figure 1: Side view of a typical natatorium

- Flat Water – area of an AQUATIC VENUE in which the water line is static except for movement made by users. Diving spargers do not void the flat water definition
- Agitated Water – area of an AQUATIC VENUE with mechanical means (AQUATIC FEATURES) to discharge, spray, or move the water's surface above and/or below the static water line of the AQUATIC VENUE. Where there is no static water line, movement shall be considered above the deck plane

- Hot Water – area of an AQUATIC VENUE with a water temperature over 90 degrees Fahrenheit
- Deck – area of floor spaces at or near the same elevation as pool surfaces often used for observation and access. Common names are pool deck, wet deck, and perimeter deck.
- Stadium Seating – area of high-occupancy seating provided above pool level for observation. Generally bleacher style at a higher elevation than the pool surfaces.

The Density factor in MAHC Table 4.6.2.7.1 could be modified if the designer/engineer of the INDOOR AQUATIC FACILITY can document the intended use is different (i.e., a swimming POOL is a flat water venue and is normally 20 ft^2 per person, but when designing a flat water wading pool, which has a higher density of bathers, the number could be modified to15 ft^2 per person).

For INDOOR AQUATIC FACILITIES with more than one type of water or seating, the total outside air required is calculated by adding together the air required for each type.

The number of cubic feet per minute (cfm) of outdoor air for an INDOOR AQUATIC FACILITY shall be calculated with the following equation:

$$
\begin{gathered}
\text{Area of Flat Water in } ft^2 \times \text{ Flat Water } R_{MAHC} \\
+ \\
\text{Area of Agitated Water in } ft^2 \times \text{ Agitated Water } R_{MAHC} \\
+ \\
\text{Area of Hot Water in } ft^2 \times \text{ Hot Water } R_{MAHC} \\
+ \\
\text{Area of Deck in } ft^2 \times \text{ Deck } R_{MAHC} \\
+ \\
\text{Area of Stadium Seating in } ft^2 \times \text{ Stadium Seating } R_{MAHC} \\
= \\
\text{Total cfm of required outdoor air for indoor aquatic facility}
\end{gathered}
$$

MAHC Table 4.6.2.7.1 above was established to provide a guide for designers to achieve acceptable air quality while considering the main factors that affect air quality:

Water treatment, BATHER load, and water surface area (splashing, aeration). The following outlines the discussion by the Technical Committee. One of the goals was to establish a more comprehensive formula than is currently published in the ASHRAE 62 ventilation document (e.g., adding additional air requirements to the minimum ASHRAE standards). The formula should include consideration for the type of feature as well as what type of water treatment is being utilized to maintain the water chemistry. The

Technical Committee realized early on that there is very little research in the off-gassing of chemicals for INDOOR AQUATIC FACILITIES. ASHRAE completed a preliminary research project[36] but did not perform detailed research on various AQUATIC VENUES and treatment methods. The committee had to use the experience of its members on what was working in the real world and what was not working to modify the formula used in ASHRAE 62. In other words, the committee had the final answer and developed a modified formula that yielded the desired results. This formula calculated the minimum air required in ASHRAE 62 and then added additional air turnover requirements depending on the type and area of AQUATIC FEATURE or deck/spectator area.

The matrix was set up with three types of AQUATIC VENUES: Flat Water, Agitated Water, and Hot Water as each type of AQUATIC VENUE differs in how it affects air quality. One of the key drivers that the Technical Committee identified that made these AQUATIC VENUES different was the expected BATHER loading density. With increased BATHERS per unit volume of water there is an increase in the organic contamination from the pool users and thus the presence of combined CHLORINE or combined bromine. The second factor was how much surface area of the AQUATIC VENUE water would come in contact with the air to increase the expected off-gassing of chemicals.

The rationale for developing guidance related to density and AQUATIC VENUE types is as follows:

1) Flat water
   - Contribute to poor air quality only when there are BATHERS splashing, releasing trichloramine and other DBPs into the air.
   - These AQUATIC VENUES generally are for swimming
   - The density was established at 20 ft^2per person. This represents an average horizontal swimmer occupying a 5ft by 4ft area.
   - Assuming a person is swimming horizontally; a full body length is an average 5 ft with a 5 ft span to equal 25 ft^2. There was a need to account for higher density in shallow areas where users wade vertically versus swim horizontally. The middle ground was decided to be 20 ft^2.

2) Agitated water
   - These are
   - AQUATIC VENUES with AQUATIC FEATURES that mechanically disturb the water surface such as spray features, waterslides, etc. They contribute to poor air quality any time those AQUATIC FEATURES are operating. This constant introduction of DBPs into the air requires more fresh air for these venues.
   - These AQUATIC VENUES generally are for wading and enjoyment of features without swimming

---

[36] Cavestri, RC, Seeger-Clevenger, D. Chemical off-gassing from indoor swimming pools [Internet]. Dublin (OH): American Society of Heating, Refrigerating, and Air Conditioning Engineers; 2008 Ju [cited 2011 Mar 3]. 40 p. Available from: http://rp.ashrae.biz/page/RP1083.pdf.

- The density was established at 15 ft^2 per person. This represents an average vertical user occupying a 5ft by 3ft area. This also complies with the Illinois State Pool Code.

3) Hot Water
   - These AQUATIC VENUES require more chemicals and release more DBPs due to increased chemical demand, increased introduction of BATHER waste, and increased evaporation, which deposits more DBPs into the air per square foot than any other AQUATIC VENUE. This type of features requires the most outside air.
   - These AQUATIC VENUES generally are for lounging such as hot tubs, warming pools, etc.
   - The density was established at 10 ft^2 per person. This represents an average user sitting in a 3ft by 3ft area.

4) Deck and Spectator Areas
   - For leisure pools, one can assume 50 ft^2 per person based on Illinois pool code. Adding seating and tables, which separates groups, the square footage allows for less density.
   - For spectator area, the committee used 6.6 ft^2 per person for stadium seating from the ASHRAE 62.1 Table. This seating is generally well above the water level.

Using the ASHRAE 62.1 definitions for outside air as a baseline and utilizing the ASHRAE method to determine minimum outside air requirements plus adding additional fresh air depending on feature type from Table 4.6.2.7.1, the formula is:

Minimum outside air in cfm = (R_a X AQUATIC VENUEand Deck area in ft^2) + (Aquatic Venue A area in ft^2 X (R_p / Density factor)) + (Aquatic Venue B area in ft^2 X (R_p /Density)) + (Deck area in ft^2 X (R_p/Density factor))+ (R_a X Spectator area in ft^2) + (Spectator area in ft^2 X (R_p / Density factor))

R_a = cfm of outside air needed for an aquatic space of any type without occupants. Using factor from ASHRAE 62.1 See Table 4.6.2.7.1 for R_a value
R_p = additional cfm needed per person occupying the AQUATIC VENUE above that calculated with R_a and ASHRAE 62.1. R_p value is based on type of AQUATIC VENUE for reasons stated above. See Table 4.6.2.7.1 for appropriate R_p value.
R_p = additional cfm needed per person occupying deck or spectator space above that calculated with R_a and ASHRAE 62.1. Occupant density differs based on deck or spectator usage. See See Table 4.6.2.7.1 for appropriate R_p value.

This calculation allows for calculating minimum outside air required for an AQUATIC FACILITY that has varying sizes and types of AQUATIC VENUES. Engineers can calculate for individual AQUATIC VENUES and deck spaces and add them together for the entire facility.

Design professionals experience factored into the final cfm/ft^2. Design professionals knew from experience where the final number needed to be, added in reasonable density factors and then addressed the individual characteristics of the AQUATIC VENUES to include splashing at the surface and the temperature of the water.
To calculate the minimum cfm of fresh air required:

Minimum number of cfm of fresh air for AQUATIC FACILITY by type =

(R_a X Aquatic Venue and Deck area in ft^2) + (Aquatic Venue A area in ft^2 X (R_p / Density factor))+ (Aquatic Venue B area in ft^2 X (R_p /Density)) + *(Deck area in ft^2 X (R_p/Density factor))+ (R_a X Spectator area in ft^2) + (Spectator area in ft^2 X (R_p/Density factor))*

Example 1: Aquatic Facility with Flat Water Feature

Aquatic Venue	Area (ft^2)	Fresh Air Required (cfm)
Deck Minimum	30,000	14,400
Water=Flat	15,000	7,500
Water=Agitated	0	0
Water=Hot	0	0
Deck Area Only	15,000	3,000
	Feature Area SubTotal	24,900
Total cfm/ft^2 feature/deck area		**0.83**
Spectator Area minimum	6,500	390
Spectator additional	6,500	7,386
Total cfm		32,676
Total cfm/ft^2 w/ spectator area		**0.90**

Example 2: Aquatic Facility with Agitated and Hot Water Venues

Aquatic Venue	Area (ft^2)	Fresh Air Required (cfm)
Deck Area	60,000	28,800
Water=Flat	0	0
Water=Agitated	25,000	41,667
Water=Hot	2,000	12,000
Deck Area Only	33,000	6,600
	Pool Area SubTotal	89,067
Total cfm/ ft^2 pool/deck area		**1.48**
Spectator area minimum	2,500	150
Spectator area additional	2,500	2,841
Total cfm		92,058
Total cfm/ ft^2 w/ spectator area		**1.47**

Appendix 2: Summary of Health and Exposure Data for Chemical and Biological Contaminants

Trichloramine threshold research reference synopses:

- Trichloramine has a pungent CHLORINE odor, is a strong irritant, and causes excessive tearing of the eyes[37]
- Methods for sampling include[38] INRS method [INRS 2007], NIOSH draft methods [method not published] using ion chromatography (IC) and Inductively coupled plasma atomic emission spectroscopy (ICP-AES).
- Based on concentration-response data in mice, the author recommends threshold limit values (TLV) for a short-term exposure limit (TLV-STEL[39]) of 1.5 mg/m^3 and an allowable time weighted average (TLV-TWA[40]) of 0.5 mg/m^3 for trichloramine.[41]
- Health complaints from teenage swimmers and soccer players showed a significant increase in respiratory complaints at chloramine concentrations of 0.37 mg/m^3 or greater.[42]
- Symptoms, in a separate study, were not observed until the chloramine concentrations reached 0.5 mg/m^3, and everyone reported symptoms when the levels reached 0.7 mg/m^3.[43]
- In a study of 334 lifeguards and 63 indoor pools, the prevalence of mucous membrane irritation among lifeguards exposed to trichloramine levels above 0.5 mg/m^3 was 86% for eye irritation, 61% nose irritation, 29% throat irritation, and 42% dry cough.[44]
- Airborne trichloramine was measured at six indoor swimming facilities and researchers found an elevated prevalence of respiratory symptoms in swimming pool workers. Mean trichloramine concentration of 0.56 mg/m^3, with the highest concentration reaching 1.34 mg/m^3. General respiratory symptoms were

[37] Barbee SJ, et al. Acute inhalation toxicology of nitrogen trichloride. Am Ind Hyg Assoc J. 1983;44(2):145-6.
[38] Hery M, et al. Exposure to chloramines in the atmosphere of indoor swimming pools. Ann Occup Hyg 1995;39(4):427-439.
[39] the short-term exposure limit or maximum concentration for a continuous exposure period of 15 minutes (with a maximum of four such periods per day, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA is not exceeded.)
[40] the allowable time-weighted average concentration for a normal 8-hour workday or 40-hour week to which a person can be repeatedly exposed for 8 hours a day, day after day, without adverse effect
[41] Gagnaire F, Azim S, Bonnet P, Hecht G, Hery M. Comparison of the sensory irritation response in mice to chlorine and nitrogen trichloride. J Appl Toxicol. 1994;14(6):405-9.
[42] Lévesque B, Duchesne JF, Gingras S, Lavoie R, Prud'Homme D, Bernard E, Boulet LP, Ernst P. The determinants of prevalence of health complaints among young competitive swimmers. Int Arch Occup Environ Health. 2006;80(1):32-9.
[43] Hery M, Hecht G, Gerber JM, Gendre JC, Hubert G, Rebuffaud J. Exposure to chloramines in the atmosphere of indoor swimming pools. Ann Occup Hyg 1995;39(4):427-439.
[44] Massin N, Bohadana AB, Wild P, Héry M, Toamain JP, Hubert G. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. Occup Environ Med. 1998;55(4):258-63.

significantly higher in pool employees compared to the Dutch population sample (odds ratios ranged from 1.4 to 7.2).[45]
- Researchers generated trichloramines at 0.5 mg/m^3 in a challenge chamber and exposed the participants to a series of 10-minute exposures followed by spirometry. Results showed a decrease in pulmonary function.[46]
- Trichloramine is the most volatile and prevalent chloramine compound in the air around swimming pools[47], has low solubility, and decomposes rapidly in sunlight.
- The World Health Organization proposes a 0.5 mg/m^3 provisional value although it states that more research is needed to investigate health effects in people who use the pool for extended periods of time and the role of trichloramine in possibly causing or exacerbating asthma[48].
- Although proposed standards and past studies indicate that a comfort level for indoor pool areas would be to keep trichloramine concentrations below 0.5 mg/m^3, there have been some concerns that this level may not be low enough to prevent symptoms.[49]

Trihalomethane (THM) threshold research reference synopses:
- Animal toxicity studies demonstrate and characterize hepatotoxicty and nephrotoxicity[50]
- Investigation of THMs in tap water and swimming pool water. The concentrations of total THMs in swimming pool water was higher than those in tap water, particularly, brominated-THMs. This poses a possible cancer risk related to exposure.[51]
- Environmental and biological monitoring of THMs was performed in order to assess the uptake of these substances after a defined period in five competitive swimmers. Analyses were performed by gas chromatography. In relation to biological monitoring, $CHCl_3$, $CHBrCl_2$ and $CHBr_2Cl$ were detected in all alveolar air samples collected inside the swimming pool[52]

---

[45] Jacobs JH, Spaan S, van Rooy GB, Meliefste C, Zaat VA, Rooyackers JM, Heederik D. Exposure to trichloramine and respiratory symptoms in indoor swimming pool workers. Eur Respir J. 2007;29(4):690-8.
[46] Thickett KM, McCoach JS, Gerber JM, Sadhra S, Burge PS. Occupational asthma caused by chloramines in indoor swimming-pool air. Eur Respir J. 2002;19(5):827-32.
[47] Thickett KM, McCoach JS, Gerber JM, Sadhra S, Burge PS. Occupational asthma caused by chloramines in indoor swimming-pool air. Eur Respir J. 2002;19(5):827-32.
[48] World Health Organization. Guidelines for safe recreational water environments. Volume 2: Swimming pools and similar recreational-water environments 2006.
[49] Massin N, Bohadana AB, Wild P, Héry M, Toamain JP, Hubert G. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. Occup Environ Med. 1998;55(4):258-63.
[50] Lilly PD, et al. Trihalomethane comparative toxicity: acute renal and hepatic toxicity of chloroform and bromodichloromethane following aqueous gavage. Fundam Appl Toxicol. 1997;40(1):101-10.
[51] Panyakapo M, et al. Cancer risk assessment from exposure to trihalomethanes in tap water and swimming pool water. J Environ Sci (China). 2008;20(3):372-8.
[52] Aggazzotti G, et al. Blood and breath analyses as biological indicators of exposure to trihalomethanes in indoor swimming pools. Sci Total Environ. 1998;217(1-2):155-63.

- Methods for testing halogenated hydrocarbons: NIOSH method 1003 halogenated hydrocarbons http://www.cdc.gov/niosh/docs/2003-154/pdfs/1003.pdf; experimental method for sampling THMs - Membrane introduction mass spectrometry[53]. *Standard Method* 6232 C Trihalomethanes and Chlorinated Organic Solvents (Purge & Trap/Gas Chromatographic/Mass Spectrometric Method) in water found at http://www.standardmethods.org/store/ProductView.cfm?ProductID=161.

Biologicial contamination research reference synopses:

- *Mycobacterium avium* complex "MAC" is reduced with higher halogen presence and higher turnover rate in hot tubs.[54]
- Mycobacteria are prevalent in pool water and in air. They tend to aerosolize more than other pool water CONTAMINANTS.[55]
- *Legionella* presence increased in hot water, in water with pH greater than 7.8 and CHLORINE less than 0.2 ppm.[56]
- *Legionella* was more prevalent in showers than pools[57]. Low temperatures in showers showed higher *Legionella* prevalence. Over 109^{o}F (43^o C) resulted in no *Legionella*.
- For Gram negative bacteria - endotoxin levels of 14,400 in hot tub were considered a contributing factor to acute illness of BATHERS in WI.[58];
- 45 - 400 EU (endotoxin units)/m^3 was associated with acute airflow obstruction, mucous membrane irritation, chest tightness, cough, shortness of breath, fever, and wheezing.[59, 60, 61, 62]
- Chronic health effects associated with airborne endotoxin exposures include chronic bronchitis, bronchial hyper-reactivity, chronic airways obstruction, hypersensitivity pneumonitis, and emphysema.[63]

---

[53] Li J, Blatchley ER 3rd. Volatile disinfection byproduct formation resulting from chlorination of organic-nitrogen precursors in swimming pools. Environ Sci Technol. 2007;41(19):6732-9.
[54] Glazer CS, et al. Nontuberculous mycobacteria in aerosol droplets and bulk water samples from therapy pools and hot tubs. J of Occup Environ Hyg. 2007;4(11):831-40.
[55] Angenent LT, et al. Molecular identification of potential pathogens in water and air of a hospital therapy pool. PNAS 2005;102(13):4860-5.
[56] Goutziana G, et al. *Legionella* species colonization of water distribution systems, pools and air conditioning systems in cruise ships and ferries. BMC Public Health. 2008;8:390.
[57] Leoni E, et al. Prevalence of Legionella spp. in swimming pool environment. Water Res. 2001;35(15):3749-53.
[58] Fields BS, et al. Pontiac fever due to *Legionella micdadei* from a whirlpool spa: possible role of bacterial endotoxin. J Infect Dis 2001:184(10):1289-92.
[59] Castellan RM, et al. Inhaled endotoxin and decreased spirometric values. An exposure-response relation for cotton dust. N Engl J Med. 1987;317(10):605-10.
[60] Smid T, et al. Dust- and endotoxin-related acute lung function changes and work-related symptoms in workers in the animal feed industry. Am J Ind Med. 1994;25(6):877-88.
[61] Milton DK, et al. Worker exposure to endotoxin, phenolic compounds, and formaldehyde in a fiberglass insulation manufacturing plant. Am Ind Hyg Assoc J. 1996;57(10):889-96.
[62] Milton DK, et al. Endotoxin exposure-response in a fiberglass manufacturing facility. Am J Ind Med. 1996;29(1):3-13.

- "Lifeguard lung" has been associated with indoor swimming pool use[64]
- A permanent decrease in pulmonary function, along with respiratory symptoms, has been reported in epidemiological studies.[65]
- The *Limulus* amebocyte lysate (LAL) assay used to analyze for endotoxin LAL assay, is a comparative bioassay.[66] However, changes in the LAL test procedures themselves can erroneously appear as changes in the measured endotoxin activity levels. Until problems with the LAL test are resolved, endotoxin results cannot be compared to samples collected at different times or analyzed by different laboratories. For these reasons, the American Conference of Governmental Industrial Hygienists (ACGIH) has proposed that RLVs (Relative Limit Value[67]), rather than the more usual TLVs, be used as a reference for endotoxin.[68]

---

[63] Castellan RM. Respiratory health effects of inhaled endotoxins: byssinosis and beyond. In: McDuffie H, Dosman J, Semchuk K, Olenchock S, eds. Agricultural Health and Safety - Workplace, Environment, Sustainability. Boca Raton, FL: CRC Press, 1995; 97–100.
[64] Rose CS, et al. "Lifeguard lung": endemic granulomatous pneumonitis in an indoor swimming pool. Am J Public Health. 1998;88(12):1795-800.
[65] Milton DK. Endotoxin and other bacterial cell-wall components. In: Macher J, ed. Bioaerosols: assessment and control. Cincinnati, OH: American Conference of Governmental Industrial Hygienists. 1999; 23–1 to 23–14.
[66] Milton DK. Endotoxin and other bacterial cell-wall components. In: Macher J, ed. Bioaerosols: assessment and control. Cincinnati, OH: American Conference of Governmental Industrial Hygienists. 1999; 23–1 to 23–14.
[67] Relative Limit Values require that samples be collected from an area considered to represent background levels of endotoxin and be analyzed at the same time as the samples from areas of interest. The RLV is a comparison between the environment in question and background levels. ACGIH states that if health effects are consistent with endotoxin exposure, and if the endotoxin exposures exceed 10 times the simultaneously determined background levels, then the RLV action level has been exceeded, and action should be taken to reduce exposure. The proposed maximum RLV rises to 30 times the background level in an environment where no symptoms are reported. When exposures exceed the RLV action level or maximum RLV, remedial actions to control endotoxin levels are recommended. It is important to note that the nature of the relationship between the RLV and health effects has not been elucidated at this time.
[68] Milton DK. Endotoxin and other bacterial cell-wall components. In: Macher J, ed. Bioaerosols: assessment and control. Cincinnati, OH: American Conference of Governmental Industrial Hygienists. 1999; 23–1 to 23–14.