# Model Aquatic Health CODE
# Draft Module

## Ventilation Module ANNEX Sections for the First 60-day Review Posted for Public Comment on 04/13/2011

## Currently Open for Public Comment that Closes on 06/12/2011

### MAHC Ventilation Module Abstract

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

1) Increased make-up air required in addition to that required in the ASHRAE 62 standard for indoor pools.
2) Determination of 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) Inclusion in calculations of additional make-up air from surge tanks or gutters that introduce fresh air.
4) 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.

### MAHC Ventilation Module Review Guidance

The **Model Aquatic Health CODE (MAHC) Steering** (http://www.cdc.gov/healthywater/swimming/pools/mahc/steering-committee/) **and Technical** (http://www.cdc.gov/healthywater/swimming/pools/mahc/technical-committee/) **Committees** appreciate your willingness to review this draft MAHC module. Your unique perspectives and science-based suggestions will help ensure that the best available standards and practices for protecting aquatic public health are available for adoption by state and local environmental health programs.

Review Reminders:

- Please download and use the **MAHC Comment Form** (http://www.cdc.gov/healthywater/swimming/pools/mahc/structure-content/) to submit your detailed, succinct comments and suggested edits. Return your review form by June 12, 2011, as an email attachment to **MAHC@cdc.gov**.

- If part of a larger group or organization, please consolidate comments to speed the MAHC response time to public comments.

- To provide context for this module review, please consult the **MAHC Strawman Outline** (http://www.cdc.gov/healthywater/pdf/swimming/pools/mahc/structure-content/mahc-strawman.pdf). Section headers of related content have been included in this draft module to assist reviewers to see where each section fits into the overall MAHC structure. Additional MAHC draft modules that contain this content will be or already have been posted for your review.

- 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 published MAHC will be regularly updated through a collaborative all-stakeholder process.

Please address any questions you may have about MAHC or the review process to **MAHC@cdc.gov**. You may also request to be on the direct email list for alerts ("Get Email Updates" is in a box on the right hand side of the Healthy Swimming website at www.cdc.gov/healthyswimming) on the other draft MAHC modules as they are released for public comment.

Thank you again, and we look forward to your help in this endeavor.
Sincerely,

Douglas C. Sackett, Director
MAHC Steering Committee

The Ventilation 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).

***Reviewer Note on Module Section Numbering:***

Please use the specific section numbers to make your comments on this Draft Model Aquatic Health Code module. These numbers may eventually change during the editing of the compiled Draft that will be issued for a final round of comments.

## *Reviewer 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 in this Module:

See the Ventilation Module, Code Section

## Glossary Terms in this Module:

See the Ventilation 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 Module
# ANNEX Section
# 4.0 Design Standards and Construction

| *Key word* | Section | CODE |
| --- | --- | --- |
| | **4.0** | **Design Standards and Construction** |
| | **4.6** | **Indoor/Outdoor Environment** |
| | 4.6.1 | Lighting |
| | 4.6.2 | Ventilation |

*Ventilation Committee Background*

**Background to Ventilation 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.

*Building Ventilation* **4.6.2.1 Building Ventilation**

| *Key word* | Section | CODE |
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As a result of this varied and sometimes vague approach to defining "proper" ventilation, it is critical that the MAHC begins to better define ventilation 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 systems of these 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 Ventilation Module 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 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 Ventilation 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 committee approached this section assuming designs will be evaluated by the agency having jurisdiction in the location which the system is to be installed.

The purpose of the ventilation system is to assure the health and comfort of the users of the 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,

Key word Section CODE

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 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

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[1] 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.

[2] 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.

[3] 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.

[4] 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.

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

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

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

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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/statistics/wbdoss/surveillance.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 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].

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

[9] Bowen A, Kile J, Austin C, Otto C, Blount B, Kazerouni N, Wong H-N, Mainzer H, Mott J, Beach MJ, Fry AM 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, 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.

[12] Yoder J, Hlavsa M, Craun GF, Hill V, Roberts V, Yu P, Hicks LA, Alexander NT, Calderon RL, Roy SL, Beach MJ. Surveillance for waterborne disease and outbreaks associated with recreational water use and other aquatic facility-associated health events — United States, 2005–2006. MMWR Surveill Summ 2008;57:1-38.

[13] 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.

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

[15] 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.

| Key word | Section | Code |
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| | | 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]<br><br>Biological by-products: A variety of biological organisms that grow naturally in the environment (e.g., *Legionella*, *Mycobacterium avium* complex, gram negative bacteria) or their constituents (e.g., proteins, lipopolysaccharides, 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 their |

[16] 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.

[17] 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.

[18] Font-Ribera L, Villanueva CM, Nieuwenhuijsen MJ, Zock JP, Kogevinas M, Henderson. Swimming Pool Attendance, Asthma, Allergies and Lung Function in the ALSPAC Child Cohort. Am J Respir Crit Care Med. 2010 Oct 1. [Epub ahead of print].

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

[20] 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.

[21] Fields BS, Benson RF, Besser RE. *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, Golbin JM, Ryu JH. Causes and presenting features in 85 consecutive patients with hypersensitivity pneumonitis. Mayo Clin Proc. 2007;82(7):812-6.

[24] 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.

[25] 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. American J Public Health. 1998;88(12):1795-800.

| *Key word* | Section | CODE |
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| | | constituents can be minimized with adequate AQUATIC FACILITY ventilation, maintenance, and required water quality. |
| *Indoor Facility Areas* | 4.6.2.1.2 | Modifications include but are not limited to 1) adding new aquatic features or venues to an existing facility, 2) modifications that impact ventilation such as changing ceiling height, space volume adjustments |
| *Open Buildings Exempt* | 4.6.2.1.3 | **Open Buildings:**<br><br>The Ventilation Technical Committee decided that "open" buildings would not be included in the scope of the Ventilation Module of the MAHC as there are many variables to consider for open buildings such as variations in weather, geographic zone, etc. 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. In order to clearly define what an open building is, the IBC definition is used so designers/architects can use it to drive the design of the overall building. |
| *ASHRAE 62* | 4.6.2.1.6 | **Additional ASHRAE 62 Equivalents**<br><br>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 Ventilation Technical Committee.<br><br>1) Indoor air quality – chemical, biological, and physical CONTAMINANT load<br>2) Moisture removal – humidity and temperature<br>3) Cost of energy – important to larger sites |

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[26] 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.

[27] 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.

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| | | 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 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 ventilation based on square footage of the facility and yet 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 venues with varied attractions. Air movement will need to be targeted within these 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.

*Additional ASHRAE 62 Equivalents* 4.6.2.1.7 **Ventilation Matrix**

Table 1 in the MAHC 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 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

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utilized to maintain the water chemistry. The sub-committee realized early on that there is very little research in the off-gassing of chemicals for indoor facilities. ASHRAE completed a preliminary research project[28] 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 adds additional outside air depending on the type and area of AQUATIC VENUE or deck/spectator/stadium seating 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 their 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 inorganic and 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
   - Contributes 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

[28] 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

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- The density was established at 20 $ft^2$ per 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 a mechanical means (AQUATIC FEATURES) of disturbing 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 AQUATIC VENUEs.
- These AQUATIC VENUES generally are for wading and enjoyment without swimming
- 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 AQUATIC VENUE 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/Stadium seating 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

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square footage allows for less density.
- For spectator/stadium seating areas, 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 the minimum outside air requirements and then adding additional fresh air for each AQUATIC VENUE type, deck space, and stadium seating, the number of cubic feet per minute (cfm) of fresh air for an AQUATIC FACILITY is:

Wet area x Ra
+
Stadium seating area x Ra
+
Aquatic venue area x ($R_o$/ Density factor for that type of area)
+
Deck area x ($R_o$/density factor for deck)
+
Stadium seating area x ($R_o$/density factor for seating)

$R_a$ = cfm/ft2 required for the area WITHOUT OCCUPANTS

$R_o$ = cfm/OCCUPANT

OCCUPANT = area in $ft^2$ / density at peak occupancy ($ft^2$/person)

Design professional 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.

For indoor aquatic facilities with more than one type of AQUATIC VENUE, the total outside air required is calculated by adding together the air required to address the contaminants from the following sources diagramed in Figure 1:

- The Aquatic Facility WITHOUT OCCUPANTS

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- The wet area, which is all pools plus the deck, no stadium seating (a certain amount of outside air is needed to address chemical off-gassing from a treated pool without occupants.)
- The stadium seating area (a certain amount of outside air is needed to address this space that is generally away from the pools but is still impacted as it is part of the aquatic facility.)

- The Aquatic Facility WITH OCCUPANTS
  - The deck where occupants travel, sit, lounge, etc. (a certain amount of outside air is needed to address the chemicals existing close to the pool. This area has a significantly different density than stadium seating and its locale has a different level of contamination.)
  - The stadium seating area (when occupied, a certain amount of outside air is needed to address $CO_2$ and other contaminants from the persons sitting in this densely occupied area)
  - The individual aquatic venues/pools (a certain amount of outside air is needed to address the off-gassing from the pool, which is dependent on the density of occupants, the exposed surface area, and the temperature of the pool)
    - Flat Water - AQUATIC FEATURE in which the water line is static except for movement made by users.
    - Agitated Water - AQUATIC FEATURE with mechanical means to discharge, spray, or move the water's surface above and/or below the static water line of the AQUATIC FEATURE. Where there is no static water line, movement shall be considered above the deck plane.
    - Hot Water - AQUATIC FEATURE with a temperature over 90 degrees Fahrenheit.

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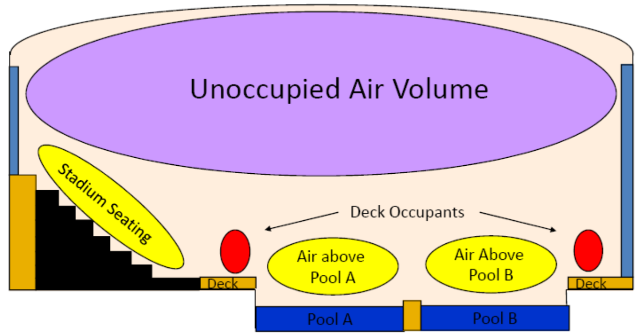


Fig 1. Side view of typical natatorium.

**Total MAHC minimum outside air in cfm =**

Outside air volume for the Aquatic Facility
(Wet Area (sum of pool and deck areas) X $R_a$)
+ (Stadium seating area X $R_a$)

+ Outside Air Volume to address Occupancy
+ (Aquatic Venue A area X ($R_o$ / Density factor))
+ (Aquatic Venue B area X ($R_o$ /Density factor))
+ (Deck area X ($R_o$/Density factor))
+ (Stadium seating area X ($R_o$ / Density factor))

**NOTE:** Although AQUATIC FACILITY ventilation system planning will include consideration of mechanical rooms, bath and locker rooms, and any associated rooms which have a direct opening to the AQUATIC FACILITY, these non-wet areas are not included in the section 4.6.2.1.7 calculation.

**Example 1: Aquatic Facility with Flat Water Venue.**

| Aquatic Area without Occupants | Area ($ft^2$) | $R_a$ Value* | | Outside Air Required (cfm) (Area X $R_a$) |
|---|---|---|---|---|
| Deck &Venue | 30,000 | 0.48 | | 14,400 |
| Stadium Seating Only | 6,500 | 0.06 | | 390 |

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| Occupant Outside Air | Area ($ft^2$) | $R_o$ Value* | Density Factor* | Occupant-driven outside air required (cfm)<br><br>Area x ($R_o$ / Density factor) |
|---|---|---|---|---|
| Water=Flat | 15,000 | 10 | 20 | 7,500 |
| Water=Agitated | N/A | N/A | N/A | N/A |
| Water=Hot | N/A | N/A | N/A | N/A |
| Deck Area Only | 15,000 | 10 | 50 | 3,000 |
| Stadium Seating Only | 6,500 | 7.5 | 6.6 | 7,386 |

* R values and Density Factors from Table 1, Code Section 4.6.2.1.7

**Table 1. Factors for calculating outside air Requirements for Aquatic Facilities**

| Factors | Flat Water | Agitated Water | Hot Water | Deck | Stadium Seating |
|---|---|---|---|---|---|
| $R_a$ | 0.48 | 0.48 | 0.48 | 0.48 | 0.06 |
| $R_o$ | 10 | 25 | 60 | 10 | 7.5 |
| **Density** | 20 | 15 | 10 | 50 | 6.6 |

**$R_a$** = ASHRAE 62.1 Equivalent (cubic feet per minute / square foot)
**$R_o$** = Occupant-driven cfm / person
**Density** = Peak density ($ft^2$ / person) for the area

### STEP 1: Aquatic Facility Outside Air (WITHOUT OCCUPANTS)

(Aquatic facility (sum of pool and deck areas) X $R_a$)
(30,000 $ft^2$ X 0.48) = **14,400 cfm**

**+** (Stadium seating area X $R_a$)
(6,500 X 0.06) = **390 cfm**

Subtotal = **14,790 cfm**

### STEP 2: Occupant-driven Outside Air

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**+** (Flat water venue area X (Ro / Density factor))
(15,000 ft$^2$ X (10/20)) = **7,500 cfm**

**+** (Deck area X ($R_o$ / Density factor))
(15,000 ft$^2$ x (10/50)) = **3,000 cfm**

**+** (Stadium seating area in ft$^2$ X ($R_o$ / Density factor))
(6,500 ft$^2$ x (7.5/6.6)) = **7,386 cfm**

**Subtotal Occupant-driven Outside Air**
= Flat water venue air + Deck area air + Stadium seating air
= 7,500 cfm + 3,000 cfm + 7,386 cfm
Subtotal = **17,886 cfm**

**STEP 3: Total Aquatic Facility Outside Air**
= 14,790 cfm + 17,886 cfm = **32,676 cfm**

**Conclusion:** New MAHC calculations require more than double the outside air for this flat water example than the existing ASHRAE 62 code.

**Example 2: Aquatic Facility with Agitated and Hot Water Venues.**

| **Aquatic Area without Occupants** | **Area (ft$^2$)** | **$R_a$ Value*** | | **Outside Air Required (cfm)**<br><br>**(Area X $R_a$)** |
|---|---|---|---|---|
| Deck &Venue | 60,000 | 0.48 | | 28,800 |
| Stadium Seating Only | 2,500 | 0.06 | | 150 |

| **Occupant Outside Air** | **Area (ft$^2$)** | **$R_o$ Value*** | **Density Factor*** | **Occupant-driven outside air required (cfm)**<br><br>**Area x ($R_o$ /** |
|---|---|---|---|---|

*Key word* Section CODE

| | | | | Density factor) |
|---|---|---|---|---|
| Water=Flat | N/A | N/A | N/A | N/A |
| Water=Agitated | 25,000 | 25 | 15 | 41,667 |
| Water=Hot | 2,000 | 60 | 10 | 12,000 |
| Deck Area Only | 33,000 | 10 | 50 | 6,600 |
| Stadium Seating Only | 2,500 | 7.5 | 6.6 | 2,841 |

* R values and Density Factors from Table 1, Code Section 4.6.2.1.7

**STEP 1: Aquatic Facility Outside Air (WITHOUT OCCUPANTS)**

(Aquatic facility (sum of pool and deck areas) X $R_a$)
(60,000 ft$^2$ X 0.48) = **28,800 cfm**

**+** (Stadium seating area X $R_a$)
(2,500 X 0.06) = **150 cfm**

Subtotal = **28,950 cfm**

**STEP 2: Occupant-driven Outside Air**

**+** (Agitated water venue area X ($R_o$ / Density factor))
(25,000 ft$^2$ X (25/15)) = **41,667 cfm**

**+** (Hot water venue area X ($R_o$ / Density factor))
(2,000 ft$^2$ X (60/10)) = **12,000 cfm**

**+** (Deck area X ($R_o$/ Density factor))
(33,000 ft$^2$ x (10/50)) = **6,600 cfm**

**+** (Stadium seating area X ($R_o$/ Density factor))
(2,500 ft$^2$ x (7.5/6.6)) = **2,841 cfm**

**Subtotal Occupant-driven Outside Air**

| Key word | Section | CODE |
|---|---|---|
| | | = Agitated water venue air + Hot water venue air + Deck area air + Stadium seating air<br>= 41,667 cfm + 12,000 cfm + 6,600 cfm + 2,841 cfm<br>Subtotal = **63,108 cfm** |
| | | **STEP 3: Total Aquatic Facility Outside Air**<br>= **92,058 cfm** |
| | | **Conclusion:** New MAHC calculations require over three times more outside air for this agitated and hot water venue example than the existing ASHRAE 62 code. |
| *Design Factors and Performance Requirements* | 4.6.2.1.8 | **Design Factors and Performance Requirements** |
| | | Factor 5: Known chemical, biological, and physical CONTAMINANTS. |
| | | The committee discussed the various chemical and biological CONTAMINANTS, the availability of testing protocols, and data to support developing health effect thresholds. |
| | | *Chemical Contaminants*: Trichloramines, Trihalomethanes, other chlorinated compounds |
| | | *Biological Contaminants*: *Mycobacterium avium* complex, *Legionella* spp. (primarily *L. pneumophila*), 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 1: Summary of Health and Exposure Data for Chemical and Biological CONTAMINANTS. |
| | | After evaluating possible CONTAMINANTS, the committee felt the most frequent adverse health symptoms were related to chemical CONTAMINANTS. In evaluating the various chemical CONTAMINANTS, it was found that trichloramine was the most prevalent CONTAMINANT[29]. Therefore, the |

[29] 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.

*Key word* Section CODE

Ventilation Module 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[30] 0.5 mg/m$^3$
- Levesque 2006[31] 0.37 mg/m$^3$
- Hery 1995[32] 0.5 - 0.7 mg/m$^3$
- Massin 1998[33] 0.5 mg/m$^3$
- Jacobs 2007[34] 0.56 mg/m$^3$ (average)
- Thickett 2002[35] 0.5 mg/m$^3$

In evaluating the trichloramine research, it was apparent there is was 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 facility operators to test routinely or with any consistency. For these two reasons, the 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

[30] 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.

[31] 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.

[32] 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.

[33] 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.

[34] 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.

[35] 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.

*Key word* Section CODE

determination of a threshold level. To enforce such a threshold level, the test also needs to be available and easily performed by operators and health officials. Therefore, the performance requirements for the Ventilation Module of the MAHC have parameters for fresh air, humidity, temperature, and biological CONTAMINANTS. To accomplish this, several design criteria were kept in mind.

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. See Annex in Design section for further information.

2) Humidity levels are set to avoid mold growth and damage to the building structure.

3) The Oklahoma pool code states that air temperature should be no more than 8 degrees above pool temp and no lower than 2 degrees less than pool temp based on a max pool temp of 90$^{o}$F degrees, excluding spas and hot tubs. The committee felt these parameters were satisfactory to utilize in the MAHC. It is recognized that air temperature is largely a comfort factor, but high air temperatures do affect air circulation and could lead to heat exhaustion in users.

4) Biological CONTAMINANT thresholds are already established in ASHRAE 62 and should be utilized at this point until future research is conducted. In the future, if a readily available, standard air testing method is developed and a trichloramine or other CONTAMINANT threshold can be determined, then it is the recommendation of the committee that the MAHC adopt such an action threshold for air quality. Additionally, a threshold should also be considered and/or revised for combined CHLORINE compounds in water to minimize production and off-gassing of the volatile chloramines.

<u>Factor 6:</u> Individual AQUATIC FEATURE water quality systems, including water recirculation, filtration,

*Key word* Section CODE

DISINFECTION, secondary treatment systems,

It was recognized by the Ventilation Technical Committee that the more advanced forms of water treatment (e.g., ozone, UV) 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 pool 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 included in the MAHC Ventilation Section. 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 first draft of the Ventilation Module included 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 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.

Original Table 1:

*Key word* Section CODE

| **Water Type** | ASHRAE 62.1 Equiv. **Ra** (cfm/ ft²) | ASHRAE 62.1 Equiv. $R_o$ (cfm/person) | Density Factor (ft²/person) |
|---|---|---|---|
| **Flat Water Basic** | 0.48 | 10 | 20 |
| **Flat Water Basic + UV/ ozone/other technology** | 0.48 | 2.5 | 20 |
| **Agitated Water Basic** | 0.48 | 25 | 15 |
| **Agitated Water Basic + UV/ ozone/other technology** | 0.48 | 10 | 15 |
| **Hot Water Basic** | 0.48 | 60 | 10 |
| **Hot Water Basic + UV/ ozone/other technology** | 0.48 | 40 | 10 |
| **Deck Basic** | 0.48 | 10 | 50 |
| **Stadium Seating Basic** | 0.06 | 7.5 | 6.6 |

- 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 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.*

| *Key word* | Section | CODE |
|---|---|---|

- *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 utilized 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.

*Surge Tank / Gutter Ventilation* 4.6.2.1.9 **Surge Tank/Gutter Ventilation**

It is the Ventilation 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 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

*Chemical Storage Rooms* 4.6.2.1.15 **Ventilation in Chemical Storage Rooms**

- Chemicals are typically stored in aquatic facilities for the purpose of maintenance and water treatment. They can create ventilation hazards for patrons and

| *Key word* | Section | CODE |
|---|---|---|

staff. International Mechanical Code and International Fire Code provide very specific guidance on the construction and ventilation 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 facility designed according to the above standards. Other key areas to consider for proper chemical storage 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 pool 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 pool area, consider installing emergency heating, ventilating, and air conditioning (HVAC) cutoffs in these areas.
- Ensure that the chemical storage area, pump room, and pool area are well-ventilated.
- Ventilate the chemical storage area, pump room, and pool area to the outside.

## 4.6.2.2 Air Quality – Health

*Biological Air Contaminants*

### 4.6.2.2.4 Biological Air Contaminants

Biological CONTAMINANT thresholds are established in ASHRAE 62 and should be utilized at this point until future research is conducted that would warrant changing them and methods are available to enforce them. See further discussion of these CONTAMINANTS in Annex 4.6.2.1 and Appendix 1.

| Key word | Section | CODE |
|---|---|---|
| | **4.6.2.3** | **Humidity Control** |
| *Relative Humidity* | 4.6.2.3.1 | **Relative Humidity** |

Maintaining relative humidity within acceptable levels, below 65%, in the natatorium 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 ventilation system to ensure relative humidity levels can be maintained below the recommended 24-hour average of 65% when the natatorium is occupied. It may also be necessary to install properly calibrated and maintained, real-time, relative humidity monitoring devices inside the ventilation system to ensure the mechanical system can react to changing conditions inside the natatorium. Relative humidity can fluctuate based upon a variety of factors, including occupancy and use of the facility, but a 24-hour average should normalize this measurement.

Additionally, aquatic facility operators and inspection personnel should routinely monitor the relative humidity inside the natatorium. 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.

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 natatorium. The building should be divided into representative areas if necessary, depending upon size and the variety of AQUATIC VENUES. Measurements should be taken from each occupied area. Measurements should be taken at deck level and recorded. The arithmetic average of measurements will provide an estimation of the relative humidity in the natatorium. Adjustments should be made in the system to insure the 24-hour average in the natatorium remains within the stated parameters. This may require

| *Key word* | Section | CODE |
|---|---|---|
| | | consultation with ventilation design professionals. |
| *Air Temperature* | 4.6.2.3.2 | **Air Temperature**<br><br>The Oklahoma pool code states that air temperature should be no more than 8° above pool temp and no lower than 2° less than pool temp based on a max pool temp of 90°F (32°C), excluding spas and hot tubs. The committee felt these parameters were satisfactory to utilize in the MAHC. It is recognized that air temperature is largely a comfort factor, but high air temperatures do affect air circulation and could lead to heat exhaustion in users. |

# Model Aquatic Health Code:
# Ventilation Module
# 5.0 Operation and Maintenance

| *Key word* | Section | CODE |
|---|---|---|
| | **5.0** | **Operation and Maintenance** |
| | **5.6** | **Indoor/Outdoor Environment** |
| | 5.6.1 | Lighting |
| | 5.6.2 | Ventilation |
| *Air Quality -- Health* | **5.6.2.2** | **Air Quality – Health** |
| *Combined Chlorine Reduction* | 5.6.2.2.1 | **Combined Chlorine Management** |

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 pools.

- Free CHLORINE levels could likely be maintained at a lower level due to the absence of dechlorination due to sunlight.

- Lower pH levels increases the effectiveness of CHLORINE and by maintaining pH less than 7.5, less CHLORINE is required to achieve effective

| Key word | Section | CODE |
|---|---|---|
| | | DISINFECTION[36].<br>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 ventilation equipment is installed, indoor AQUATIC FACILITY operators should develop and implement a program to operate, monitor and maintain equipment designed to reduce combined CHLORINE compounds introduced into the building from the water features in accordance with the AQUATIC FACILITY ventilation system design engineer's and/or the ventilation the equipment manufacturer's recommendations. |
| *Public Information and Health Messaging* | 5.6.2.3.2 | **Public Information and Health Messages**<br><br>The 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. |

## Appendix 1: 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]

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

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

*Key word* Section CODE

- 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]

- In one study, 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]

- In a separate study, symptoms were not observed until chloramine concentrations reached 0.5 $mg/m^3$. All participants in this study reported symptoms when the levels reached 0.7 $mg/m^3$. [43]

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[38] 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.

[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.

*Key word* Section CODE

- 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 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

[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.

[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.

*Key word* Section CODE

$mg/m^3$ 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 hepatotoxicity and nephrotoxicity.[50]

- Investigation of THMs in tap water and swimming pool water showed the concentration 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

[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, 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

[51] 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.

*Key word* Section CODE

monitoring, $CHCl_3$, $CHBrCl_2$ and $CHBr_2Cl$ were detected in all alveolar air samples collected from swimmers using the swimming pool.[52]

- Methods for testing halogenated hydrocarbons: NIOSH method 1003 halogenated hydrocarbons (Available: 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.

Biological 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]

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[52] 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.

[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, 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.

[55] 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.

[56] 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.

*Key word* Section CODE

- *Legionella* was more prevalent in showers than pools.[57] Low temperatures in showers showed higher *Legionella* prevalence. Over 109°F (43° C) resulted in no *Legionella*.

- For Gram negative bacteria - endotoxin levels of 14,400 endotoxin units/ml in the 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]

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

[58] 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.

[59] 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.

[60] 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.

[61] 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.

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Key word Section CODE

- “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, 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]

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[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.

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## 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

The Annex includes a listing of CODEs that are referenced and a bibliography of the scientific reference materials and studies that form the basis for recommendations.

## Codes Referenced in this Module

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 62, Ventilation for Acceptable Indoor Air Quality

Illinois pool code. Joint Committee on Administrative Rules, Administrative Code. Title 77: Public Health; Chapter I: Department Of Public Health; Subchapter N: Recreational Facilities; Part 820 Swimming Facility Code. Accessed 04-06-2011 at http://www.ilga.gov/commission/jcar/admincode/077/07700820sections.html.

International Building Code. “Open Building” definition

International Code Council (ICC) International Mechanical Code, Chapter 4, and/or applicable local codes.

Oklahoma pool code. Oklahoma State Department of Health. Chapter 320: Public Bathing Places. Accessed 04-06-2011 at http://www.ok.gov/health/documents/Public%20Bathing%20Places320.pdf.

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