

2018 Annex to the Model Aquatic Health Code

Scientific Rationale



U.S. Department of
Health and Human Services
Centers for Disease
Control and Prevention

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Annex to the 2018 Model Aquatic Health Code, 3RD Edition

SCIENTIFIC AND BEST PRACTICES RATIONALE

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This information is distributed solely as guidance for the purpose of assisting state and local health departments, aquatic facility inspection programs, building officials, the aquatics industry, and other interested parties in improving the health and safety at public aquatic facilities. This document does not address all health and safety concerns 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.

Foreword

Swimming, soaking, and playing in water have been global pastimes throughout written history. Twentieth-century advances in aquatics—combining disinfection, recirculation, and filtration systems—led to an explosion in recreational use of residential and public disinfected water. As backyard and community pool use has swept across the United States, leisure time with family and friends around the pool has increased. Advances in public aquatic facility design have pushed the horizons of treated aquatic facilities from the traditional rectangular community pool to the diverse multi-venue waterpark hosting tens of thousands of users a day. The expansion of indoor aquatic facilities has now made the pool and waterpark into year-round attractions. At the same time, research has demonstrated the social, physical, and psychological benefits of aquatics for all age groups.

However, these aquatics sector changes—combined with changes in the general population, chlorine-tolerant pathogens, and imperfect bather hygiene—have resulted in significant increases in reports of waterborne outbreaks, with the greatest increase occurring in man-made disinfected aquatic venues. Drowning continues to claim the lives of far too many, especially children, and thousands of people visit hospitals every year for pool chemical-associated injuries. Aquatic facility operation can still be improved through education and training. The increase in outbreaks and continued injuries suggests there would be benefits from building stronger public health regulatory programs and supporting them with strong partnerships to implement health promotion efforts, conduct research, and develop prevention guidance. It also would be useful for public health officials to continue to play their strong role in overseeing design and construction, advising on operation and maintenance, and helping inform policy and management. Working in close collaboration with building code officials strengthens the overall coordination needed to prioritize health and safety at public aquatic facilities.

The 3rd Edition of the Model Aquatic Health Code (MAHC) is the latest effort to improve the MAHC, which is a set of voluntary guidelines based on science and best practices. The MAHC was developed to help programs that regulate public aquatic facilities reduce the risk of disease, injury, and drowning in their communities. The MAHC is a leap forward from the Centers for Disease Control and Prevention's (CDC) operational and technical manuals published in 1959, 1976, and 1981 and a logical progression of CDC's Healthy Swimming Program started in 2001. The 2018 MAHC 3rd Edition underscores CDC's long-term involvement and commitment to improving aquatic health and safety. The MAHC guidance document stemmed from concern about the increasing number of pool-associated outbreaks, particularly of cryptosporidiosis, starting in the mid-1990s. Creation of the MAHC was the major recommendation of a 2005 national workshop held in Atlanta, Georgia charged with developing recommendations to reduce these outbreaks. Federal, state, and local public health officials and the aquatics sector formed an unprecedented 7-year collaboration to create the MAHC for release in 2014. The MAHC is now being regularly updated using input from the national stakeholder partnership created and maintained by the Council for the Model Aquatic Health Code (CMAHC). The CMAHC was formed to keep the MAHC up to date and current with the latest advances in the aquatics industry while also responding to public health reports of disease and injury. The CMAHC has now led two national aquatics stakeholder conferences in 2015 and 2017 to solicit, review, and vote on proposed updates to the MAHC. CDC appreciates the breadth of input and commitment to excellence that serves as the foundation for the CMAHC's work. The process and quality of recommendations have improved each time and the CMAHC is making its mark as a pre-eminent force in the aquatics arena. As CDC documents adoption of MAHC-specific guidance components and observes its impact on the aquatics sector, even ahead of adoption, it is clear that the MAHC is filling a gap in public health and safety. The partnership between public health, the aquatics sector, the CMAHC, and academia strengthens the opportunity for achieving the MAHC vision of "Healthy and Safe Aquatic Experiences for Everyone".

CDC

Atlanta, GA, 2018

Acknowledgments

The 2018 MAHC 3rd Edition utilized the CMAHC conference process to collect, assess, and relay MAHC Change Request recommendations to CDC and plans to utilize the CMAHC conference process to update all future versions of the MAHC. The second CMAHC *Vote on the Code* Biennial Conference was held October 17-18, 2017, in Broomfield, Colorado. CDC would like to acknowledge the hard work and dedication of the CMAHC Executive Director, CMAHC Technical Review Committee, CMAGC Technical Support Committees, CMAHC Board of Directors, and CMAHC membership for their dedication and time spent developing, reviewing, and voting on MAHC Change Requests. It is only through the dedicated efforts and contributions of experienced professionals that a scientifically sound, well-focused, and up-to-date MAHC is possible. CDC acknowledges with immense gratitude the substantial assistance of those who contributed to public health and aquatic safety in the development of the 2018 MAHC 3rd Edition. They deserve our heartfelt thanks and appreciation for volunteering their time, energy, and creativity to create the 2018 MAHC 3rd Edition. In addition, we would like to also give our thanks to all the reviewers across the country who provided public comments, and spent a great deal of time combing through the detail of the MAHC code and annex to submit Change Requests for improvement. Their effort was worth the time investment; the MAHC has again been greatly improved after the Conference process and associated public comment periods. As part of the 2017 CMAHC Conference, it was decided to move to a 3-year cycle to allow coordination with other code writing bodies and allow more time for substantive committee work to develop Change Requests; the next CMAC Conference will be in October 2020. See MAHC Annex Appendix 4: Acknowledgement of MAHC Development Members. This Appendix recognizes CDC's continued gratitude towards the individuals who gave their time and expertise over 7 years to develop the MAHC from dream to product.

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2018 Annex to the Model Aquatic Health Code

Scientific Rationale

PREFACE



1.0 Preface

1.1 Introduction

1.1.1 Rationale

With hundreds of millions of visits¹ to AQUATIC FACILITIES, waterparks, and natural recreational water sites each year, BATHERS expose themselves to many potential dangers in and around AQUATIC FACILITIES. In recent decades, public health practitioners have seen a dramatic increase in waterborne disease outbreaks associated with public DISINFECTED AQUATIC FACILITIES (e.g., *swimming POOLS, water parks, hot tubs, etc.*).² Drowning and falling, diving, chemical use, and suction injuries continue to be major public health injuries associated with AQUATIC FACILITIES, particularly for young children.^{3,4,5,6,7,8,9,10,11,12} Thus, public health and SAFETY is essential to consider starting with the design, construction, operation, maintenance, and management of public AQUATIC FACILITIES.

1.2 Recreational Water-Associated Illness Outbreaks and Injuries

1.2.1 RWI Outbreaks

Since 1978, the number of recreational water-associated WATERBORNE DISEASE outbreaks (WBDOs) reported annually has increased dramatically.¹³ This increase is probably due to a combination of factors including:

- The emergence of PATHOGENS, especially CHLORINE-tolerant *Cryptosporidium*,
- Increased participation in aquatic activities,
- Increases in the number of AQUATIC FACILITIES, and
- Increased recognition, investigation, and reporting of outbreaks that may have previously gone undetected.

For 2000–2014, 47 states and Puerto Rico reported a total of 498 DISINFECTED recreational water-associated WBDOs including 27,253 cases of illness and 10 deaths.¹⁴ Multiple challenges exist for providing adequate cleaning and DISINFECTING of swimming water. Sunlight, urine, exposure to air, and inorganic and organic matter (i.e. *sweat, saliva, and feces*) can quickly deplete FAC, the primary DISINFECTANT used in POOLS. AQUATIC FACILITIES also provide potential exposure to FECAL contamination from other swimmers. These incidents are common in AQUATIC FACILITIES, especially from diaper-aged BATHERS who are not toilet trained (*babies and toddlers*).¹⁵

1.2.2 Significance of *Cryptosporidium*

One such pathogen is *Cryptosporidium*¹⁶ (*fecal-orally spread from person to person or from contaminated objects/vehicles like POOL water*), which can survive for days in chlorinated AQUATIC FACILITIES because it is extremely CHLORINE resistant.^{17,18,19 20} *Cryptosporidium* causes a profuse watery diarrhea that contains large numbers of infectious OOCYSTS so, if the water or surfaces at AQUATIC FACILITIES get contaminated, an outbreak can occur. *Cryptosporidium* and other waterborne pathogens have a low infectious dose²¹ and can still be excreted from the body weeks after diarrhea ends.^{22,23} These factors increase the potential for a waterborne disease outbreak. Waterborne diseases and outbreaks can include the following:

- Gastrointestinal illness resulting from exposure to pathogens such as *Escherichia coli* O157:H7 or *Cryptosporidium*,
- Infections of the brain, skin, ear, eye, and lungs,
- Wounds, and
- Exposure to POOL-related chemicals.

There were 36 AQUATIC FACILITY-associated outbreaks reported for 2011-2012 that were caused by *Cryptosporidium*, a substantial increase from the 15 reported for treated AQUATIC FACILITIES in 1999-2000.^{24,25} In addition, during 2003-2012 *Cryptosporidium* was identified as the cause of 81.8% of gastroenteritis outbreaks at DISINFECTED AQUATIC FACILITIES, making it the leading cause of diarrheal disease outbreaks at DISINFECTED AQUATIC FACILITIES.²⁶

1.2.3 Drowning and Injuries

Drowning and falling, diving, chemical use, and suction injuries continue to be major public health injuries associated with AQUATIC FACILITIES. Drowning is a leading cause of injury death for young children ages 1 to 4, and the fifth leading cause of unintentional injury death for people of all ages.^{27,28} During 2014-2016, an average of 5,900 POOL- or SPA-related hospital emergency department (ED)-treated non-fatal drowning injuries occurred each year in children under 15 years of age; an estimated 4400 (75%) occurred in children under 5 years of age each year. POOLS accounted for 97% of these events and 20% occurred in public facilities. During 2012-2014, an average 356 POOL- or SPA-related drowning fatalities per year involved children younger than 15 years of age; an average 272 (76%) occurred in children under 5 years of age each year. The majority of deaths (96%) occurred in POOLS with 20% being in a public setting.²⁹

1.2.4 Pool Chemical-Related Injuries

For 2007-2008, 32 POOL chemical-associated health events that occurred in a public or residential setting were reported to CDC by Maryland and Michigan. These events resulted in 48 cases of illness or injury; 26 (81.3%) events could be attributed at least partially to chemical handling errors (*e.g., mixing incompatible chemicals*). ATSDR's HSEESS received 92 reports of hazardous substance events that occurred at AQUATIC FACILITIES. More than half of these events (55 [59.8%]) involved injured persons; the most frequently reported primary contributing factor was human error.³⁰ Estimates based on CPSC's NEISS data indicate that an estimated 4,876 (95% confidence interval: 2,821--6,930) emergency department (ED) visits attributable to POOL chemical-associated injuries occurred in 2012; almost half of the patients were <18 years of age.³¹

1.3 Model Aquatic Health Code

1.3.1 Background

This effort stems from a CDC-sponsored workshop titled "Recreational Water Illness Prevention at Disinfected Swimming Venues" convened on February 15-17, 2005, in Atlanta, Georgia, in response to a 2004 position statement ((<http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/2017PS/2017PSFinal/17-CC-01.pdf>) from the Council of State and Territorial Epidemiologists asking for CDC to convene such a meeting. The workshop assembled contributors from different disciplines working in state, local, and federal public health agencies and the aquatics sector to discuss ways to minimize RWI spread at DISINFECTED AQUATIC FACILITIES. The workshop recommendation to create national guidance for AQUATIC FACILITY design, operation, and management resulted in the effort to create the Model Aquatic Health Code (The MAHC). CDC agreed that public health improvements would be aided by development of such a guidance document. The guidance would be an open access, comprehensive, systematic, collaboratively developed guidance document based on science and BEST PRACTICES covering AQUATIC FACILITY design and construction, operation and maintenance, and policies and management to address existing, emerging, and future public health threats. CDC worked with public health and aquatics sector representatives across the United States from 2007 to 2014 to create the MAHC, which was first released in 2014. The MAHC 2nd Edition was released in 2016. MAHC guidance is focused on reducing the spread of RWIs and prevention of injuries at treated public AQUATIC FACILITIES using an "all hazards" approach.

1.4 Public Health and Consumer Expectations

1.5 Advantages of Uniform Guidance

1.5.1 Sector Agreement

The aquatics sector and public health officials have long recognized the advantages of well-written, scientifically sound, and up-to-date model guidance. Industry acceptance of procedures and practices is far more likely where regulatory officials "speak with one voice" about

- What is required to protect the public health,
- Why it is important, and
- Which alternatives for compliance may be accepted.

Model guidance provides

- A guide for use in establishing what is required,

- Businesses with accepted guidance STANDARDS that can be applied to training and quality assurance programs, and
- Local, state, and federal governmental bodies help with developing or updating their own CODES.

1.6 Modifications and Improvements in the 2018 MAHC

1.7 MAHC Adoption at State or Local Level

1.7.1 MAHC Adoption at State or Local Level

The MAHC is provided for use by governing bodies at all levels to regulate AQUATIC FACILITIES. At the state and local levels, the MAHC may be used in part or in whole to:

- Enact into statute as an act of the state legislative body;
- Promulgate as a regulation; or
- Adopt as an ordinance.

Typically, CODE adoption bodies (*federal, state, and local governments*) publish a notice of their intent to adopt a CODE, make copies available for public inspection, and provide an opportunity for public input prior to adoption. As is also outlined in the FDA Food Code, this is usually done in one of two ways.

- The recommended method is the "short form" or "adoption by reference" approach where a simple statement is published stating that certified copies of the proposed CODE are on file for public review. This approach may be used by governmental bodies located in states that have enabling laws authorizing the adoption of CODES by reference. An advantage to this approach is a substantial reduction in the cost of publishing and printing.
- The alternative method is the "long form" or "section-by-section" approach where the proposed CODE is published in its entirety. Both methods of adoption allow for the modification of specific provisions to accommodate existing law, administrative procedure, or regulatory policy.

1.7.2 Resolving Code Conflicts

The MAHC is committed to working with ICC and IAPMO to resolve conflicts between the three codes now and in the future as these codes evolve.

1.8 The MAHC Revision Process

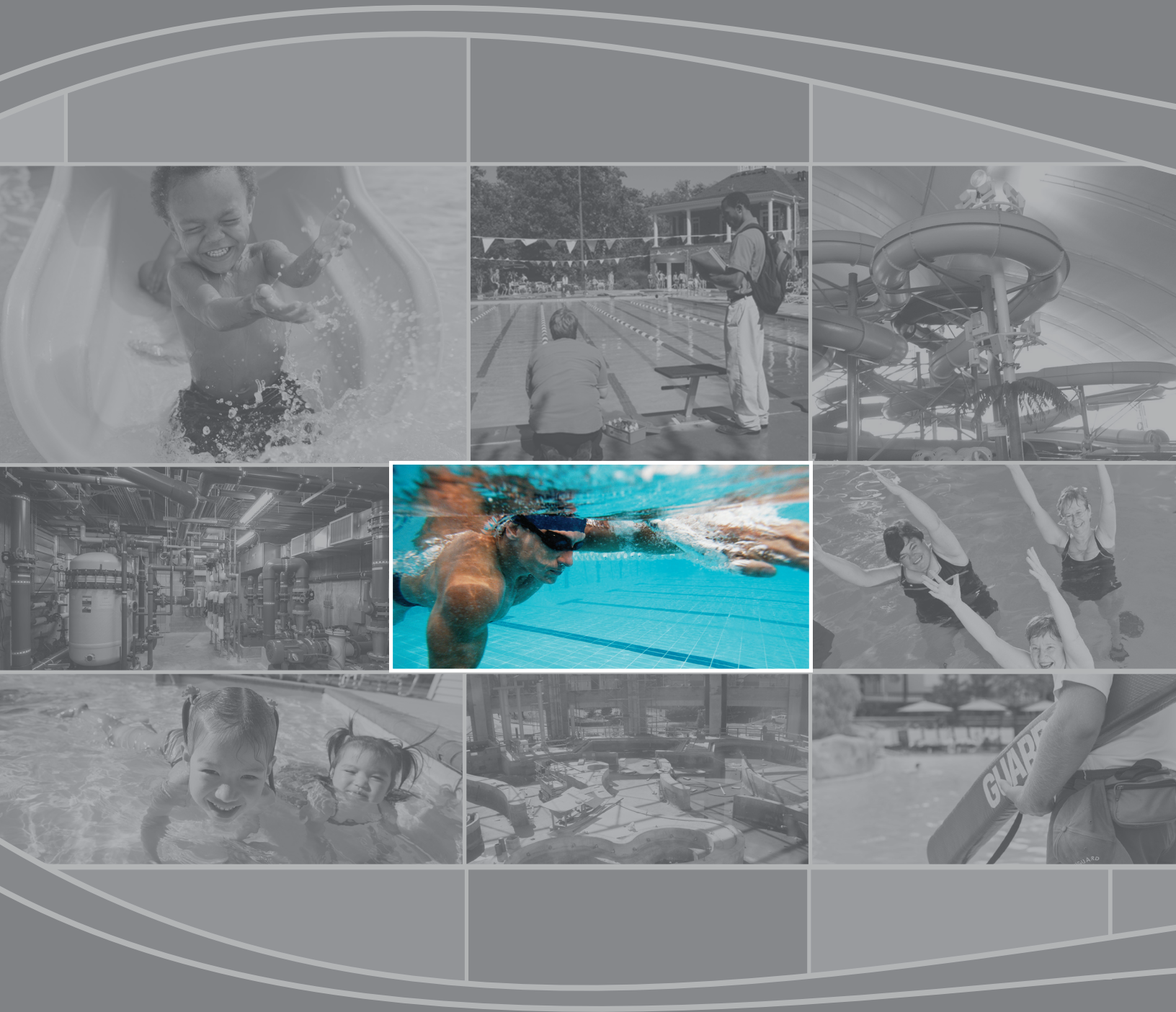
1.8.1 MAHC Revisions

Throughout the creation of the MAHC, the CDC accepted concerns and recommendations for modification of the MAHC from any individual or organization through two 60-day public comment periods via the email address MAHC@cdc.gov. During the two public comment periods, CDC received 4,407 comments. Of comments that the MAHC could accept or reject (3,825), the MAHC agreed with and incorporated 72% of the suggestions. Responses to all comments were posted on the CDC website; reasons for not accepting comments varied but included such reasons as inconsistency with existing MAHC wording, too large a change to be taken in one step, and not being consistent with current best practices. CDC realizes that the MAHC should be an evolving document that is kept up to date with the latest science, industry advances, and public health findings. As the MAHC is used and recommendations are put into practice, MAHC revisions will need to be made. As the future brings new technologies and new aquatic health issues, the Conference for the Model Aquatic Health Code (*CMAHC*, <https://cmahc.org/index.php>) with CDC participation, has instituted a biennial change request solicitation process (to be triennial starting after the 2017 CMAHC conference cycle) for collecting national input that welcomes all stakeholders to participate in making recommendations to improve the MAHC so it remains comprehensive, easy to understand, and as technically sound as possible. After CMAHC member voting, accepted recommendations are sent to CDC and weighed by CDC for final incorporation into the next edition of the MAHC. Given the vision, mission, and goals of the MAHC as discussed in MAHC 1.3, the CDC is interested in addressing any problems identified. CDC encourages interested individuals to consider raising issues and suggesting solutions through the CMAHC process.

2018 Annex to the Model Aquatic Health Code

Scientific Rationale

USER GUIDE



2.0 User Guide

2.1 Overview

2.2 MAHC Structure and Format

The MAHC utilizes the format also found in the FDA Food Code; thus within the MAHC, references are made to the FDA Food Code and the Conference for Food Protection. These are purely for reference and to gain a better scope of perspective and protocol.

2.3 Annex

2.3.1 Scientific and Best Practices Rationale

The annex is provided as a scientific and BEST PRACTICES explanatory supplement to the code; thus, the annex material is not intended to be interpreted or enforced as model code in order to keep future laws or other requirements based on the MAHC straightforward. However, the annex is provided specifically to assist users in understanding the intent and scientific or BEST PRACTICES justification behind code provisions and applying the provisions uniformly and effectively.

2.3.2 Content

To use the MAHC more effectively, users should preview the annex contents before using parts of the MAHC model CODE language. The annex is structured to present the information by the specific MAHC section number to which they apply. The Annex and Appendices also provide information and materials intended to be helpful to the user such as forms and checklists.

2018 Annex to the Model Aquatic Health Code

Scientific Rationale

GLOSSARY

OF ACRONYMS AND TERMS
USED IN THIS CODE



3.0 Glossary of Acronyms, Initialisms, Terms, Standards, Codes, and Laws Used in the MAHC Annex

3.1 Acronyms and Initialisms Used in the MAHC Annex

ACA	American Coatings Association
ACCA	Air Conditioning Contractors of America
ACI	American Concrete Institute
ADA	Americans with Disabilities Act
ADAAG	Americans with Disabilities Act Accessibility Guidance
AAU	Amateur Athletic Union
AED	Automated External Defibrillator
AHA	American Heart Association
AHJ	Authority Having Jurisdiction
AMCA	Air Movement and Control Association
ANSI	American National Standards Institute
APSP	Association of Pool and Spa Professionals
ARC	American Red Cross
ASHI	American Safety & Health Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	ASTM International (<i>formerly American Society for Testing and Materials</i>)
ATSDR	Agency for Toxic Substances and Disease Registry
BCDMH	1-bromo-3-chloro-5, 5-dimethylhydantoin
CCPRF	Citizen CPR Foundation
CDC	United States Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CEU	Continuing Education Units
CFM	Cubic Feet Per Minute
CFOC	Caring for Our Children
CFR	Code of Federal Regulations
CFP	Conference for Food Protection
CI	Chlorine Institute
CMAHC	Conference for the Model Aquatic Health Code
CoSTR	Consensus on Science and Treatment Recommendations
CPR	Cardiopulmonary Resuscitation
CPSC	United States Consumer Product Safety Commission
CSA	Canadian Standards Association
CYA	Cyanuric Acid
DIN	Deutsches Institut für Normung
DBDMH	Dibromodimethylhydantoin
DBP	Disinfection By-Product
EAP	Emergency Action Plan
ECCU	Emergency Cardiovascular Care
EPA	United States Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act

ES	European Standard
FAC	Free Available Chlorine
FDA	United States Food and Drug Administration
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FINA	<u>Fédération</u> Internationale de Natation Amateur
GFCI	Ground-Fault Circuit Interrupter
GPM	Gallons Per Minute
HazCom	Hazard Communication Standard
HMIS	Hazardous Material Identification System
HOBr	Hypobromous Acid
HOCl	Hypochlorous Acid
HSC	Health and Safety Code
HSEESS	Hazardous Substance Emergency Events Surveillance System
IAEI	International Association of Electrical Inspectors
IAF	International Aquatic Foundation
IAPMO	International Association of Plumbing and Mechanical Officials
IARC	International Agency for Research on Cancer
IBC	International Building Code
ICC	International Code Council
ICBO	International Council of Building Officials
IEEE	Institute of Electrical and Electronics Engineers
IESNA	Illuminating Engineering Society of North America
IFC	International Fire Code
ILCOR	International Liaison Committee on Resuscitation
IMC	International Mechanical Code
IPC	International Plumbing Code
ISEA	International Safety Equipment Association
ISO	International Organization for Standardization
ISPSC	International Swimming Pool and Spa Code
MAHC	Model Aquatic Health Code
METS	Metabolic Equivalents
MSBL	Maximum Sustainable Bather Load
NCAA	National Collegiate Athletic Association
NEC	National Electrical Code
NEHA	National Environmental Health Association
NEISS	National Electrical Injury Surveillance System
NEMA	National Electrical Manufacturers Association
NFHS	National Federation of State High School Associations
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NLSI	National Lightning Safety Institute
NOAA	National Oceanic and Atmospheric Administration
NPDS	National Poison Data System
NPSH	Net Positive Suction Head

NRPA	National Recreation and Park Association
NSF	NSF International (<i>formerly National Sanitation Foundation</i>)
NSPF	National Swimming Pool Foundation
ORP	Oxidation Reduction Potential
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PERC	Propane Education and Research Council
PHMB	Polyhexamethylene Biguanide Hydrochloride
PMRA	Health Canada Pest Management Regulatory Agency
POS	Perimeter Overflow System
PPE	Personal Protective Equipment
PPM	Parts Per Million
PVC	Polyvinyl Chloride
PWTAG	Pool Water Treatment Advisory Group
RED	Reduction Equivalent Dose
RLV	Relative Limit Value
RPZ	Reduced Pressure Zone
RWI	Recreational Water Illness
SDS	Safety Data Sheet
SCI	Spinal Cord Injury
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
STC	Sound Transmission Class
SVRS	Safety Vacuum Release System
TDH	Total Dynamic Head
TDS	Total Dissolved Solids
THM	Trihalomethane
TLV	Threshold Limit Value
UL	Underwriters Laboratories
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code
USACE	United States Army Corps of Engineers
USC	United States Code
USDOE	United States Department of Energy
USLSC	United States Lifeguarding Standards Coalition
USPSHTC	Uniform Swimming Pool, Spa, and Hot Tub Code
UV	Ultraviolet
UVT	Ultraviolet Transmittance
VFD	Variable Frequency Drive
VGB Act	Virginia Graeme Baker Pool and Safety Spa Act
WC	Water Closet
WHO	World Health Organization
WQTD	Water Quality Testing Device
YMCA	Young Men's Christian Association

3.2 Terms Used in the MAHC Annex

“**Activity Pool**” See “*Pool*.”

“**Agitated Water**” means 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.

“**Alpha Bar**” see “**Average Sound Absorption Coefficient**”

“**Aquatic Facility**” means a physical place that contains one or more aquatic venues and support infrastructure.

“**Aquatic Feature**” means an individual component within an aquatic venue. Examples include slides, structures designed to be climbed or walked across, and structures that create falling or shooting water.

“**Aquatic Venue Enclosure**” means an uninterrupted barrier surrounding and securing an aquatic venue.

“**Aquatic Venue**” means an artificially constructed structure or modified natural structure where the general public is exposed to water intended for recreational or therapeutic purpose and where the primary intended use is not watering livestock, irrigation, water storage, fishing, or habitat for aquatic life. Such structures do not necessarily contain standing water, so water exposure may occur via contact, ingestion, or aerosolization. Examples include swimming pools, wave pools, lazy rivers, surf pools, spas (*including spa pools and hot tubs*), therapy pools, waterslide landing pools, spray pads, and other interactive water venues.

- “**Increased Risk Aquatic Venue**” means an aquatic venue which due to its intrinsic characteristics and intended users has a greater likelihood of affecting the health of the bathers of that venue by being at increased risk for microbial contamination (*e.g., by children less than 5 years of age*) or being used by people that may be more susceptible to infection (*e.g., therapy patients with open wounds*). Examples of increased-risk aquatic venues include spray pads, wading pools and other aquatic venues designed for children less than 5 years of age as well as therapy pools.
- “**Lazy River**” means a channeled flow of water of near-constant depth in which the water is moved by pumps or other means of propulsion to provide a river-like flow that transports bathers over a defined path. A lazy river may include play features and devices. A lazy river may also be referred to as a tubing pool, leisure river, leisure pool or a current channel.
- “**Spa**” means a structure intended for either warm or cold water where prolonged exposure is not intended. Spa structures are intended to be used for bathing or other recreational uses and are not usually drained and refilled after each use. It may include, but is not limited to, hydrotherapy, air induction bubbles, and recirculation.
- “**Special Use Aquatic Venue**” means aquatic venues that do not meet the intended use and design features of any other aquatic venue or pool listed/identified in this Code.

“**Authority Having Jurisdiction**” (*AHJ*) means an agency, organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, installations, or procedures.

“**Automated Controller**” means a system of at least one chemical probe, a controller, and auxiliary or integrated component that senses the level of one or more water parameters and provides a signal to other equipment to maintain the parameters within a user-established range.

“**Available Chlorine**” See “*Chlorine*”

“**Average Sound Absorption Coefficient**” (Alpha Bar) means the weighted average sound absorption coefficient for a room calculated by weighting the sound absorption coefficients of the individual surfaces in the room according to their respective areas and taking the arithmetic average as follows (especially in the 500 Hz and 1,000 Hz frequencies): $\text{And } m^2 \text{ (or } ft^2\text{)}$; Where areas of the individual sound absorptive surfaces, $m^2 \text{ (or } ft^2\text{)}$ respective individual absorption coefficients (dimensionless). A sound absorption coefficient is of a surface, in a specified frequency band, the fraction of the randomly incident sound power which is absorbed (or otherwise not reflected) by a material metric: sabin/m^2 .

“**Backflow**” means a hydraulic condition caused by a difference in water pressure that causes an undesirable reversal of the flow as the result of a higher pressure in the system than in its supply.

“**Background Noise**” means noise from all sources unrelated to a particular sound that is the object of interest. Background noise may include airborne, structure borne and instrument noise.

“**Barrier**” means an obstacle intended to prevent direct access from one point to another.

“**Bather**” means a person at an aquatic venue who has contact with water either through spray or partial or total immersion. The term bather as defined, also includes staff members, and refers to those users who can be exposed to contaminated water as well as potentially contaminate the water.

“**Bather Count**” means the number of bathers in an aquatic venue at any given time.

“**Best Practice**” means a technique or methodology that, through experience and research, has been proven to reliably lead to a desired result.

“**Body of Water**” (*per NEC, q.v.*) means any aquatic venue holding standing water, whether permanent or storable.

“**Bulkhead**” means a movable partition that physically separates a pool into multiple sections.

“**Certified, Listed, and Labeled**” means equipment, materials, products, or services included in a list published by an ANSI-accredited certification organization where said equipment, material, product or service is evaluated against specific criteria and whose listing either states that it meets identified standards or has been tested and found suitable for a specified purpose. In sections of this code where equipment, materials, products, or services are referred to with terms such as "approved", "verified" or similar terms to a referenced standard, these terms also mean "certified, listed, and labeled."

“**Chemical Storage Space**” means a space in an aquatic facility used for the storage of pool chemicals such as acids, salt, or corrosive or oxidizing chemicals.

“**Chlorine**” means an element that at room temperature and pressure is a heavy greenish yellow gas with a characteristic penetrating and irritating smell; it is extremely toxic. It can be compressed in liquid form and stored in heavy steel tanks. When mixed with water, chlorine gas forms hypochlorous acid, the primary chlorine-based disinfecting agent, hypochlorite ion, and hydrochloric acid. Hypochlorous acid dissociation to hypochlorite ion is highly pH dependent. Chlorine is a general term used in the MAHC which refers to hypochlorous acid and hypochlorite ion in aqueous solution derived from chlorine gas or a variety of chlorine-based disinfecting agents.

- “**Available Chlorine**” means the amount of chlorine in the +1 oxidation state, which is the reactive, oxidized form. In contrast, chloride ion (Cl^-) is in the -1 oxidation state, which is the inert, reduced state. Available Chlorine is subdivided into Free Available Chlorine and Combined Available Chlorine. Pool chemicals containing Available Chlorine are both oxidizers and disinfectants. Elemental chlorine (Cl_2) is defined as containing 100% available chlorine. The concentration of Available Chlorine in water is normally reported as mg/L (*PPM*) “as Cl_2 ”, that is, the concentration is measured on a Cl_2 basis, regardless of the source of the Available Chlorine.
- “**Free Chlorine Residual**” means the portion of the total available chlorine that is not “combined chlorine” and is present as hypochlorous acid ($HOCl$) or hypochlorite ion (OCl^-). The pH of the water determines the relative amounts of hypochlorous acid and hypochlorite ion. $HOCl$ is a very effective bactericide and is the active bactericide in pool water. OCl^- is also a bactericide, but acts more slowly than $HOCl$. Thus, chlorine is a more effective bactericide at low pH than at high pH. A free chlorine residual must be maintained for adequate disinfection.

“**Cleansing Shower**” See “*Shower.*”

“**Code**” means a systematic statement of a body of law, especially one given statutory force.

“**Combustion Device**” means any appliance or equipment using fire. These include, but may not be limited to, gas or oil furnaces, boilers, pool heaters, domestic water heaters, etc.

“**Construction Joint**” means a watertight joint provided to facilitate stopping places in the construction process. Construction joints also serve as contraction joints which control cracking.

“**Contamination Response Plan**” means a plan for handling contamination from formed-stool, diarrheal-stool, vomit, and blood.

“**Contaminant**” means a substance that soils, stains, corrupts, or infects another substance by contact or association.

“**Corrosive Material**” means pool chemicals, fertilizers, cleaning chemicals, oxidizing cleaning materials, salt, de-icing chemicals, other corrosive or oxidizing materials, pesticides, and such other materials which may cause injury to people or damage to the building, air-handling equipment, electrical equipment, safety equipment, or fire-suppression equipment, whether by direct contact or by contact via fumes or vapors, whether in original form

or in a foreseeably likely decomposition, pyrolysis, or polymerization form. Refer to labels and Safety Data Sheets.

“**Crack**” means any and all breaks in the structural shell of a pool vessel or deck.

“**Cross-Connection**” means a connection or arrangement, physical or otherwise, between a potable water supply system and a plumbing fixture, tank, receptor, equipment, or device, through which it may be possible for non-potable, used, unclean, polluted and contaminated water, or other substances to enter into a part of such potable water system under any condition.

“**CT Inactivation Value**” means a representation of the concentration of the disinfectant (*C*) multiplied by time in minutes (*T*) needed for inactivation of a particular contaminant. The concentration and time are inversely proportional; therefore, the higher the concentration of the disinfectant, the shorter the contact time required for inactivation. The CT value can vary with pH or temperature change so these values must also be supplied to allow comparison between values.

“**Deck**” means surface areas serving the aquatic venue, including the dry deck, perimeter deck, and pool deck.

- “**Dry Deck**” means all pedestrian surface areas within the aquatic venue enclosure not subject to frequent splashing or constant wet foot traffic. The dry deck is not perimeter deck or pool deck, which connect the pool to adjacent amenities, entrances, and exits. Landscape areas are not included in this definition.
- “**Perimeter Deck**” means the hardscape surface area immediately adjacent to and within 4 feet (1.2 m) of the edge of the swimming pool also known as the “wet deck” area.
- “**Pool Deck**” means surface areas serving the aquatic venue, beyond perimeter deck, which is expected to be regularly trafficked and made wet by bathers.

“**Diaper-Changing Station**” means a hygiene station that includes a diaper-changing unit, hand-washing sink, soap and dispenser, a means for drying hands, trash receptacle, and disinfectant products to clean after use.

“**Diaper-Changing Unit**” means a diaper-changing surface that is part of a diaper-changing station.

“**Dichloramine**” means a disinfection by-product formed when chlorine binds to nitrogenous waste in pool water to form an amine-containing compound with two chlorine atoms ($NHCl_2$). It is a known acute respiratory and ocular irritant.

“**Disinfection**” means a treatment that kills or irreversibly inactivates microorganisms (*e.g., bacteria, viruses, and parasites*); in water treatment, a chemical (*commonly chlorine, chloramine, or ozone*) or physical process (*e.g., ultraviolet radiation*) can be used.

“**Disinfection By-Product**” (*DBP*) means a chemical compound formed by the reaction of a disinfectant (*e.g. chlorine*) with a precursor (*e.g. natural organic matter, nitrogenous waste from bathers*) in a water system (*pool, water supply*).

“**Drop Slide**” See “*Slide*.”

“**Dry Deck**” See “*Deck*.”

“**Emergency Action Plan**” (*EAP*) means a plan that identifies the objectives that need to be met for a specific type of emergency, who will respond, what each person’s role will be during the response and what equipment is required as part of the response.

“**Enclosure**” means an uninterrupted constructed feature or obstacle used to surround and secure an area that is intended to deter or effectively prevent unpermitted, uncontrolled, and unfettered access. It is designed to resist climbing and to prevent passage through it and under it. Enclosure can apply to aquatic facilities or aquatic venues.

“**EPA Registered**” means all products regulated and registered under the Federal Insecticide, Fungicide, and Rodenticide Act (*FIFRA*) by the EPA; <https://www.epa.gov/laws-regulations/summary-federal-insecticide-fungicide-and-rodenticide-act>. EPA registered products will have a registration number on the label (*usually it will state “EPA Reg No.” followed by a series of numbers*). This registration number can be verified by using the EPA National Pesticide Information Retrieval System (<http://ppis.ceris.purdue.edu/#>).

“**Equipment Room**” means a space intended for the operation of pool pumps, filters, heaters, and controllers. This space is not intended for the storage of hazardous pool chemicals.

“**Exit Gate**” means an emergency exit, which is a gate or door allowing free exit at all times.

“**Fixture**” See “*Plumbing Fixture*” and/or “*Hygiene Fixture*.”

“Flat Water” means 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.

“Floatation Tank” (a.k.a. Float Tank, Float Room/Pod/Spa/Chamber, Isolation Tank, or Sensory Deprivation Tank) means a tub that contains a saturated solution of magnesium sulfate having a specific gravity of 1.23 to 1.3, provides a light and sound reduced environment, and is maintained at a temperature of approximately 92-96°F / 33.3-35.6°C.

“Floatation Tank Solution” means a saturated solution of magnesium sulfate having a specific gravity of 1.23 to 1.3.

“Flume” means the riding channels of a waterslide which accommodate riders using or not using mats, tubes, rafts, and other transport vehicles as they slide along a path lubricated by a water flow.

“Foot Bath” means standing water in which bathers or aquatics staff rinse their feet.

“Free Chlorine Residual” OR “Free Available Chlorine” See *“Chlorine.”*

“Ground-Fault Circuit Interrupter” (GFCI) means a device for protection of personnel that de-energizes an electrical circuit or portion thereof in the event of excessive ground current.

“Hand Wash Station” means a location which has a hand wash sink, adjacent soap with dispenser, hand drying device or paper towels and dispenser, and trash receptacle.

“Hot Water” means an aquatic venue with water temperature over 90 degrees Fahrenheit (*30 degrees Celsius*).

“Hygiene Facility” means a structure or part of a structure that contains toilet, shower, diaper-changing unit, hand wash station, and dressing capabilities serving bathers and patrons at an aquatic facility.

“Hygiene Fixtures” means all components necessary for hygiene facilities including plumbing fixtures, diaper-changing stations, hand wash stations, trashcans, soap dispensers, paper towel dispensers or hand dryers, and toilet paper dispensers.

“Hyperchlorination” means the intentional and specific raising of chlorine levels for a prolonged period of time to inactivate pathogens following a fecal or vomit release in an aquatic venue as outlined in MAHC 6.5.

“Imminent Health Hazard” means a significant threat or danger to health that is considered to exist when there is evidence sufficient to show that a product, practice, circumstance, or event creates a situation that requires immediate correction or cessation of operation to prevent injury based on the number of potential injuries and the nature, severity, and duration of the anticipated injury or illness.

“Increased Risk Aquatic Venue” See *“Aquatic Venue.”*

“Indoor Aquatic Facility” means a physical place that contains one or more aquatic venues and the surrounding bather and spectator/stadium seating areas within a structure that meets the definition of “Building” per the 2018 International Building Code. It does not include equipment, chemical storage, or bather hygiene rooms or any other rooms with a direct opening to the aquatic facility. Otherwise known as a natatorium.

“Infinity Edge” means a pool wall structure and adjacent perimeter deck that is designed in such a way where the top of the pool wall and adjacent deck are not visible from certain vantage points in the pool or from the opposite side of the pool. Water from the pool flows over the edge and is captured and treated for reuse through the normal pool filtration system. They are often also referred to as “vanishing edges,” “negative edges,” or “zero edges.”

“Inlet” means wall or floor fittings where treated water is returned to the pool.

“Interactive Water Play Aquatic Venue” means any indoor or outdoor installation that includes sprayed, jetted or other water sources contacting bathers and not incorporating standing or captured water as part of the bather activity area. These aquatic venues are also known as splash pads, spray pads, wet decks. For the purposes of the MAHC, only those designed to recirculate water and intended for public use and recreation shall be regulated.

“Interior Space” means any substantially enclosed space having a roof and having a wall or walls which might reduce the free flow of outdoor air. Ventilation openings, fans, blowers, windows, doors, etc., shall not be construed as allowing free flow of outdoor air.

“Island” means a structure inside a pool where the perimeter is completely surrounded by the pool water and the top is above the surface of the pool.

“Landing Pool” See *“Pool.”*

“Lazy River” See *“Aquatic Venue.”*

“Lifeguard Supervisor” means an individual responsible for the oversight of lifeguard performance and emergency response at an aquatic facility. A qualified lifeguard supervisor is an individual who has successfully completed a lifeguard supervisor training course and holds an unexpired certificate for such training; and who has met the pre-service and continuing in-service requirements of the aquatic facility according to this code.

“mg/L” means milligrams per liter and is the equivalent metric measure to parts per million (*ppm*).

“Monitoring” is the regular and purposeful observation and checking of systems or facilities and recording of data, including system alerts, excursions from acceptable ranges, and other facility issues. Monitoring includes human or electronic means.

“Moveable Floors” means a pool floor whose depth varies through the use of controls.

“No Diving Marker” means a sign with the words “No Diving” and the universal international symbol for “No Diving” pictured as an image of a diver with a red circle with a slash through it.

“Noise Criterion” means the single number rating that is somewhat sensitive to the relative loudness and speech interference properties of a given noise spectrum. The method consists of a family of criterion curves extending from 63 to 8,000 Hz and a tangency rating procedure. The criterion curves define the limits of octave band spectra that must not be exceeded to meet occupant acceptance in certain spaces.

“Oocyst” means the thick-walled, environmentally resistant structure released in the feces of infected animals that serves to transfer the infectious stages of sporozoan parasites (*e.g., Cryptosporidium*) to new hosts.

“Oxidation” means the process of changing the chemical structure of water contaminants by either increasing the number of oxygen atoms or reducing the number of electrons of the contaminant or other chemical reaction, which allows the contaminant to be more readily removed from the water or made more soluble in the water. It is the “chemical cleaning” of pool water. Oxidation can be achieved by common disinfectants (*e.g., chlorine, bromine*), secondary disinfection/sanitation systems (*e.g. ozone*) and oxidizers (*e.g. potassium monopersulfate*).

“Oxidation Reduction Potential” (ORP) means a measure of the tendency for a solution to either gain or lose electrons; higher (*more positive*) oxidation reduction potential indicates a more oxidative solution.

“Patron” means a bather or other person or occupant at an aquatic facility who may or may not have contact with aquatic venue water either through partial or total immersion. Patrons may not have contact with aquatic venue water, but could still be exposed to potential contamination from the aquatic facility air, surfaces, or aerosols.

“Peninsula / Wing Wall” means a structural projection into a pool intended to provide separation within the body of water.

“Perimeter Deck” See “Deck.”

“Perimeter Gutter System” means the alternative to skimmers as a method to remove water from the pool’s surface for treatment. The gutter provides a level structure along the pool perimeter versus intermittent skimmers.

“Plumbing Fixture” means a receptacle, fixture, or device that is connected to a water supply system or discharges to a drainage system or both and may be used for the distribution and use of water; for example: toilets, urinals, showers, and hose bibs. Such receptacles, fixtures, or devices require a supply of water; or discharge liquid waste or liquid-borne solid waste; or require a supply of water and discharge waste to a drainage system.

“pH” means the negative log of the concentration of hydrogen ions. When water ionizes, it produces hydrogen ions (H^+) and hydroxide ions (OH^-). If there is an excess of hydrogen ions the water is acidic. If there is an excess of hydroxide ions the water is basic. pH ranges from 0 to 14. Pure water has a pH of 7.0. If pH is higher than 7.0, the water is said to be basic, or alkaline. If the water’s pH is lower than 7.0, the water is acidic. As pH is raised, more hypochlorous acid ionization occurs and chlorine disinfectants decrease in effectiveness.

“Pool” means a subset of aquatic venues designed to have standing water for total or partial bather immersion. This does not include spas.

- **“Activity Pool”** means a water attraction designed primarily for play activity that uses constructed features and devices including pad walks, flotation devices, and similar attractions.
- **“Landing Pool”** means an aquatic venue or designated section of an aquatic venue located at the exit of one or more waterslide flumes. The body of water is intended and designed to receive a bather emerging from the flume for the purpose of terminating the slide action and providing a means of exit to a deck or walkway area.
- **“Skimmer Pool”** means a pool using a skimmer system.

- **“Surf Pool”** means any pool designed to generate waves dedicated to the activity of surfing on a surfboard or analogous surfing device commonly used in the ocean and intended for sport as opposed to general play intent for wave pools.
- **“Therapy Pool”** means a pool used exclusively for aquatic therapy, physical therapy, and/or rehabilitation to treat a diagnosed injury, illness, or medical condition, wherein the therapy is provided under the direct supervision of a licensed physical therapist, occupational therapist, or athletic trainer. This could include wound patients or immunocompromised patients whose health could be impacted if there is not additional water quality protection.
- **“Wading Pool”** means any pool used exclusively for wading and intended for use by young children where the depth does not exceed 2 feet (0.6 m).
- **“Wave Pool”** means any pool designed to simulate breaking or cyclic waves for purposes of general play. A wave pool is not the same as a surf pool, which generates waves dedicated to the activity of surfing on a surfboard or analogous surfing device commonly used in the ocean and intended for sport as opposed to general play intent for wave pools.

“Pool Deck” See “Deck.”

“Pool Slide” See “Slide.”

“Public Water Systems” means water systems including community water systems, non-transient/non-community water systems, or transient non-community water systems with exceptions as noted by AHJ and EPA.

“Purge” means to introduce a large volume of outdoor air to flush the interior space.

“Qualified Lifeguard” means an individual who has successfully completed an AHJ-recognized lifeguard training course offered by an AHJ-recognized training agency, holds a current certificate for such training, has met the pre-service requirements, and is participating in continuing in-service training requirements of the aquatic facility.

“Qualified Operator” means an individual responsible for the operation and maintenance of the water and air quality systems and the associated infrastructure of the aquatic facility and who has successfully completed an AHJ-recognized operator training course to operate an aquatic facility offered by an AHJ-recognized training agency and holds a current certificate for such training.

“Raceway” means an enclosed channel of metallic or nonmetallic materials designed expressly for holding wires, cables, busbars or additional functions as permitted.

“Recirculation System” means the combination of the main drain, gutter or skimmer, inlets, piping, pumps, controls, surge tank or balance tank to provide pool water recirculation to and from the pool and the treatment systems.

“Reduction Equivalent Dose (RED) bias” means a variable used in UV system validation to account for differences in UV sensitivity between the UV system challenge microbe (*e.g., MS2 virus*) and the actual microbe to be inactivated (*e.g., Cryptosporidium*).

“Reverberation” means the persistence of sound in an enclosed or partially enclosed space after the source of sound has stopped due to repeated reflections from the room surfaces; by extension, in some contexts, the sound that so persists.

“Reverberation Time – RT₆₀” means, for airborne sound, the time it takes a reverberant sound field to decay 60 dB after the source is interrupted. If an ambient sound field limits the ability to measure 60 dB of decay, then this time can be extrapolated for the measure of the shorter decay.

“Rinse Shower” See “Shower.”

“Safety” (*as it relates to construction items*) means a design standard intended to prevent inadvertent or hazardous operation or use (*i.e., a passive engineering strategy*).

“Safety Plan” means a written document that has procedures, requirements and/or standards related to safety which the aquatic facility staff shall follow. These plans include training, emergency response, and operations procedures.

“Safety Team” means any employee of the aquatic facility with job responsibilities related to the aquatic facility’s emergency action plan.

“Safety Vacuum Release System” (SVRS) means as defined in 15 USC 8002 (5) “a vacuum release system capable of providing vacuum release at a suction outlet caused by a high vacuum occurrence due to a suction outlet flow blockage.” A SVRS may be a mechanical device installed on the exposed single main suction pipe before a filtration or feature pump or an electrical device located as an attachment to the filtration or feature pump control system or is integral with the filtration or feature pump or motor itself.

“Sanitize” means reducing the level of microbes to that considered safe by public health standards (*usually* 99.999%). This may be achieved through a variety of chemical or physical means including chemical treatment, physical cleaning, or drying.

“Saturation Index” means a mathematical representation or scale representing the ability of water to deposit calcium carbonate, or dissolve metal, concrete or grout.

“Secondary Disinfection Systems” means those disinfection processes or systems installed in addition to the standard systems required on all aquatic venues, which are required to be used for increased risk aquatic venues.

“Shower” means a device that sprays water on the body.

- **“Cleansing Shower”** means a shower located within a hygiene facility using warm water and soap. The purpose of these showers is to remove contaminants including perianal fecal material, sweat, skin cells, personal care products, and dirt before bathers enter the aquatic venue.
- **“Rinse Shower”** means a shower typically located in the pool deck area with ambient temperature water. The main purpose is to remove dirt, sand, or organic material prior to entering the aquatic venue to reduce the introduction of contaminants and the formation of disinfection by-products.

“Skimmer” means a device installed in the pool wall whose purpose is to remove floating debris and surface water to the filter. They shall include a weir to allow for the automatic adjustment to small changes in water level, maintaining skimming of the surface water.

“Skimmer Pool” See “Pool.”

“Slide” means an aquatic feature where users slide down from an elevated height into water.

- **“Drop Slide”** means a slide that drops bathers into the water from a height above the water versus delivering the bather to the water entry point.
- **“Pool Slide”** means a slide having a configuration as defined in The Code of Federal Regulations (*CFR*) Ch. II, Title 16 Part 1207 by CSPC, or is similar in construction to a playground slide used to allow users to slide from an elevated height to a pool. They shall include children’s (*tot*) slides and all other non-flume slides that are mounted on the pool deck or within the basin of a public swimming pool.
- **“Waterslide”** means a slide that runs into a landing pool or runout through a fabricated channel with flowing water.

“Sound Absorption” means (1) the process of dissipating sound energy and (2) the property possessed by materials, objects and structures, such as rooms, for absorbing sound energy.

“Sound Transmission Class (STC)” means a one-number rating of the sound-blocking ability of a partition, door, window, etc., calculated in accordance with ASTM E413 from measurements of one-third-octave band sound pressure levels and sound absorption made in a laboratory and in accordance with ASTM E90.

“Spa” See “Aquatic Venue.”

“Special Use Aquatic Venue” See “Aquatic Venue.”

“Standard” means something established by authority, custom, or general consent as a model or example.

“Storage” means the condition of remaining in one space for one hour or more. Materials in a closed pipe or tube awaiting transfer to another location shall not be considered to be stored.

“Superchlorination” means the addition of large quantities of chlorine-based chemicals to kill algae, destroy odors, or improve the ability to maintain a disinfectant residual. This process is different from hyperchlorination, which is a prescribed amount to achieve a specific CT inactivation value whereas superchlorination is the raising of free chlorine levels for water quality maintenance.

“Supplemental Treatment Systems” means those disinfection processes or systems which are not required on an aquatic venue for health and safety reasons. They may be used to enhance overall system performance and improve water quality.

“Surf Pool” See “Pool”

“**SVRS**” See “Safety Vacuum Release System”

“**Theoretical Peak Occupancy**” means the anticipated peak number of bathers in an aquatic venue or the anticipated peak number of occupants of the decks of an aquatic facility. This is the lower limit of peak occupancy to be used for design purposes for determining services that support occupants. Theoretical peak occupancy is used to determine the number of showers. For aquatic venues, the theoretical peak occupancy is calculated around the type of water use or space:

- “**Flat Water**” means an aquatic venue in which the water line is static except for movement made by users usually as a horizontal use as in swimming. Diving spargers do not void the flat water definition.
- “**Agitated Water**” means 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 so people are standing or playing vertically. Where there is no static water line, movement shall be considered above the deck plane.
- “**Hot Water**” means an aquatic venue with a water temperature over 90°F (32°C).
- “**Stadium Seating**” means an area of high-occupancy seating provided above the pool level for observation.

“**Therapy Pool**” See “Pool.”

“**Toe Ledge**” See “Underwater Ledge.”

“**Trichloramine**” means a disinfection by-product formed when chlorine binds to nitrogenous waste in pool water to form an amine-containing compound with three chlorine atoms (NCl_3). It is a known acute respiratory and ocular irritant. It has low solubility in water and is rapidly released into the air above pools where it can accumulate, particularly in indoor settings.

“**Trihalomethanes**” (*THM*) means chemical compounds in which three of the four hydrogen atoms of methane (CH_4) are replaced by halogen atoms. Trihalomethanes are environmental pollutants and many are considered carcinogenic.

“**Turnover**” or “**Turnover Rate**” or “**Turnover Time**” means the period of time, usually expressed in hours, required to circulate a volume of water equal to the capacity of the aquatic venue.

“**Underwater Bench**” means a submerged seat with or without hydrotherapy jets.

“**Underwater Ledge**” or “**Underwater Toe Ledge**” means a continuous step in the pool wall that allows swimmers to rest by standing without treading water.

“**UV Transmissivity**” means the percentage measurement of ultraviolet light able to pass through a solution.

“**Wading Pool**” See “Pool.”

“**Waterslide**” See “Slide.”

“**Water Replenishment System**” means a way to remove water from the pool as needed and replace with make-up water in order to maintain water quality.

“**Water Quality Testing Device**” (*WQTD*) means a product designed to measure the level of a parameter in water. A WQTD includes a device or method to provide a visual indication of a parameter level, and may include one or more reagents and accessory items.

“**Wave Pools**” See “Pool.”

“**Wing Wall / Peninsula**” See “Peninsula / Wing Wall.”

3.3 Codes, Standards, and Laws Cited in the MAHC Annex

Acoustical Society of America (ASA)

- ANSI/ASA S12.60-2010/Part 1 (R2015), Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools
- ANSI/ASA S12.60-2009/Part 2 (R2014), Acoustical Performance Criteria, Design

Requirements, and Guidelines for Schools, Part 2: Relocatable Classroom Factors

Air Conditioning Contractors of America (ACCA)

- ANSI/ACCA 10 Manual SPS-2011 (RA 2017); Manual SPS HVAC Design for Swimming Pools and Spas

Air Movement Control Association (AMCA)

- AMCA 201-02 (R2011), Fans and Systems
- American Coatings Association (ACA)***
- Hazardous Materials Identification System (HMIS), Fourth Edition
- American Concrete Institute (ACI)***
- ACI 302.1R-15, Guide to Concrete Floor and Slab Construction
- American Heart Association (AHA)***
- American Heart Association (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC)
 - 2015 AHA Guidelines Update for CPR and ECC
 - www.citizencpr.org
- American National Standards Institute (ANSI)***
- ANSI A137.1:2017 American National Standards Specifications for Ceramic Tile
- American National Standards Institute / International Aquatic Foundation (IAF)***
- ANSI/IAF-9
- American National Standards Institute / International Safety Equipment Association (ISEA)***
- ANSI /ISEA Z308.1-2015: American National Standard – Minimum Requirements for Workplace First Aid Kits and Supplies
- American Red Cross (ARC)***
- American Red Cross, Lifeguarding Manual, 2017
- American Safety & Health Institute (ASHI)***
- ASHI CPR, AED and Basic First Aid Combination Training, 2018
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)***
- ANSI/ASHRAE Standard 62.1-2016: Ventilation for Acceptable Indoor Air Quality
 - 2015 ASHRAE Handbook - HVAC Applications
 - 2017 ASHRAE Handbook – Fundamentals
- American Society of Mechanical Engineers (ASME)***
- ASME A112.19.17-2010, Manufactured Safety Vacuum Release Systems (SVRS) for Residential and Commercial Swimming Pool, Spa, Hot Tub, and Wading Pool Suction Systems
- American Society for Testing and Materials (ASTM)***
- ASTM E90 – 09 (2016): Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements
 - ASTM E413 – 16 (2016): Classification for Rating Sound Insulation
 - ASTM E1477 – 98a (2017): Standard Test Method for Luminous Reflectance Factor of Acoustical Materials by Use of Integrating-Sphere Reflectometers
 - ASTM F1346 – 91 (2010): *Standard Performance Specification for Safety Covers and Labeling Requirements for All Covers for Swimming Pools, Spas and Hot Tubs*
 - ASTM F2285 – 04 (2016)e1: Standard Consumer Safety Performance Specification for Diaper Changing Tables for Commercial Use
 - ASTM 2374-17 (2017): Standard Practice for Design, Manufacture, Operation, and Maintenance of Inflatable Amusement Devices
 - ASTM F2376-17a (2017): Standard Practice for Classification, Design, Manufacture, Construction and Operation of Water Slides Systems
 - ASTM F2387-04 (2012): Standard Specification for Manufactured Safety Vacuum Release Systems (SVRS), for Swimming Pools, Spas and Hot Tubs.
 - ASTM F2461-16e1 (2016): Standard Practice for Manufacture, Construction, Operation and Maintenance of Aquatic Play Equipment
- Americans with Disabilities Act Accessibility Guidelines (ADAAG)***
- 2010 ADA Standards for Accessible Design
- Association of Pool and Spa Professionals (APSP)***
- ANSI/APSP/ICC-1 2014, American National Standard for Public Swimming Pools
 - ANSI/APSP-9 2005, Standard for Aquatic Recreation Facilities
 - ANSI/APSP-16 2011, American National Standard for Suction Fittings for Use in

Swimming Pools, Wading Pools, Spas, and Hot Tubs

Canadian Standards Association (CSA)

- Z83.8-2016/CSA 2.6-2016 – Gas Unit Heaters, Gas Packaged Heaters, Gas Utility Heaters, and Gas-Fired Duct Furnaces
- ANSI Z21.13-2017/CSA 4.9-2017 – Gas-Fired Low Pressure Steam and Hot Water Boilers
- CSA 22.1 – 2018 Canadian Electrical Code, Part I (24th Edition), Safety Standard for Electrical Installations
- CAN/CSA-C22.2 NO. 0-10 (R2015) – General Requirements – Canadian Electrical Code, Part II

Caring for Our Children (CFOC)

- National Health and Safety Performance Standards; Guidelines for Early Care and Education Programs, Third Edition, 2011 (revised October 1, 2015)
 - Also known as *Caring for Our Children*, 3rd Edition (CFOC3)
- Accessed at: <http://nrckids.org>

Chlorine Institute (CI)

- Pamphlet 82; Recommendations for Using 100 & 150 Pound Chlorine Cylinders at Swimming Pools, Edition 3, January 2015

Citizen CPR Foundation (CCPRF)

- ECCU Emergency Cardiovascular Care Update Conference
- See: www.citizencpr.org

Conference for Food Protection (CFP)

- Standards for Accreditation of Food Protection Managers Certification Programs, 2016 Edition

Consumer Product Safety Commission (CPSC)

- National Electronic Injury Surveillance System (NEISS) Data
- 15 USC Chapter 106, Pool and Spa Safety (as amended to 2014): Virginia Graeme Baker Pool and Spa Safety Act (VGB Act)
- Interpretations and Staff Guidelines for the Virginia Graeme Baker Pool and Spa Safety Act
- 16 CFR 1207 – Safety Standard for Swimming Pool Slides

Deutsches Institut für Normung (DIN)

- DIN 19643-1: 2012-11 Treatment of Water of Swimming Pools and Baths – Part 1: General Requirements
- DIN 19643-2: 2012-11 Treatment of Water of Swimming Pools and Baths – Part 2: Combinations of Process with Fixed Bed Filters and Precoat Filters
- DIN 19643-3: 2012-11 Treatment of Swimming Water of Swimming Pools and Baths – Part 3: Combinations of Process with Ozonation
- DIN 19643-4: 2012-11 Treatment of Swimming Water of Swimming Pools and Baths – Part 4: Combinations of Process with Ultrafiltration
- DIN 19643-5: 2012-11 Treatment of Swimming Water of Swimming Pools and Baths – Part 5: Combinations of Process Using Bromine as Disinfectant, Produced by Ozonation of Bromide Rich Water

Environmental Protection Agency (EPA)

- EPA 815-R-06-007: *Ultraviolet Disinfectant Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule*, November 2006
- EPA 815-R-99-014: *Alternate Disinfectants and Oxidants Guidance Manual*, April 1999
- *Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986*, 42 U.S.C. Chapter 116
- EPA 550-B-15-001: *List of Lists – Consolidated List of Chemicals Subject to the Emergency Planning and Community Right-To-Know Act (EPCRA), Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Section 112(r) of the Clean Air Act*, March 2015
- https://www.epa.gov/sites/production/files/2015-03/documents/list_of_lists.pdf
- OSWER 90-008.1, June 1990, EPA *Chemical Emergency Preparedness and Prevention Advisory*, Swimming Pool Chemicals: Chlorine
- 7 USC §136 et. seq. (1996), *Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)*
- 40 CFR Subchapter E – *Pesticide Programs*

European Standard (ES)

- EN 13451-11:2014 – Swimming Pool Equipment – Part 11: Additional Specific Safety Requirements and Test Methods for Moveable Pool Floors and Moveable Bulkheads. (Also known as BS EN 13451-11, CSN EN 13451-11, or DIN EN 13451-11)
- BS EN 60268-1:2011 Sound System Equipment. Objective Rating of Speech Intelligibility by Speech Transmission Index (British Standard)

Fédération Internationale de Natation Amateur (FINA)

- Facilities Rules 2017 – 2021, 22 September 2017

Food and Drug Administration (FDA)

- Food Code: 2017 Recommendations of the United States Public Health Service Food and Drug Administration

Health Canada Pest Management Regulatory Agency (PMRA)

- Pest Control Products Act (S.C. 2002, c. 28)
- Pesticide Product Information Database

Illuminating Engineering Society of North America (IESNA)

- IES RP-6-15 Sports and Recreational Area Lighting (2015)
- The Lighting Handbook, 10th Edition (2011)

Institute of Electrical and Electronics Engineers (IEEE)

- IEEE Std 241-1990 – IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (reaffirmed in 1997)

International Association of Electrical Inspectors (IAEI)

- Soares Grounding and Bonding, 13th Edition, 2017

International Association of Plumbing and Mechanical Officials (IAPMO)

- IAPMO/ANSI UMC 1 2015 (2015 Uniform Mechanical Code)
- IAPMO/ANSI UPC 1 2015 (2015 Uniform Plumbing Code)
- IAPMO/ANSI USPSHTC 1 2015 (2015 Uniform Swimming Pool, Spa, and Hot Tub Code)

International Code Council (ICC)

- ICC 300-2012 IS-BLE: 2012 ICC Standard on Bleachers, Folding and Telescopic Seating, and Grandstands
- ICC/ANSI A117.1-2017 Standard for Accessible and Usable Buildings and Facilities
- 2018 International Building Code (IBC)
- 2018 International Fire Code (IFC)
- 2018 International Mechanical Code (IMC)
- 2018 International Plumbing Code (IPC)
- 2018 International Swimming Pool and Spa Code (ISPSC)

International Liaison Commission of Resuscitation (ILCOR)

- 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care With Treatment Recommendations (CoSTR)
- www.ilcor.org

International Organization for Standardization (ISO)

- ISO/IEC Guide 50:2014. Safety Aspects – Guidelines for Child Safety in Standards and Other Specifications

National Collegiate Athletic Association (NCAA)

- 2017-18 and 2018-19 NCAA Men's and Women's Swimming and Diving Rules

National Electrical Manufacturers Association (NEMA)

- NEMA 250-2014, Enclosures for Electrical Equipment (1,000 V Maximum)
- ANSI/NEMA Z535, 2011 (R2017): Safety Alerting Standards

National Federation of State High School Associations (NFHS)

- 2017-18 NFHS Swimming and Diving Rules Book

National Fire Protection Association (NFPA)

- NFPA 1: Fire Code, 2018 Edition
- ANSI Z223.1/NFPA 54: National Fuel Gas Code, 2018 Edition
- NFPA 70: National Electrical Code (NEC), 2017 Edition
- NFPA 70: National Electric Code (NEC) Handbook
- NFPA 211: Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances, 2016 Edition

- NFPA 400: Hazardous Materials Code, 2016 Edition
- NFPA 5000: *Building Construction and Safety Code, 2018 Edition*
- NFPA 652: *Standard on the Fundamentals of Combustible Dust, 2016 Edition*
- NFPA 704: *Standard System for the Identification of the Hazards of Materials for Emergency Response, 2017 Edition*

National Institute for Occupational Safety and Health (NIOSH)

- NIOSH Pocket Guide to Chemical Hazards, September 2007, (NPG) (DHHS (NIOSH) Publication No, 2005-149)
- 42 CFR Part 84, Respiratory Protective Devices, 1995

National Oceanic and Atmospheric Administration (NOAA)

- NOAA Technical Memorandum ERL PMEL-67, *Eyeball Optics of Natural Waters: Secchi Disk Science*, Rudolph W. Preisendorfer, Pacific Marine Environmental Laboratory, Seattle, WA, April 1986.

National Recreation and Park Association (NRPA)

- Aquatic Facility Operator Manual, 6th Edition

National Swimming Pool Foundation (NSPF)

- Pool & Spa OperatorTM Handbook, 2017 Edition

NSF International (NSF)

- NSF/ANSI 14 - 2016b, Plastics Piping System Components and Related Materials
- NSF/ANSI 50 - 16a, Equipment for Swimming Pools, Spas, Hot Tubs and Other Recreational Water Facilities

Occupational Safety and Health Agency (OSHA)

- 29 CFR 1910.304 – Wiring design and protection.
 - (Last updated 73 FR 64205, Oct. 29, 2008)
- 29 CFR 1910.1000 Air contaminants.
 - (Last updated 81 FR 16861, Mar. 25, 2016)
- 29 CFR 1910.1030: - Bloodborne Pathogens.
 - (Last updated 77 FR 19934, Apr. 3, 2012)
- 29 CFR 1910.1200 – Hazard Communication Standard (HSC/HazCom 2012 or HazCom 2012)
- 29 CFR 1910.1200(g) Safety Data Sheets (SDS)

Pool Water Treatment Advisory Group (PWTAG)

- Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 3rd Edition, 2017

Propane Education and Research Council (PERC)

- Instruction Sheet IV: *Identifying and Correcting Burner Problems*

Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)

- SMACNA HVAC Systems Duct Design, 4th Edition, 2006

Underwriters Laboratories (UL)

- UL 50 2015-10-16 Enclosures for Electrical Equipment, Non-Environmental Considerations
- UL 50E 2015-10-16 Enclosures for Electrical Equipment, Environmental Considerations
- UL 379 2013-06-19 Standard for Power Units for Fountain, Swimming Pool, And Spa Luminaries
- UL 508 1999-01-28 Standard for Industrial Control Equipment
- UL 676 2015-08-10 Standard for Underwater Luminaries and Submersible Junction Boxes
- UL 727 2018-01-31 Standard for Oil-Fired Central Furnaces
- UL 1081 2016-08-09 Standard for Swimming Pool Pumps, Filters, and Chlorinators
- UL 1241 2003-06-11 Standard for Junction Boxes for Swimming Pool Luminaries
- UL 1777 2015-10-02 Standard for Chimney Liners
- UL 1995 2015-07-31 Heating and Cooling Equipment
- UL 2075 2013-03-05 Standard for Gas and Vapor Detectors and Sensors
- UL 2452 2006-04-21 Outline of Investigation for Electric Swimming Pool and Spa Cover Operators
- UL 2759 2011-09-26 Standard for Sustainability for Hard Surface Cleaners
- UL 8750 2015-09-15 Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products
- UL 60335-2 2017-09-29 Standard for Household and Similar Electrical

Appliances: Particular Requirements for Electrically Powered Pool Lifts

- UL 61010-1 2012-05-11 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements

U.S. Codes:

- California Health and Safety Code (HSC), Article 4. Lead Materials, Section 116875, January 1, 2009
- Florida Administrative Code, Chapter 64E-9 Public Swimming Pools and Bathing Places, 7-20-2016
- Hawaii Administrative Rules, Title 11, Chapter 10, Public Swimming Pools, July 15, 2002
- Illinois Swimming Facility Code, Section 820, October 4, 2013
- New York Uniform Code Part 6, Subpart 6-1 Swimming Pool Rules and Regulations, July 6, 2011
- Ohio Administrative Code, Chapter 3701-31 Public Swimming Pools, Public Spas, and Special Use Pools, 04-01-2011
- Oregon Administrative Rules, Chapter 333 – Division 60, Public Swimming Pools, September 1, 2014
- Texas Administrative Code, Title 25, Chapter 265, Subchapter L, Standards for Public Pools and Spas, September 1, 2004
- Wisconsin Administrative Code, Chapter SPS 390, Design and Construction of Public Swimming Pools and Water Attractions, 03-01-2009

USA Diving

- USA Diving Competitive and Technical Rules, 2018

United States Army Corps of Engineers (USACE)

- USACE Air Leakage Test Protocol for Building Envelopes - Version 3: 2012-05-11
- http://www.wbdg.org/FFC/ARMYCOE/usace_airleakagetestprotocol.pdf

U.S. Department of Energy (USDOE)

- USDOE Air Leakage Testing and Air Sealing in Existing Multifamily Units, October 2012
- http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/air_sealing_multifamily.pdf

USA Swimming

- USA Swimming 2017 Rulebook

Virginia Graeme Baker Pool and Spa Safety Act (VGB Act)

- Available at: <http://poolsafely.gov/state-local-officials/pool-spa-safety-act-requirements/>
- Interpretation Guidance: <http://poolsafely.gov/pool-spa-safety-act/interpretations-guidelines/>

World Health Organization (WHO)

- Guidelines for Safe Recreational Water Environments – Volume 2 Swimming Pools and Similar Environments, 2006

YMCA of the USA (YMCA)

- On the Guard: The YMCA Lifeguard Manual, 2016 Edition

2018 Annex to the Model Aquatic Health Code

Scientific Rationale

DESIGN AND CONSTRUCTION



4.0 Aquatic Facility Design Standards and Construction

4.0.1 Basic Design Considerations for Handling Particle Contamination Burden, Chlorine and Disinfectant Demand, and Disinfection By-Product Issues

4.0.1.1 Particle Contamination Burden

4.0.1.1.1 Filtration Flow Rate

The particle contamination burden determines the filtration flow rate for a given AQUATIC FACILITY. It is not possible to predict the particle contamination burden for every individual AQUATIC VENUE because the sources will likely vary significantly from one AQUATIC FACILITY to another. However, it is important to understand the upper limit of particle contamination to provide information for filtration designs. If the upper limit of the particle contamination burden is known, then it should be possible for the designer to specify a filtration system that can handle the maximum particle burden and ensure that water turbidity does not increase above an allowable or desirable level. Essentially, the RECIRCULATION SYSTEM needs to be designed to remove particles at least at the same rate at which they are being added by the environment (*e.g., windblown and settling dust*), BATHERS (*e.g., personal care products, body excretions*), and other sources.

4.0.1.1.2 Determining Maximum Rate of Particle Contamination

The best means for determining this maximum rate of particle contamination is through direct measurement at operating facilities to ensure the data are indicative of normal activity. The rate of contamination (*n, particles/time/gallon*) is likely to vary by AQUATIC VENUE location, BATHER COUNTS, BATHER age, time of year, time of day, weather, and proximity to urban and desert environments.

4.0.1.1.3 Data Search

An extensive literature search turned up no relevant data defining the particulate contamination burden in AQUATIC FACILITIES. It is recommended that a model be developed that describes particle addition and subsequent removal by the filtration system. This would include developing a correlation between particle size and turbidity or clarity index; this correlation is needed from a practical point of view since future regulations are likely to be developed based on turbidity or clarity. These data could then be used for making concrete, data-based decisions on removal rate requirements and help with defining the required filtration and circulation capacities.

4.0.1.2 Disinfectant Demand

DISINFECTANT consumption can occur by the reaction of the DISINFECTANT with BATHERS, BATHER waste, and other environmentally-introduced CONTAMINANTS, as well as simple decomposition of the active halides (*i.e., HOCl or HOBr*) into inactive halide ions (*chloride or bromide*). DISINFECTANT decomposition rates will also vary depending on a variety of factors including pH, water temperature, UV light, and BATHER COUNT. Data on DISINFECTANT demand are generally lacking in the literature on all EPA-registered DISINFECTANTS. There are some data available for CHLORINE DISINFECTANT demand, but there are very few for bromine, PHMB, and metal systems.

4.0.1.3 Chlorine Disinfectant Demand

4.0.1.3.1 Contribution of Bather Count

Several studies have investigated the BATHER COUNT'S contribution to CHLORINE demand in AQUATIC VENUE water; however, there is a lack of consistency in how BATHER COUNT was measured. Some studies report data as CHLORINE demand, others as potassium permanganate demand, dissolved organic carbon, or total organic carbon.
32, 33, 34, 35

4.0.1.3.2 Varies in Magnitude

The available data for CHLORINE DISINFECTANT demand indicates that the CHLORINE demand from BATHERS can vary by over an order of magnitude, with the largest value measured being 10 g Cl₂/BATHER (*or 2.2 lb/100 BATHERS*).³⁶

4.0.1.3.3 Simple Decomposition of Chlorine

There are few published data on the CHLORINE demand that occurs in AQUATIC VENUES due to the simple decomposition of CHLORINE. It is well known that CHLORINE is not stable at high temperatures and in the

presence of UV. Both of these factors will reduce active CHLORINE to inactive chloride, without any BATHER waste being present.

4.0.1.3.4 *Rate of Chlorine Loss*

The rate of CHLORINE loss (*pounds of CHLORINE per hour*) due to UV degradation will depend on a number of factors, including the size of the AQUATIC VENUE, the depth of the water and the intensity of the sunshine. It will also depend on the concentration of CYA present, since CYA can help prevent the decomposition of CHLORINE by UV. Given the number of variables, it is difficult to predict CHLORINE decomposition rates in specific AQUATIC VENUES.

4.0.1.3.5 *Reducing Chlorine Loss*

The rate of CHLORINE loss can be reduced by the use of other OXIDIZERS, including potassium monopersulfate and ozone, or UV, which can destroy CONTAMINANTS which would otherwise react with CHLORINE. Additional research on the contributing factors to DISINFECTANT demand (*i.e. nitrogenous waste*) may be warranted in the future as treatment methods are developed to reduce or eliminate them by means other than OXIDATION. It is anticipated that this research would identify the introduction rate of the CONTAMINANT, resulting concentrations, and the effect that reduction or elimination of this CONTAMINANT would have on DISINFECTANT demand or other ancillary benefits (*i.e. reduction of combined CHLORINES*).

4.0.1.3.6 *Chemical Feed Pump Sizing*

Further data collection on CHLORINE usage in real world AQUATIC VENUE situations under different environmental and operational conditions could be used to develop an effective rate law from which the sizing of chemical feed pumps could then be calculated.^{37, 38} The criteria for specifying a chemical feed pump for an AQUATIC VENUE are based on its ability to feed against the process piping pressure and to provide sufficient feed rate to maintain a DISINFECTANT residual in the water. Several states require chemical feed pumps for CHLORINE to be capable of providing up to 10 ppm of CHLORINE in the pipe returning water from the RECIRCULATION SYSTEM back to the POOL. Once actual CHLORINE usage is obtained, a surplus SAFETY factor could be introduced to slightly oversize the feed pump to ensure that the DISINFECTANT dosing amount can be increased to meet increases in demand. Any such sizing requirements need to specify the timeframe within which the pump must be able to satisfy the CHLORINE dosing required. The 2018 MAHC 3rd Edition adds a performance based criteria for designing chemical feed systems.

4.0.1.4 *Disinfection By-Product Issues*

4.0.1.4.1 *Chlorination of Water*

Chlorination, using CHLORINE as the DISINFECTANT, is the most common procedure for AQUATIC VENUE water DISINFECTION and inactivation of waterborne microbial pathogens. BATHER activity and environmentally-introduced material provides a broad range of precursors with which DISINFECTANTS can react (*e.g., perspiration, urine, mucus, skin particles, hair, body lotions, fecal material, soil, etc.*). When CHLORINE reacts with these precursors, a variety of chemical reactions take place, including the formation of DBPs^{39, 40, 41, 42, 43}. DBPs may also be introduced into the AQUATIC VENUE via the water used to fill the AQUATIC VENUE depending on the supply water quality. Municipal fill water can also include chloramines as some municipal systems switch from chlorination to chloramination to meet EPA DBP requirements.⁴⁴ CHLORINE gas, if used, is also extremely toxic.^{45, 46, 47}

4.0.1.4.2 *Types of Disinfection By-Products*

DBPs can be organic^{48, 49} [*e.g., THMs, chlorinated phenols, halo ketones, haloacetic acids, and haloacetonitriles (HANs)*] or inorganic^{50, 51, 52} (*e.g. chloramines and cyanogen chloride*). The major by-products of DISINFECTION using HOBr and HOCl are bromoform ($CHBr_3$) and chloroform ($CHCl_3$), respectively. Chloroform and bromoform are highly volatile compounds that can be inhaled in AQUATIC VENUE environments and also readily absorbed through the skin.^{53, 54, 55}

4.0.1.4.3 *Classes of Organic DBPs*

Some classes of organic DBPs⁵⁶ are:

- THMS (*total THM is the sum of the concentrations of chloroform, bromoform, bromodichloromethane, and dibromochloromethane*);

- Chlorinated phenols (*2-chloro-, 2,4-dichloro- and 2,4,6-trichlorophenol*), haloketones (*1,1-dichloropropanone, 1,1,1-trichloropropanone*);
- Haloketones (*bromopropanone, 1,1-dichloropropanone, 1,1,1-trichloropropanone, etc.*);
- Haloacetic acids (*Total haloacetic acids include the sum of the concentrations of mono-, di-, and trichloroacetic acids and mono- and dibromoacetic acids*);
- Haloacetonitriles (*HANs*) include (*dichloro-, trichloro-, dibromo- and bromochloroacetonitrile*), chloropicrin, chloral hydrate, 3-chloro-4-(*dichloromethyl*)-5-hydroxy-2(5H)-furanone, etc.; and
- Organic chloramines.

4.0.1.4.4 Trihalomethane Concentration in Drinking Water

According to European Union regulations, the concentration of THMs in drinking water should not exceed 100 micrograms per liter ($100 \mu\text{g/L}$) of water for consumption⁵⁷; while in the United States the EPA has established a legal maximum of $80 \mu\text{g/L}$ ⁵⁸. The DIN 19643-1 Swimming Pool Standard specifies a STANDARD maximum of $20 \mu\text{g/L}$.⁵⁹

4.0.1.4.5 Inorganic DBPs

Inorganic DBPs include chloramines and cyanogen chloride. Inorganic chloramines include monochloramine (NH_2Cl), DICHLORAMINE (NHCl_2) and TRICHLORAMINE (NCl_3) and are generated from the reaction of hypochlorite with ammonia and amino-compounds that originate from sweat and urine of the swimmers. TRICHLORAMINE is relatively volatile and partitions easily from water into air.⁶⁰

4.0.1.4.6 Factors that Determine DBP Levels

The conditions that determine production and air levels of DBPs have been suggested to depend on several factors:

- Number of swimmers in the AQUATIC VENUE and their associated hygiene;
- CHLORINE concentration;
- Water temperature;
- Concentration of organic precursors in the AQUATIC VENUE water;
- Chemical structure of the organic precursors;
- Bromide content;
- Indoor air circulation;
- The extent of out-gassing of volatile DBPs;
- pH;
- Level of water agitation (*undisturbed vs. being sprayed*); and
- Concentration of inorganic chloramine from the fill water.

Further research is needed to determine how much DBPs are being created in AQUATIC VENUE water, including the production and retention rate.

4.0.1.4.7 Health Effects

Outbreaks of ocular and respiratory distress associated with indoor air quality have been documented.^{61,62,63,64,65,66,67} Numerous studies have examined the link between air quality in INDOOR AQUATIC FACILITIES and ocular, dermal, and respiratory health effects, including asthma, with mixed results in swimmers, occupational categories such as lifeguards, and elite swimmers who practice regularly for extended times.^{68,69,70,71,72, 73, 74,75,76,77,78} To date, however, several analyses of the data find the link to asthma is inconclusive.^{79,80,81,82} Multiple large studies available now suggest swimming does not increase the risk of asthma.^{83,84,85,86} To the contrary, one prospective study found swimming increased lung function and reduced the risk of asthma symptoms at 7 years of age.⁸⁷ Another large study showed that 6 to 12 year old children who swam regularly before age 2 years did not have an increased risk of asthma, wheezing, or eczema.⁸⁸ The health benefits associated with swimming may therefore include improvement of asthma symptoms and cardiovascular fitness. Pediatricians have long recommended swimming for asthmatic children because of its lower asthmagenicity compared with other forms of exercise. The Belgian Superior Health Council⁸⁹ reviewed the available science related to AQUATIC VENUE swimming and the development of childhood asthma. The Council, in its 2011 report

No. 8748 (*and reiterated in its 2012 report*) concludes swimming remains highly advisable, even in the case of asthma. According to the Council, “For this target group, the advantages of swimming under good hygienic conditions in MONITORED AQUATIC VENUES outweigh the risk of toxicity linked to CHLORINE and its by-products.” Also see Annex 4.6.2.1

4.0.1.4.8 *Benefits Outweigh Risks*

Despite the health risks of DBPs in general, the concentration of organic DBPs found in AQUATIC VENUES is generally low. Therefore, although research results have shown that DBPs do form in detectable concentrations in most AQUATIC VENUES^{90,91,92} and levels of exposure can be measured^{93,94}, it appears that the benefits of DISINFECTION far outweigh the risks posed by its by-products.⁹⁵ The World Health Organization, states that “the risks from exposure to chlorination by-products in reasonably well-managed AQUATIC VENUES would be considered to be small and must be set against the benefits of aerobic exercise and the risks of infectious disease in the absence of DISINFECTION.”⁹⁶ Improved water quality management is recommended to minimize formation and accumulation of these compounds.

4.0.1.4.9 *Urea Concentrations in Pool Water*

A major CONTAMINANT in AQUATIC VENUE water is urea. Urea is chiefly derived from swimmers urinating in AQUATIC VENUE water, but is also present in swimmer’s sweat. It has been shown that urea reacts with HOCl to produce TRICHLORAMINE. However, while breakpoint destruction of ammonia is very fast, reaction of HOCl with urea is very slow. Therefore, urea is difficult to remove quickly by shocking the AQUATIC VENUE water. There are no guidelines in the United States for MONITORING the urea concentration in AQUATIC VENUE water or suggested levels of concern. Input of urea is most effectively minimized by changes in swimmers’ behavior and hygiene.^{97,98, 99,100,101}

4.1 **Plan Submittal**

4.1.1 **Plan Submittal**

4.1.2 **Content of Design Report**

4.1.2.1 **Basis of Design Report**

4.1.2.1.1 *Names / Addresses*

AQUATIC FACILITY plans should include a map indicating the exact location of the AQUATIC FACILITY with street address and geographic location information including the GPS coordinates.

4.1.2.3 **Technical Specifications**

4.1.2.3.1 *Accompanying Drawings*

Appurtenances include everything added to a POOL tank that can be used by swimmers or POOL operators. In addition to diving boards and platforms, WATERSLIDES and other AQUATIC FEATURES, these also include handrails, grab rails, fill spouts, ladders and ladder railings, floating lane dividers, POOL surface sprays under diving boards, starting platforms, floating play toys, POOL SLIDES, and other AQUATIC FEATURES.

4.1.2.3.2 *Technical Details*

Detailed specifications including POOL water temperatures, space design, dry bulb and dew point temperatures, and relative humidity are required to ensure that there is no misunderstanding, ambiguity, or omission between the design professional, owner/operator, and the AHJ reviewer.

4.1.2.3.2.2 **Intended Use**

The owner/operator and design professionals (engineer and architect) need to coordinate intended use, type of AQUATIC VENUE (FLAT WATER, AGITATED WATER, HOT WATER) and intended typical operating water temperature. This is critical towards ensuring owner/operator expectations are fully met. It also helps ensure the HVAC system and building envelope are designed for intended use.

4.1.2.3.5 *Theoretical Peak Occupancy*

Design professionals need to consider the THEORETICAL PEAK OCCUPANCY of an AQUATIC FACILITY as part of the design process. This requires calculation and integration of peak occupancy numbers for the water as well as the

surrounding DECK and seating areas. The rationale for the THEORETICAL PEAK OCCUPANCY density factor numbers for specific AQUATIC VENUE types is as follows:

1. FLAT WATER
 - a. These AQUATIC VENUES generally are for swimming.
 - b. The density factor was established at 20 ft² per person. This represents an average horizontal BATHER occupying a 5 foot (1.5 m) by 4 foot (1.2 m) area.
 - c. Assuming a BATHER is swimming horizontally; a full body length is an average 5 foot (1.5 m) with a 5 foot span to equal 25 ft² (2.3 m²). There was a need to account for higher densities in shallow areas where BATHERS waded vertically versus swim horizontally. The middle ground decided was 20 ft² (1.9 m²).
2. AGITATED WATER
 - a. These AQUATIC VENUES generally are for wading, splashing, and enjoyment of features without swimming.
 - b. The density factor was established at 15 ft² (1.4 m²) per BATHER. This represents an average vertical BATHER occupying a 5 foot (1.5 m) by 3 foot (91 cm) area. This also complies with the Illinois Swimming Facility Code.
3. HOT WATER
 - a. These AQUATIC VENUES generally are for lounging such as hot tubs, warming POOLS, etc.
 - b. The density factor was established at 10 ft² (0.9 m²) per BATHER. This represents an average user sitting in a 3 foot (91 cm) by 3 foot (91cm) area.
4. DECK and Spectator Areas
 - a. For DECKS at leisure POOLS, one can assume a density factor of 50 ft² (4.6 m²) per BATHER of DECK space based on Illinois Swimming Facility Code. When adding seating and tables, which separate groups, the square footage allows for a reduced density.
 - b. For spectator areas, the MAHC Committee chose a density factor of 6.6 ft² (0.6 m²) per PATRON for STADIUM SEATING from ASHRAE 62.1. This seating is generally well above the water level.

The density factors in MAHC 4.1.2.3.5.3 may be modified for higher BATHER or PATRON density, but they shall not be modified to be lower than the density factors listed. The designer/engineer of the AQUATIC FACILITY or AQUATIC VENUE can document the intended use is different. For example, a swimming POOL that is normally a FLAT WATER venue has a density factor of 20 ft² (1.9 m²) per BATHER. However, when designing a FLAT WATER WADING POOL with more vertical use than horizontal swimming, the POOL would have a higher density of BATHERS so the density factor could be modified to 15 ft² (1.4 m²) per BATHER.

Example: MAHC 4.1.2.3.5.3 assigns the letter D to represent the BATHER “density factor”. The D number is listed in terms of square feet of POOL water surface per BATHER. This means that a numerically lower D results in a numerically higher number of BATHERS. When designing an AQUATIC FACILITY, if the expected use will be more BATHERS per square foot than what is listed, then it can be modified to reflect that (i.e., if the expected BATHER density for FLAT WATER is 1/10 ft² instead of 1/20 ft², one can use 1/10 ft² BUT they can’t use 1/30 ft² for FLAT WATER).

4.1.3 Plan Approval

The construction of public AQUATIC FACILITIES should not be undertaken without a thorough review and approval of the proposed construction plans by the AHJ. Construction costs for AQUATIC FACILITIES can be in the millions of dollars and very costly mistakes in design and equipment choices can occur if plans are not reviewed before construction. These mistakes could result in both public health hazards and additional remodeling costs. Most AHJs require that plans be submitted for review and approval by the regulatory authority before a public AQUATIC FACILITY can be constructed. Although there is considerable variation in the amount of information and detail required on the plans, most of the jurisdictions require at least a plot plan with sufficient detail to allow for a reasonable review of the proposed project. The licensed professional engineer or architect should have at least 1 year of previous experience with public AQUATIC FACILITY design. Most states will allow any professional engineer or architect to design an AQUATIC FACILITY. However, since AQUATIC DESIGN technology is sufficiently complex, specific prior experience in AQUATIC FACILITY construction and design is strongly recommended. A minimum of 1 year of previous experience in AQUATIC FACILITY design and construction is recommended.

Any final approval of plans by the AHJ should be dependent on approval by all other appropriate agencies. For example, the assumption of responsibility for reviewing plans for structural SAFETY and ensuring the AQUATIC FACILITY is designed to withstand anticipated loading, not only the POOL shell, but also in cases where the POOL may be located on an upper floor of a building or a rooftop is generally that of the local building department. If there is no local building CODE department or requirements, the design engineer or architect must assume responsibility. This may include requiring the architect or engineer to certify the structural stability of the POOL shell during full and empty conditions.

4.1.3.3 Replacements

Most jurisdictions allow for replacements in-kind.

4.1.4 Compliance Certificate

4.1.4.4 Systems Commissioning

“Commissioning” or “testing of BATHER SAFETY” means completing a test, evaluation, or demonstration that confirms that the AQUATIC FACILITY, AQUATIC VENUES, AQUATIC VENUE FEATURES, and other equipment in question does not compromise the SAFETY of the PATRONS.

4.2 Materials

4.2.1 Aquatic Venues

4.2.1.5 Design Parameters

There are multiple forms of acceptable finishes available, including but not limited to: paint, marcite plaster finish, quartz plaster finish, aggregate plaster finish, vinyl or PVC liner / paneling systems, stainless steel, tile, etc. Each system has advantages and disadvantages associated with cost, durability, clean-ability, etc. These advantages and disadvantages are also subject to installation design issues (*e.g. indoors/outdoors, above/below water level, environmental effects, freezing or temperature exposures, etc.*).

4.2.1.7 Smooth Finish

SKIMMER POOLS require a 6 inch (152 mm) to 12 inch (305 mm) high finish due to the varying height of water associated with in-POOL surge capacity of SKIMMER POOL systems. Gutter or POSs require a minimum finish height of 2 inches (51 mm). If dark colors are utilized for the POOL finish, the POOL finish should not exceed a maximum height of 12 inches (305 mm) for contrasting purposes. Typical finishes include: tile, stainless steel, vinyl, fiberglass, etc.

4.2.1.8 Slip Resistant

Water 3 feet (0.9 m) and less is considered shallow water and the majority of BATHERS are capable of walking on the POOL bottom at these depths, so a slip-resistant surface is required. At depths greater than 3 feet (0.9 m), most BATHERS are sufficiently buoyant making the coefficient of friction for the POOL floor surface less important. Slip resistant surfaces shall meet or exceed the minimum coefficient of friction as set forth by the following:

- ADAAG
- OSHA

4.2.2 Indoor Aquatic Facility

4.2.2.2 Condensation Prevention

Special care should be used in the construction of air-pressure-supported buildings to prevent the movement of moisture into building surfaces, conduits, etc.

4.2.2.2.1 Cold Weather

Paints suitable for use as vapor retarders usually have high solids, and must be carefully applied to achieve a rating of 0.4 perm for one coat. It is important to get very good coverage without gaps or thin spots. The paint supplier or manufacturer should be consulted for ratings and BEST PRACTICES.

4.2.2.2.2 Paint or Coating

The EPA states that there are three main ways to ensure good indoor air quality – ventilation, filtration, and source control. Ventilation and filtration are handled in Section 4.6.2 of the MAHC, but source control is also

important. Many man-made products produce volatile organic compound (VOC) emissions and numerous studies have proven their potentially detrimental impact on human health. These potentially harmful emissions can be off-gassed from many products, including wet applied products (paints, coatings, adhesives, sealants). This section is intended to set minimum requirements for limiting VOC off-gassing from paints and coatings that could cause public health impact during and after the application of these products. (<https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality>). One U.S. perm equals 1.0 grain of moisture per square foot per hour per inch-of-mercury differential pressure. One U.S. perm equals 57 SI perm.

4.2.2.3 Mechanical Systems

4.2.2.3.3 Indoor Aquatic Facility Air Pressure

Air-pressure-supported INDOOR AQUATIC FACILITIES may require pressurization of adjoining or connected spaces.

4.2.2.3.4 Air Ducts

Refer to the ASHRAE Handbook of HVAC Applications on Natatorium Design for recommendations. Coated steel, aluminum, and fabric ducts may be options to consider.

4.2.2.4 Indoor Aquatic Facility Doors

Where exterior doors of an INDOOR AQUATIC FACILITY may be exposed to temperatures below the freezing temperature of water, the frames should be constructed to minimize the risk of the door freezing closed. The issue here is one of emergency exit. There is a large amount of water vapor available to freeze into the gap between doors, etc., that can inhibit emergency exiting. **Exception:** Other doors should be acceptable, subject to approval by the AHJ, where heating systems are so arranged as to maintain such doors at least 5°F (-15°C) above the freezing temperature of water.

4.2.2.4.5 Automatic Door Closer

It is a critical SAFETY issue that a door both closes completely and latches to prevent young unsupervised children from accessing the AQUATIC FACILITY and/or venue.

4.2.2.5 Indoor Aquatic Facility Windows

Windows are usually maintained above -air dew point to prevent condensation and mold growth by heated supply air flowing over them. Heavy window frames on the interior side interfere with the proper flow of this heated air by the Coanda effect (*a corollary of Bernoulli's principle*). There are many ways to mechanically address window condensation issues. Air supply can be dumped on glazing from both above and below. Fin tube heaters have also been effectively employed along sills in many instances.

- Also see: ASHRAE Handbook of Fundamentals¹⁰²

4.3 Equipment Standards [N/A]

4.4 Aquatic Facility and Venue Operation Maintenance [N/A]

4.5 Aquatic Venue Structure

4.5.1 Design for Risk Management

Working with the owner and/or aquatic risk management consultant, the designer can outline the anticipated zones of PATRON surveillance and place fixed lifeguard stations accordingly. It is important to have a person knowledgeable in aquatic risk management to advise on placement of fixed lifeguard stations and the general design of the AQUATIC VENUE as it relates to placement of lifeguards so to avoid blind spots, glare issues, and other obstructions being included in the design. This also allows the owner to influence design so it meets the anticipated labor requirements. In some operations where the AQUATIC VENUE design requires more lifeguards, this puts pressure on owners to minimize labor by extending zones of PATRON surveillance. Small design changes could reduce zone size without taking away from PATRON enjoyment. This is also a critical need when considering alterations such as the addition of new AQUATIC FEATURES (e.g., WATERSLIDES, mushroom) that change visibility and, consequently, the PATRON zones of surveillance and increase the number of lifeguards needed. This knowledge is important to have while deciding on the benefits of the new AQUATIC FEATURE so they can be balanced with the increased labor cost.

4.5.2 Bottom Slope

4.5.2.1 Under Five Feet

A maximum slope of 1:12 is used in water under 5 feet (*1.5 m*) for consistency with ADAAG since these ramps can be used for access. Variances may be considered by the AHJ.

4.5.2.3 Drain

POOLS should be designed to allow for the water to drain to a low point in order to prevent standing water from creating a contamination issue.

4.5.3 Pool Access / Egress

4.5.3.1 Accessibility

As required by the Department of Justice, all POOL designs shall be compliant with the Americans with Disabilities Act Accessibility Guidelines (*ADAAG*). The POOL design shall not create SAFETY hazards with regards to maintaining necessary clearances, not infringing upon the recirculation of AQUATIC VENUE water, or creating areas for potential entrapment.

4.5.4 Stairs

4.5.4.3 Deep Water

It is common, especially in high-end diving wells with ten-meter towers, for there to be “swim-out” stairs underneath the dive tower. This provision is allowing for those types of deep water stairs without requiring the stairs to continue down to the bottom of the POOL (*which may be 17 feet deep and impractical in the diving well example*).

4.5.4.8 Perimeter Gutter Systems

It is not the intent of this section to eliminate the “roll out gutter” as they need to be a minimum 6 inches (*15.2 cm*) from DECK to water level.

4.5.5 Handrails

4.5.5.3 Upper Railing

The 28 inch (*71.1 cm*) minimum may seem inconsistent with ADAAG. However, most handrails at POOLS are not used for ADAAG accessibility. If railings are provided for ADAAG purposes, they will need to meet the ADAAG 34 inch (*86.4 cm*) STANDARDS. The current MAHC language stipulates that 28 inches (*711 cm*) is a minimum, which does not preclude a designer from using 34 inch (*86.4 cm*) railings.

4.5.5.5 ADAAG Accessibility

In addition to meeting ADAAG criteria (e.g., height, spacing), the MAHC contains other necessary design criteria for handrails (e.g., support, transfer loads). In the end, ADAAG STANDARDS will always take precedence over anything in the MAHC. Another source for guidance is the *Architectural Barrier’s Guide* – refer to Swimming Pools, Wading Pools, and Spas section numbers 242 and 1009.

4.5.5.7 Dimensions

Dimensions of handrails should conform to requirements of MAHC Table 4.5.5.7 and MAHC Figure 4.5.5.7.1. Current federal ADAAG requirements require that top gripping surfaces of handrails shall be 34 inches minimum and 38 inches maximum vertically above stair nosings.

4.5.6 Grab Rails

4.5.7 Recessed Steps

4.5.8 Ladders

4.5.8.1 General Guidelines for Ladders

4.5.8.2 Ladder Handrails

ADAAG Accessibility

This pertains to the handrail comments in MAHC Annex 4.5.5.5. The MAHC does not intend to choose only certain aspects of ADAAG to enforce; the MAHC intends that all components of the current ADAAG requirements will stand irrespective of the MAHC language. However, ADAAG does not address structural requirements.

4.5.8.2.4 Pool Wall

This is a design criterion for POOLS in some of the western states. The initial intent was to design against entrapment between the railing and the POOL wall -- both for fingers and also the hands/wrists/arms of smaller children. CPSC recommends 4 inches (*10.2 cm*) based on child anthropometry tables. Anthropometric charts were reviewed in establishing the current allowable range.

4.5.8.2.5 Support

The structural requirements in the ladder, handrail, railing section are taken from commercial manufacturers and their recommended data.

4.5.9 Zero Depth (Sloped) Entries

4.5.10 Disabled Access

4.5.10.1 Conform to ADAAG Standards

Please refer to the governing Department of Justice at www.access-board.gov.

4.5.11 Color and Finish

4.5.11.1 White or Light Pastel

POOL floors and walls should be white or light pastel in color such that the following items can be identified from the POOL DECK:

- Person or body submerged in the water,
- Algae growth,
- Debris or dirt within the POOL, and
- CRACKS in surface finish of the POOL.

The term “light pastel color” should be consistent with Munsell color value 6.5 or higher.

School, facility or team logos incorporated on the POOL finishes are acceptable but will require review by the AHJ to ensure the design of such logos do not impede the color and finish functionality listed above.

Ultimately, water clarity is the primary criteria with which to be concerned. If a POOL has crystal clear water conditions and a BATHER is lying on the floor of a POOL with a blue finish versus one with a white finish, it is logical to think that the BATHER would be more identifiable against the darker finish. However, there's also the argument for recognizing dirt and debris at the bottom of the POOL.

4.5.11.1.1 Munsell Color Value

The State of Wisconsin uses the Munsell color chart and requires values of 6.5 or greater. The Munsell color system looks at color purity, hue, and lightness to assign a value. This system is used in other industries and information on this system is easily available.

A contractor could provide a mock-up during the submittal process to the AHJ or engineer for review and approval. Plaster and other quartz aggregate manufacturers have reflectance testing that is available for finish samples.

The American Plasterer’s Council defers to ASTM E1477 – 98a to determine LRV values. It's a fairly simple test method where "Test specimens are measured for (*total*) luminous reflectance factor by STANDARD color-measurement techniques using a spectrophotometer, tristimulus (*filter*) colorimeter, or other reflectometer having a hemispherical optical measuring system, such as an integrating sphere." The specular component is included to provide the total reflectance factor condition. The instrument STANDARD is referenced to the perfect reflecting diffuser. Luminous reflectance factor is calculated as CIE tristimulus value Y for the CIE 1964 (*10°*) STANDARD observer and CIE STANDARD illuminant D 65 (*daylight*) or F 2 (*cool white fluorescent*).

4.5.12 Walls

4.5.12.4 No Protrusions, Extensions, Means of Entanglement, or Obstructions

There should be no projections from a POOL wall that could cause BATHER entrapment or injury. Exceptions to this include projections including, but not limited to, structures or elements such as stairs, grab rails, ladders, hand holds, PENINSULAS, WING WALLS, underwater lights, SAFETY ropes, WATERSLIDES, play features, other approved POOL amenities, UNDERWATER BENCHES, and UNDERWATER LEDGES.

4.5.13 Structural Stability

Expansion and/or CONSTRUCTION JOINTS should be utilized when determined prudent by a licensed structural engineer. Any joints should utilize waterproofing strategies such as water stops as they are subject to compromising a POOL'S integrity regarding water tightness. The condition of all joints should be inspected regularly to ensure their condition.

4.5.14 Hand Holds

Based on anthropometric data for children between 6.5 to 7.5 years of age, the difference between their stature and vertical grip reach averages 9.3 inches (23.6 cm) so this measurement is incorporated as 9 inches (22.9 cm).

4.5.15 Infinity Edges

4.5.15.1 Perimeter Restrictions

Often with INFINITY EDGE POOLS, the space immediately on the other side of the INFINITY EDGE is an inaccessible area because the DECK needs to end in order to achieve the “infinity” effect—typically this is achieved by an elevation difference—the DECK continues to extend around the POOL perimeter, but below the edge. The MAHC goal was to allow these types of design features while ensuring that these areas of the POOL are safe and still readily accessible for emergency response.

4.5.15.3 Handholds

INFINITY EDGES can be accomplished with an obtuse angle or knife edge, or even a C701 handhold. It is typically submerged a fraction of an inch.

4.5.15.6 Maximum Height

Building CODES typically require a railing for heights greater than 30 inches (76.2 cm) for SAFETY purposes.

4.5.16 Underwater Benches

UNDERWATER BENCHES are intended to allow BATHERS to sit in locations along the POOL wall. These chair/bench-like structures either protrude into the POOL from the POOL wall or are recessed into the POOL wall. To accommodate the size of most people, the seat itself is often 16 inches (40.6 cm) to 18 inches (45.7 cm) wide and is located 12 inches (30.5 cm) to 24 inches (61.0 cm) below the water line. Use of hydrotherapy jets along UNDERWATER BENCHES should be considered during the design phase. Where hydrotherapy jets are used at UNDERWATER BENCHES in swimming POOLS they could potentially push young children from benches, prevent young and weak swimmers from reaching the handhold at the perimeter of the POOL in the location of the bench, or could impart motion to an unconscious victim making it more difficult to identify a victim in need of rescue. This could increase risk of drowning particularly for small children not being supervised. In addition, air entrained by hydrotherapy jets obscures visibility below the water surface which can prevent recognition of a victim submerged below the water surface. More data would help assess this potential risk.

4.5.16.1 Slip Resistant

Slip-resistant surfaces shall meet or exceed the minimum coefficient of friction as set forth by the following groups:

- American National Standards Institute (ANSI) designated STANDARD
- Americans with Disabilities Act Accessibility Guidance (ADAAG)
- Occupational Safety and Health Administration (OSHA)

4.5.16.3 Maximum Water Depth

The 5 foot (1.5 m) depth restriction is to address the potential SAFETY issue of stepping or otherwise moving off a bench into deep water. The seat depth below the water line is limited to 20 inches (50.8 cm) maximum so a non-

swimmer may be comfortable at that depth but once they move from the bench into a greater water depth it may exceed their comfort and/or skill level.

4.5.17 Underwater Ledges

4.5.17.1 Slip Resistant

An UNDERWATER TOE LEDGE for resting (“*tired swimmer’s ledge*”) may be appropriate in any POOL with water depths greater than 5 feet (*1.5 m*). They may be provided at the deep end of a competition POOL or other POOL with swim lanes. A ledge for resting may also be provided along the sidewalls of the same POOLS to allow resting for swimmers using the POOL for recreational swimming.

4.5.17.3 Five Feet or Greater

A ledge for resting should not allow a person to use the ledge to cross from a shallow area into a deeper area of a POOL.

4.5.17.4 Structural Support

UNDERWATER LEDGES for structural support for an upper wall (*structural ledge*) are often located at a water depth of about 3 feet (*0.9 m*) depending on the wall manufacturer. The upper wall is a product manufactured of stainless steel, fiberglass, acrylic, or other materials. The support ledge and wall below the ledge is concrete, gunite, or other materials that the wall manufacturer specifies. Although POOLS using this wall structure are generally smaller POOLS, these POOLS can be any depth.

4.5.18 Underwater Shelves

UNDERWATER SHELVES can be areas such as an expanded top tread of a stairway or a separate area many feet wide and long. The main purpose is for lounging in very shallow water or in chairs, or contoured as couches.

4.5.19 Depth Markers and Markings

4.5.19.1 Location

4.5.19.1.2 Depth Measurements

Non-traditional AQUATIC VENUES such as ACTIVITY POOLS and LAZY RIVERS may have designated entry and exit points and are generally consistent in depth throughout the AQUATIC VENUES. Other AQUATIC VENUES may have landscaping or other BARRIERS so that there is a defined entry such as in a LAZY RIVER. AQUATIC VENUES should install depth markers on the AQUATIC VENUE wall or, when defined entry points are provided, post the depth on entry signs. This requirement is not intended to apply to competition AQUATIC VENUES where skilled divers train and compete in 4 to 6 feet (*1.2 to 1.8 m*) of water and are under the supervision of a certified instructor or coach.

4.5.19.1.3 Below Handhold

Vertical depth markings should be provided just below the handhold for POOLS with DECK level gutters. They could also be considered on the wall of the INDOOR AQUATIC FACILITY if within a reasonable distance from the POOL. For DECK level gutter POOLS, vertical depth markings are more visible just below the water level when compared with locating them on a building wall or fence which may be ten feet (*3 m*) to 50 feet (*15.2 m*) away and obstructed by DECK equipment, POOL appurtenances, etc.

4.5.19.2 Construction / Size

4.5.19.2.3 Color and Height

Depth markers 4 inches (*10.2 cm*) in height are common among several state CODES and found in ANSI/IAF-9 and ANSI/APSP/ICC-1 2014. Also, Human Factors Standards recommends 1 inch (*2.5 cm*) of letter height to ten feet (*3.0 m*) of viewing distance for oversized letters or 1 inch (*2.5 cm*) of letter height to 16.6 feet (*5.1 m*) which is ideal. A 1 inch (*2.5 cm*) letter height to 30 feet (*9.1 m*) of viewing distance is the minimum.

4.5.19.2.4 Feet and Inches

Some states may require both units of measurement in feet, inches, and meters. Some states do not allow for abbreviation of units. Designers may consider using both units of measure on POOLS since thousands and possibly millions of travelers and immigrants enjoy water recreation facilities in the US. Travelers and new immigrants may not be familiar with imperial measurements such as feet and inches, especially those who come from non-English speaking countries. As a result, those individuals don’t have a clear understanding of the length of a foot

and therefore may not realize how deep the water is with imperial depth markings---this is essential knowledge for drowning prevention.

4.5.19.4 No Diving Markers

4.5.19.4.1 Depths

The symbol is required as it is the universally recognized symbol for “NO DIVING” and can be understood by those who do not read and non-English speaking individuals. Diving boards are permitted only when the diving envelope conforms to the STANDARDS of the certifying agency that regulates diving at the facility - NCAA, NFHS, FINA, or USA Diving. If the AQUATIC VENUE does not have competitive diving, then the diving envelope must conform to these diving envelope STANDARDS. The intent of this section is to prohibit recreational and/or unsupervised users from performing DECK level diving into water 5 feet (1.5 m) or shallower. It is not intended to apply to competitive divers competing under the auspices of an aquatics governing body (e.g., FINA, USA Swimming, NCAA, NFHS, YMCA) or under the supervision of a coach or instructor. The vast majority of current STANDARDS allow for diving off the side of the POOL in water 5 feet (1.5 m) deep or greater. Water depths of at least 5 feet (1.5 m) are generally considered as safe for diving from the edge of a POOL where the coping/DECK is the typical 6 inches (150 mm) above the water surface. AQUATIC VENUE size and geometry may necessitate additional depth marking placements about all sides of the AQUATIC VENUE. The ARC recommends 9 feet (2.7 m) of water depth based on analyses of spinal cord injuries.¹⁰³ The organization has clarified this recommendation to state, “Be sure water is at least nine-feet deep unless performed with proper supervision and in water depths that conform with the rules of the concerned regulating body, such as USA Swimming, NCAA, AAU, NFHS, YMCA of the USA, and FINA.” Although there are some national data on spinal cord injuries (SCIs) in general, data on diving-specific SCIs are limited, particularly for SCIs involving public POOL-related competition diving.

General data on spinal cord injuries: For SCIs in general, approximately 40 SCIs/million population occur each year in the US (about 12,400 injuries for 2010) with approximately 4.5% related to diving injuries.¹⁰⁴ SCIs are a catastrophic public health problem leading to disability and decreased life expectancy with a large economic and social burden for those that suffer the injury.^{105,106} The MAHC recommends that these national data be re-analyzed with aquatics in mind to gather more detailed information on SCIs related to diving in treated AQUATIC VENUES, particularly public AQUATIC VENUES.

DECK level diving and swimming POOL-related SCIs: Most SCIs are related to diving into open water (lakes, ocean)¹⁰⁷ or use of private/residential POOLS. Analysis of the National Spinal Cord Injury Statistical Center data shows that 341 enrollees from 1973-1986 had an SCI as a result of diving into swimming POOLS¹⁰⁸. Almost all of the injuries (87%) resulted from diving into private residential POOLS and 57% of injuries were a result of diving into water less than 4 feet (1.2 m) with almost four out of five dives (76.8%) being DECK level dives. Almost half (49%) of injuries involved alcohol use and 46% occurred during parties. In a summary of 194 neck injuries from DECK level dives into in-ground POOLS (33% private residential)¹⁰⁹, 86.6% were in water less than or equal to 4 feet (1.2 m); 99.0% were in water less than or equal to 5 feet (1.5 m). Only one injury occurred in water between 6 and 7 feet (1.8 to 2.1 m). Another global review study showed that 89% of diving-associated neck injuries occurred in water less than 5 feet.¹¹⁰ These data support keeping non-competition DECK level diving to water depths greater than 5 feet (1.5 m). In a study of U.S emergency department (ED) data from 2006-2014, an estimated 83,000 ED visits for injuries occurred as a result of diving into swimming POOLS. The majority were male and significantly more patients were in the 15-24 age category. Spinal cord injuries were more common in those over age 25, whereas intracranial injuries occurred more frequently in younger patients. The total charges for the six-year period approached \$620 million.¹¹¹

International “NO DIVING” MARKER EXAMPLE: Figure 4.5.19.4.1.1



Also see: ANSI/NEMA Z535: Safety Alerting Standards

4.5.19.5 Depth Marking at Break in Floor Slope

A contrasting band is required at the slope transition between shallow water and deep water as an additional means of caution (*along with the SAFETY rope and warning signage*) to BATHERS.

4.5.19.6 Dual Marking System

A symmetrical AQUATIC VENUE design is a design which is circular in nature where there is a shallow end around the entire perimeter and the bottom slopes from the perimeter towards a deeper portion in the center.

4.5.19.8 Wading Pool Depth Markers

A WATERSLIDE RUN-OUT in a WADING POOL may hold up to 6 inches (15.2 cm) of water without necessitating a no-diving sign or depth marker.

4.5.20 Aquatic Venue Shell Maintenance [N/A]

4.5.21 Special Use Aquatic Venues

Since the development of the MAHC, SURF POOLS were identified as different from WAVE POOLS, and many of the requirements for MAHC 4.0: Design and Construction are not applicable to SURF POOLS. The term SPECIAL USE AQUATIC VENUE has been added to potentially allow construction and use of SURF POOLS and any other, yet to be identified, AQUATIC VENUE or POOL that, while meeting the intent of CODE applicability to public AQUATIC FACILITIES, cannot practically be designed to meet existing design STANDARDS and keep the intended use. It is anticipated that appropriate design STANDARDS will be developed and incorporated in the CODE as part of the MAHC revision process.

There are three types of SURF POOL systems currently available or being developed.

1. Sheet flow – this sheet of water typically 1.5 inch (3.8 cm) thick moving at a high velocity – example: FlowRider.
2. Thick flow – a deeper section of water typically 8 inch (20.3 cm) to 14 inch (35.6 cm) flowing at a medium velocity – example: Surfstream.
3. SURF POOL – large 20,000 to 80,000 square feet (1858 to 7432 m²) POOLS with reefs intended to produce surfable waves. Wave systems range in design from a flying reef (*example: Wavegarden*) to pneumatic or hydraulic systems (*example: Thyphoon Lagoon*). SURF POOLS built just for surfing are intended for only a few riders at once and can have fairly complex wave dampening systems on the walls and in shallow water.

4.6 Indoor / Outdoor Environment

4.6.1 Lighting

4.6.1.2 Windows / Natural Light

This would most likely be achieved through the use of photo sensors that would be triggered by a pre-established minimum light level. Manual controls would almost certainly be set based on time of day. As the amount of daylight fluctuates throughout the year, these would need to be adjusted.

4.6.1.3 Light Levels

The minimum light levels are as recommended in the IES RP-6-15, “Sports and Recreational Area Lighting” for the recreational class of use. Higher light levels are recommended for various competitive classes of use. There is a difference between indoor and outdoor settings because outdoor settings usually have a higher contrast with darkness that does not occur indoors.

4.6.1.4 Overhead Lighting

Avoid glare by keeping overhead lighting directed 60-90 degrees horizontal of the eye. Glare on water can be avoided by direct lighting (*i.e., the more direct the light, the less opportunity for glare*). Also consider maintaining a close ratio of the lighting underwater and overhead to obtain a balance thus avoiding glare.

4.6.1.4.1 Artificial Lighting

Glare from artificial light that interferes with the lifeguard’s view of the swimmers shall be avoided.

4.6.1.5 Underwater Lighting

Current regulations specify an under-water light level equivalent to ½ watt per square foot of AQUATIC VENUE surface area. This value is based on outdated incandescent lighting technology. For today’s light sources for higher-efficiency lamps (*i.e., more light output per watt*), this requirement no longer makes sense. Consider using a measure of light output (*e.g., lumens*) instead. Based on an existing 300W General Electric R40 AQUATIC VENUE lamp that produces 3,750 initial lumens of light output, the conversion between watts and lumens is as follows:

$$0.5 \text{ watts/sq.ft.} \times 3,750 \text{ lumens/300 watts} = 6.25 \text{ lumens/sq.ft.}$$

Example:

Lighting comparison between Incandescent & LED lamps for a 2,400 square foot (223 m²) AQUATIC VENUE.

- 300 watt Incandescent Lamps (12.5 lumens per watt = 3,750 lumens per lamp)
 - 2,400 square feet x 0.5 watts/square foot x lamp/300watts = 4 lamps
- 30 watt LED Lamps (125 lumens per watt = 3,750 lumens per lamp)
 - 2,400 square feet x 6.25 lumens/square foot x lamp/3,750 lumens = 4 lamps

Notice that LED lamps are 90% more efficient (*lumens/watt*) than Incandescent lamps.

“A replacement lamp will need to provide 6.25 lumens per square foot of surface area.”

Additional Information:

The incandescent lamp has an average life of 2,000 hours. For an AQUATIC VENUE that is operational 12 hours per day for 365 days (4,380 hours per year), the incandescent lamp failure rate would be approximately two times a year. Note that in-water AQUATIC VENUE lighting remains on when the AQUATIC VENUE is closed to swimming. For the 50,000 hour life of an LED lamp, the failure rate would be 11.4 years. The AQUATIC VENUE surface replacement would be a determination of replacement lamps and not the lamp itself. Annual energy savings per lamp would be 1,183 KWH.

4.6.1.5.1 Minimum Requirement

A common practice has been to express underwater lighting requirements in watts per square foot of POOL surface. Light output efficacy (*lumens per watt*) can vary greatly depending on the light source. Incandescent lighting, the most historically prevalent underwater light source, also has the lowest or worst efficacy. Some of the most common incandescent lamps are listed below, along with their initial lumen output and calculated efficacy.

Table 4.6.1.5.1: Common Incandescent Lamps and Their Initial Lumen Output and Efficacy

Lamp	Initial Lumens	Efficacy (Lumens/Watt)
200 Watt PAR 46	2270	11.35
200 Watt PAR 56	2270	11.35
300 Watt PAR 56	3840	12.80
500 Watt PAR 64	6500	13.00

For the purposes of these requirements, the underwater lighting requirements have been converted from incandescent watt equivalents to initial lamp lumens using a conversion factor of 12.0 lumens per watt. The converted watts per square foot of POOL surface requirements are 0.5 watts [outdoor], 1.5 watts [indoor], 1.5 watts [outdoor-diving], 2.5 watts [indoor-diving]. White lighting is best for illuminating underwater surfaces for the detection of a swimmer. Colored lighting makes it more difficult to distinguish a body underwater. Designers should discuss output requirements with manufacturers when considering colored lighting since colored lights may not deliver the same illumination levels as white lights and may, therefore, not meet MAHC requirements. It is recommended that future studies be conducted to determine minimum lighting requirements based on water depth, hours of operation, and overhead lighting design. The main goal is to be able to see the bottom of the POOL, in particular a person on the bottom, at all times when the POOL is open to the public.

4.6.1.6 Night Swimming with No Underwater Lights

Providing higher lighting levels (*15 footcandles (161 lux)*) than the minimum requirements (*10 footcandles (108 lux)*) of MAHC 4.6.1.3.1 eliminates the requirement for underwater lighting in outdoor POOLS.

4.6.1.7 Emergency Lighting

This section isn't intended to provide less stringent requirements, just a baseline STANDARD of design for locales that may not address this requirement. The industry commonly uses 0.5 foot-candle (5.4 lux) as an industry design STANDARD.

4.6.1.8 Glare

Consider the sun's positioning through different seasons as well as the window placement to avoid glare. Consider moveable lifeguard stands or positions to avoid glare in different seasons. Consider tint and shades when natural light causes glare. Windows and any other features providing natural light into the POOL space and overhead POOL lighting should be arranged to avoid glare on the POOL surface that would prevent identification of objects on the POOL bottom. Careful consideration should be given to the placement of windows and skylights about the POOL. Natural light from directly overhead is less likely to create glare than light through windows at the sides and ends of the POOL. Control of glare from artificial light is more likely if the angle of incidence of the main light beam is less than 50 degrees from straight down. Diffuse or indirect light sources may also help to minimize glare. The MAHC had a very difficult time coming to a consensus on wording regarding glare that could be defended and enforced from a regulatory standpoint. How does a plan reviewer determine that glare based on design documents are excessive (*perhaps only in certain months of the year*)? The MAHC decided to put design recommendations would best be addressed in the Annex.

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 NEHA recommendations regarding ventilation were reviewed prior to the release of the 1st edition of the MAHC. The MAHC 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 with 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 aquatics industry has always had a challenge with indoor air quality. With the relatively recent increases in building large indoor waterparks, which have high BATHER COUNTS and contamination burdens and exposure times 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 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 during MAHC development and also identifies areas where more research is needed before additional parameters can be set. The MAHC’s intent is 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 MAHC approached this section assuming designs will be evaluated by the AHJ in the location in which the system is to be installed. Following the first public comment period during MAHC development, the ventilation requirements were dramatically changed and draft material was removed from both the CODE and Annex. The thinking behind those initial recommendations was saved for future consideration in MAHC, Appendix 2.

4.6.2.1 Purpose

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.

Disinfection By-Products

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 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 reviews discuss the acute and potentially long-term health effects (*e.g., asthma, bladder cancer*) of exposure to these compounds in the aquatic setting since many of the studies are cross-sectional or ecologic in design, which makes it difficult to definitively link exposures, actual exposure levels, and swimming.^{112,113,114,115,116,117,118} 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^{119,120} and raw produce.¹²¹ Similar symptoms of ocular and respiratory distress have been documented in outbreaks associated with use of INDOOR AQUATIC FACILITIES.^{122,123,124,125,126,127} Other suspected chloramine-associated outbreaks are listed in past issues of CDC’s Waterborne Disease and Outbreak Surveillance Summaries that can be viewed at www.cdc.gov/healthywater/surveillance/rec-water-surveillance-reports.html. Also see MAHC Annex 4.0.1.4.7.

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 AQUATIC FACILITY environment and cause infections^{128,129} and hypersensitivity/allergic reactions (*e.g., “Hot tub lung”; “Lifeguard lung”, Pontiac fever*).^{130,131,132,133,134} The levels of pathogens and their constituents can be minimized with adequate INDOOR AQUATIC FACILITY ventilation, maintenance, and required water quality.

4.6.2.2 Exemptions

The MAHC 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.

4.6.2.5 ASHRAE 62.1 Compliance

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 MAHC:

- Indoor air quality - chemical, biological, and physical CONTAMINANT load;
- Moisture removal – humidity and temperature;
- Cost of energy – important to larger sites.

When determining the factors a design professional considers, much discussion centered around ASHRAE 62.1 and the parts of design not specifically listed in ASHRAE 62.1 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 PATRONS and the building, which requires movement of air. The current ASHRAE 62.1 STANDARD states 0.48 cfm/ft² fresh air is the minimum but still requires an air change. The MAHC considers air delivery rate like TURNOVER for AQUATIC VENUES. To assure good indoor air quality, it is likely that the design should consider THEORETICAL PEAK OCCUPANCY, water type (*e.g., flat, agitated, hot*) and the size and use of the building. The current STANDARDS approach to ventilation is based on square footage of the AQUATIC FACILITY and yet AQUATIC FACILITIES vary in size. Some facilities have a 20 foot (*6.1 m*) ceiling and in the case of indoor waterparks and stadium-style INDOOR AQUATIC FACILITIES, the ceiling heights can reach 60+ feet (*18.3 m*). In addition, the water surface area has a great deal to do with the amount of CONTAMINANTS released into the air but this is generally not included in design criteria. There are many microclimates in larger AQUATIC FACILITIES with varied AQUATIC VENUES and AQUATIC FEATURES. Air movement will need to be targeted within these microclimates. The challenge is that ASHRAE 62.1 only takes into account the building square footage and number of spectators rather than BATHERS. ASHRAE fundamentals require an air delivery rate for the volume of air. Designers felt water chemistry, fresh air, THEORETICAL PEAK OCCUPANCY, water surface area and type, and distribution of air (barring condensation) are more or equally as important as the air delivery rate.

4.6.2.6 Air Handling System Design

4.6.2.6.2 Design Factors and Performance Requirements

Known chemical, biological, and physical CONTAMINANTS:

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

Table 4.6.2.6.2: Known Chemical, Biological, and Physical Contaminants:

Chemical	Biological
Trichloramines	<i>Mycobacterium avium</i> complex
Trihalomethanes	<i>Legionella</i> spp. (primarily <i>L. pneumophila</i>)
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 1: 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 TRICHLORAMINE was the most prevalent CONTAMINANT reported¹³⁵. Therefore, this section of the MAHC focused on TRICHLORAMINE as the major chemical CONTAMINANT for design considerations.

The bullets below summarize findings on the threshold amounts that produced adverse health symptoms.

- Gagniere¹³⁶ 0.5 mg/m³
- Levesque¹³⁷ 0.37 mg/m³
- Hery¹³⁸ 0.5 - 0.7 mg/m³

- Massin¹³⁹ 0.5 mg/m³
- Jacobs¹⁴⁰ 0.56 mg/m³ (average)
- Thickett¹⁴¹ 0.5 mg/m³

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/operators to test routinely or with any consistency. For these two reasons, the MAHC could not establish a threshold to be enforced in 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:

- 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.
- 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 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. In the interim, bio-MONITORING for TRICHLORAMINES can be effectively accomplished by training POOL operators to be on alert for the distinctive chloramine odor and eye and lung irritation it causes. Since the odor threshold for TRICHLORAMINE is ~0.1 mg/m³ and, as illustrated above, health symptoms start happening around 0.3-0.5 mg/m³, odor MONITORING can generally work well as an early warning system. It was recognized by the MAHC 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 versus controlling combined CHLORINE levels. Further research is needed to determine the effectiveness of UV and ozone on destroying DBPs or creating new DBPs before they can be considered in the design of an AIR HANDLING SYSTEM. Guidance is 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 MAHC 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 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.*
- *UV systems must have a wavelength of 254 and/or 282 nanometers to reduce monochloramine, DICHLORAMINE, and TRICHLORAMINE.*

Another concern is that although it is believed UV and ozone are effective at breaking down TRICHLORAMINE, we do not know its effect on the other CONTAMINANTS such as THMS. 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 DISINFECTION SYSTEM is used to break down TRICHLORAMINE, it does not mean the other airborne CONTAMINANTS are also destroyed by the SECONDARY DISINFECTION SYSTEM. The photochemistry may be different so efficacy may have to be determined for other compounds.

4.6.2.6.3 Other Air Handling Systems

Ventilation in Chemical Storage Spaces

The design for CHEMICAL STORAGE SPACE was included in the initial version of the MAHC Ventilation and Air Quality module AIR HANDLING SYSTEM design posted for public comment. It was removed in the revised indoor AIR HANDLING SYSTEM design area of the MAHC as part of revising the definition of an INDOOR AQUATIC FACILITY for which the AIR HANDLING SYSTEM does not include CHEMICAL STORAGE SPACE or other space outside the negative pressure zone around the AQUATIC VENUE. However, the building of an INDOOR AQUATIC FACILITY will still require consideration of the ventilation of CHEMICAL STORAGE SPACES using separate AIR HANDLING SYSTEMS so the text has been moved to MAHC 4.9.2.

4.6.2.7 Performance Requirements for Air Handling Systems

4.6.2.7.1 Minimum Outdoor Air Requirements

During MAHC development, significant numbers of public comments were received regarding the proposed increase, above ASHRAE 62.1 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 MAHC decided to defer to ASHRAE 62.1 outdoor air requirements in final versions of the MAHC. The MAHC preserved the work done by the Technical Committee by moving the proposed CODE language for additional outdoor air to *Appendix 2: Air Quality Formula* 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.

4.6.2.7.2 System Alarm

There are several methods to add a MONITORING station to the outside air portion of the AIR HANDLING SYSTEM to establish the volume of outside air being introduced into the AQUATIC FACILITY. Such a MONITORING station should be installed. In addition, it should be noted that a negative pressure must be maintained during all operating modes. This negative pressure must be set-up at the commission stage by the installing contractor or by means of automatic operation by the AIR HANDLING SYSTEM or Building Automation System.

4.6.2.7.6 Relative Humidity

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 amount of atmospheric moisture is dependent on temperature, relative humidity is a function of both moisture content and temperature. The QUALIFIED OPERATOR and inspection personnel should routinely MONITOR the relative humidity inside the INDOOR AQUATIC FACILITY. Relative humidity levels should be MONITORED using a properly calibrated humidity meter, and it can fluctuate based upon a variety of factors, including occupancy and use of the INDOOR AQUATIC FACILITY, but a range of 40% to 60% can be accepted. Maintaining relative humidity within acceptable levels 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.

For consideration in designing a facility 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. Taking an arithmetic average of measurements will provide an estimation of the relative humidity in the INDOOR AQUATIC FACILITY. This may require consultation with design professionals.

4.6.2.7.8 Disinfection By-Product Removal

It is the MAHC'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, and
- Use of a cooling tower to force water to off-gas TRICHLORAMINE before reintroducing water to the POOL area.

4.6.2.7.11 Purge

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. The intent is to run the AIR HANDLING SYSTEM at PURGE capacity until the CONTAMINANT causing odor/eye/lung discomfort has dissipated to an acceptable level. The lack of an assay for airborne chloramines, means that "acceptable" is arbitrary and unenforceable since it relies on an operator assessment. When appropriate tests are available, the MAHC will set a numerical action threshold that would be enforceable.

4.6.2.7.12 Air Handling System Filters

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. However, 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.

Air Quality – Health

No rapid, simple, and commercially available tests for di- and tri-chloramine exist at the current time. However, MONITORING for TRICHLORAMINES can also be effectively accomplished by training POOL operators to be on alert for the distinctive chloramine odor and eye and lung irritation it causes. The odor threshold for TRICHLORAMINE is 0.1 mg/m^3 and health symptoms start happening around $0.3\text{-}0.5 \text{ mg/m}^3$, so odor MONITORING generally works well as an early warning system.^{142,143,144,145,146,147}

Air Turnover Rates

MONITORING combined CHLORINES in the water or VOC concentrations in the air can be used as an alternative to measuring air quality. The AQUATIC FACILITY design engineer should specify what the alternative measurement limit should be in establishing an alternate ventilation AIR DELIVERY SYSTEM.

4.6.3 Indoor / Outdoor Aquatic Facility Electrical Systems and Components

Nothing in this CODE should be construed as providing relief from any applicable requirements of the NEC or other applicable CODE.

4.6.3.1 General Guidelines

Wiring

Wiring located near or associated with equipment for BODIES OF WATER should be installed in compliance with the NEC or with other applicable CODE, except where the MAHC is more restrictive.

- See NEC Article 100: *Location, Wet*.
- See NEC Article 110.11: *Deteriorating Agents*.

Sealed Conduit

Electrical conduit that enters or passes through an INDOOR AQUATIC FACILITY should be sealed at the point of entry into the INDOOR AQUATIC FACILITY against the movement of liquids and vapors through the conduit.

Exceptions may include:

- A conduit which only passes through an INDOOR AQUATIC FACILITY, and which has no fittings or joints exposed to INDOOR AQUATIC FACILITY air, should be acceptable without a seal.
- Rigid or intermediate conduit which passes through an INDOOR AQUATIC FACILITY, and which is assembled with threaded couplings only should be acceptable without a seal where at least three threads are engaged at every joint.
- Conduit which passes through an INDOOR AQUATIC FACILITY, and which is assembled with rain-tight compression fittings only should be acceptable without a seal.
- Otherwise-approved non-metallic conduit assembled by glued joints or other solvent-welding method shall be acceptable without a seal where approved by the AHJ.

Note: An explosion-proof seal is not required, unless required by the AHJ.

- See CSA C22.2, Canadian Standards Association.
- See NEC Art. 110.11: *Deteriorating Agents*; National Electric Code.
- See NEMA 250, National Electrical Manufacturers Association.
- See UL 50, Underwriters Laboratories.
- See UL 508, Underwriters Laboratories.

Where such devices must be installed in an INDOOR AQUATIC FACILITY or in spaces containing INDOOR AQUATIC FACILITY air, ENCLOSURES rated NEMA 4X are preferred.

Electric Panels

Electrical panel boards, distribution centers, motor-control centers, fuse panels, circuit-breaker panels, and similar equipment should not be installed in INDOOR AQUATIC FACILITIES or in any space that normally contains INDOOR AQUATIC FACILITY air. Exceptions may include:

- Equipment which is CERTIFIED, LISTED, AND LABELED for the conditions should be acceptable where approved by the AHJ.
- Where SAFETY switches or equipment-disconnect switches must be installed in an INDOOR AQUATIC FACILITY or in spaces containing INDOOR AQUATIC FACILITY air, e.g. per NEC, they should be rated for the conditions.
- Whips consisting of liquid-tight flexible metal conduit are preferable to BX cable or type AC conduit.

For More Information:

- See CSA C22.2, Canadian Standards Association.
- See NEC Art. 110.11: *Deteriorating Agents*; National Electrical Code.
- See NEMA 250, National Electrical Manufacturers Association.
- See UL 50, Underwriters Laboratories.
- See UL 508, Underwriters Laboratories.

Exposed Wiring

Where INDOOR AQUATIC FACILITY lights, attachments, fasteners, and any associated wiring whips are exposed to INDOOR AQUATIC FACILITY air, they should be rated for the conditions¹⁴⁸.

- See ANSI/IEEE 241, Section 5.17.6.
- See Soares Book on Grounding, 8th Ed., 2001, p157.
- See NEC Art. 250-110(2).

Metal Raceways

Metal RACEWAYS should be equipped with a grounding conductor sized according to NEC Article 250 to maintain device ground potential in the event of degradation of the RACEWAY.

- See CSA C22.2, Canadian Standards Association.
- See NEC Article 110.11: *Deteriorating Agents*, National Electrical Code See NEMA 250,
- See UL 50, UL 508.

Any electrical switch installed in an INDOOR AQUATIC FACILITY shall be rated for the atmosphere. Exception may include a switch which is otherwise protected, as in a gasketed weather-tight box with a weather-tight actuator cover shall be acceptable¹⁴⁹.

4.6.3.1.2 Indoor Aquatic Facilities

- See NEC Art. 300.7; *Raceways Exposed to Different Temperatures*, National Electrical Code.
- See Air Leakage Test Protocol for Building Envelopes.
- See Air Leakage Testing and Air Sealing in Existing Multifamily Units.

4.6.3.2 Electrical Equipment in Interior Chemical Storage Spaces

Raceways

All RACEWAYS and RACEWAY devices and boxes in a CHEMICAL STORAGE SPACE should be non-metallic or otherwise rated for the atmosphere¹⁵⁰.

- See NEC Art. 110.11: *Deteriorating Agents*.
- See NEC Art. 378.10: *Non-Metallic Raceways*.
- See NFPA 70HB08 NEC Handbook, Art. 100, “Labeled”, Explanatory Note.
- See SDS Calcium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Sodium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Hydrochloric Acid, Section 10 Stability and Reactivity Data.
- See SDS Muriatic Acid, Section 10 Stability and Reactivity Data.

Sealed

RACEWAYS should be sealed at the point of entry to the CHEMICAL STORAGE SPACE to prevent the egress of liquids, fumes, vapors, and gases from the CHEMICAL STORAGE SPACE via the conduit¹⁵¹.

Note: Explosion-proof seals are not required, unless required by the AHJ.

- See NEC Art. 300.7: *Raceways Exposed to Different Temperatures*.

Metal Raceways

Metal RACEWAYS should be equipped with a grounding conductor sized according to NEC Article 250 to maintain device ground potential in the event of degradation of the RACEWAY¹⁵².

- See ANSI/IEEE 241, Section 5.17.6.
- See Soares Book on Grounding, 13th Ed., 2017.
- See NEC Article 250-110(2).

Electronics

All electrical equipment, devices and FIXTURES should be CERTIFIED, LISTED, AND LABELED for the expected atmosphere of the space.

- See NFPA 70HB08 NFPA NEC Handbook, Article 100: *Labeled, Explanatory Note*.
- See NFPA 70HB08 NFPA NEC Handbook, Article 100: *Listed, FPN*.

Light Switches

Any light switches installed inside interior CHEMICAL STORAGE SPACES should be approved for use in wet and CORROSIVE atmospheres, or shall be otherwise protected, as by a weather-proof actuator cover with a gasket.

- See NEC Article 110.11: *Deteriorating Agents*.

Permanent Electrical Devices

All permanently connected electrical devices should be grounded per the NEC or other applicable CODE, using a separate grounding conductor which does not depend on the conductive integrity of any metal conduit exposed to CHEMICAL STORAGE SPACE air¹⁵³.

- See ANSI/IEEE 241, Section 5.17.6.
- See *Soares Book on Grounding*, 13th Ed., 2017.
- See NEC Article 250-110(2).

4.6.3.2.1 Wet and Corrosive

- See NEC Article 100: *Location, Wet*.
- See NEC Article 110.11: *Deteriorating Agents*.
- See SDS Calcium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Sodium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Hydrochloric Acid, Section 10 Stability and Reactivity Data.
- See SDS Muriatic Acid, Section 10 Stability and Reactivity Data.

4.6.3.2.2 Electrical Conduit

- See NEC Article 110.11: *Deteriorating Agents*.
- See NEC Article 300.7: *Raceways Exposed to Different Temperatures*.
- See SDS Calcium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Sodium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Hydrochloric Acid, Section 10 Stability and Reactivity Data.
- See SDS Muriatic Acid, Section 10 Stability and Reactivity Data.

4.6.3.2.3 Electrical Devices

Electrical panel boards, circuit breakers, disconnects, motors, motor overloads, and similar devices or equipment are included¹⁵⁴.

- See NEC Art. 110.11: *Deteriorating Agents*.

4.6.3.2.4 Protected Against Breakage

- See SDS Calcium Hypochlorite, Section 7 *Handling and Storage*, “Keep away from heat. Keep away from sources of ignition.”
- See SDS Calcium Hypochlorite, Section 10 Stability and Reactivity Data

4.6.4 Pool Water Heating

Evaporation Control

Other CODES do not address the need for constant control of INDOOR AQUATIC FACILITY air temperature in order to control evaporation. They also do not address the need for heat on specific surfaces. INDOOR AQUATIC FACILITY heating equipment should be selected and installed to preserve compliance with the NEC, the National Fuel Gas Code (ANSI Z223.1/NFPA 54 *if applicable*), the 2018 International Mechanical Code, or other applicable CODES, the terms of equipment listing and labeling, and with the equipment manufacturer’s installation instructions. A method of space heating capable of continuously maintaining the temperature of the air in an INDOOR AQUATIC FACILITY at or above the design temperature relative to the POOL water temperature shall be provided. ASHRAE 99.6% climate data is the most reliable for INDOOR AQUATIC FACILITY load calculations.

- See 2017 *ASHRAE Handbook of Fundamentals*¹⁵⁵

Uncontrolled Condensation

Uncontrolled condensation in a building can lead to the growth of molds, with subsequent health effects. Uncontrolled condensation in a building can lead to property damage from rust, rot, ice pressure, and other.

Condensation can be controlled by:

- Controlling the evaporation rate of the water,
- Controlling the temperature and relative humidity of the room air, and
- Maintaining all exposed building surfaces above room-air dew point.

Evaporation Rate

The POOL evaporation rate is affected by the:

- Size of the POOL,
- Agitation of the water,
- Heat of vaporization of the water at that temperature and pressure,
- Temperature difference between the POOL water and the room air and the associated difference in vapor pressures, and
- Speed of the air over the POOL'S surface.
- See Places of Assembly, 2017 *ASHRAE Handbook of Fundamentals*¹⁵⁶

Example for Note: A design POOL-water temperature is 82°F (27.8°C) with a design air temperature of 84°F (28.9°C). If it is decided to raise the POOL water temperature to 83°F (28.3°C); the air temperature should be raised to 85°F (29.4°C) to maintain the same evaporation rate. Any surface which is exposed to room air and which cools below the dew point of the room air will become wet with condensation. Such surface may not be visible, e.g. inside a wall.

Space Heating

- Space heating should be available year-round.
- Space heating should not be disabled seasonally.

Exceptions may include:

- Space heating need not be provided during such times as the POOL(s) may be drained completely, all AQUATIC FEATURES and other evaporative loads are disabled and drained, and the room relative humidity does not rise above the design range.
- Space heating may not be required if ventilation with outdoor-air is sufficient to prevent room temperature from falling below the design range, and room relative humidity from rising above the design range.

Seasonal Disabling

Where POOLS are filled or partially filled, the evaporation rate will increase as room air temperature decreases. Seasonal disabling of space heating could allow a drop of room temperature, with a subsequent increase in evaporation rate and possible uncontrolled condensation.

Surfaces where the temperature may decrease below the design dew point of the space under normal operation shall be identified as part of the design process. At least one inspection should be done during the first heating season to identify any other such surfaces. The addition of heat to surfaces identified may be necessary to maintain their temperature above the design dew point for the space. Where forced air is used to heat identified surfaces, the heating method specified shall be so installed as to heat the room's air supply. The temperature, flow rate, and delivery of the supply air for each identified surface shall be such as to heat that surface above the design dew point of the space, under the worst-case design conditions. Such surfaces may have low values of thermal resistance. Such surfaces may include, but are not limited to windows and their frames, doors and their frames, any metal structural members that penetrate the vapor retarder, and any under-insulated sections of walls or roofs.

- See Thermal and Water Vapor Transmission Data, 2017 *ASHRAE Handbook of Fundamentals*¹⁵⁷

Combustion Heaters

Where combustion space heaters or combustion heaters required are located inside a building, the space in which the heater(s) or an assembly including the heater(s) is located shall be considered to be an EQUIPMENT ROOM for the purposes of MAHC 4.9.1. The requirements of MAHC 4.9.1 shall apply. Exceptions may be made for space heaters that have been CERTIFIED, LISTED, AND LABELED for installation in the atmosphere without requiring ISOLATION from chemical fumes and vapors.

Note: Not all space heaters CERTIFIED, LISTED, AND LABELED for heating INDOOR AQUATIC FACILITY air are CERTIFIED, LISTED, AND LABELED for installation in an INDOOR AQUATIC FACILITY. Combustion space heaters should not be installed in an INDOOR AQUATIC FACILITY, unless the heater is rated for the atmosphere.

4.6.4.1 High Temperature

This temperature limit shall not be construed to be the maximum limit of the bulk water (water in the heater) temperature. Bulk-water temperature limits can be much higher. The temperature limit of MAHC 4.6.4.1 is for water in contact with BATHERS. To meet the limits set in 4.6.4.1, water heaters can:

- Heat the water stream to the limit of MAHC 4.6.4.1 and return the water directly to the AQUATIC VENUE, or
- Heat the bulk water above the limit set in MAHC 4.6.4.1 and then use mixing or other methods to ensure that BATHERS are not exposed to temperatures above the limit of MAHC 4.6.4.1.¹⁵⁸

Examples of “applicable CODES” include but are not limited to:

- IMC 304.1.
- NEC, and
- National Fuel Gas Code (*if applicable*).

4.6.4.4 Equipment Room Requirements

Combustion heaters should not be installed in an INDOOR AQUATIC FACILITY, or exposed to other chemical fumes, unless the heater is rated for the atmosphere. Many POOL heaters are located in CORROSIVE environments that can compromise the heater and venting systems leading to an increased risk of building occupant exposure to harmful products of combustion such as carbon monoxide.

4.6.5 First Aid Area

4.6.5.1 Station Design

A conveniently designated first aid station location should be provided for use when BATHERS report with minor injuries and/or illness. The first aid station must be easy to locate and must have first aid supplies to care for minor injuries and more serious injuries until emergency assistance can arrive. Some AQUATIC FACILITIES may have a formal First Aid Station that is a stand-alone and others may have a location for first aid equipment. The MAHC allows for flexibility in design to call out the location for first aid equipment rather than designate a stand-alone station. Some AQUATIC FACILITIES are large and a single first aid station is not as practical as distributing first aid equipment throughout the AQUATIC FACILITY (*e.g., to individual AQUATIC VENUES*). From a design standpoint, the designer must address the location of such equipment and as stated in MAHC 4.5.1, should work with the owner and/or aquatic risk management consultant to designate these locations.

4.6.6 Emergency Exit

4.6.7 Drinking Fountains

4.6.7.1 Provided

A drinking fountain is required at an AQUATIC FACILITY simply to encourage swimmers to keep hydrated and not to drink the POOL water. At an outdoor AQUATIC FACILITY, the drinking fountain can be located inside an adjacent building to allow year-round use when the AQUATIC FACILITY is closed for the winter. The drinking fountain would not need to be winterized. When a drinking fountain is not located in the AQUATIC FACILITY, it should not be located more than 25 feet (7.6 m) from the AQUATIC FACILITY entrance. The AHJ may approve a bottled water supply in place of a drinking fountain. The water from a bottled water supply shall be as readily accessible to BATHERS as would the water from a drinking fountain.

4.6.8 Garbage Receptacles

4.6.9 Food and Drink Concessions

4.6.10 Spectator Areas

4.6.10.2 Deck

4.6.10.2.1 Additional Width

The MAHC tried to distinguish the word “BARRIER” from “ENCLOSURE.” Those definitions are in the glossary. As currently defined, a “BARRIER” is simply intended to be an obstacle intended to deter direct access from one point to another. For example, a simple post and rope solution would meet MAHC intent.

4.6.10.3 Balcony

The intent is to prevent people from using a balcony as a diving platform. If a balcony is close to overhanging an AQUATIC VENUE, some people may try and use it to jump or dive into the AQUATIC VENUE. The more substantial and preventive the BARRIER at the balcony is, the less likely is that a person will use it.

4.6.10.4 Bleachers

Many building CODE jurisdictions may not be aware of the new ICC 300 bleacher STANDARD. Once jurisdictions adopt the 2007 IBC and supplements, the bleacher STANDARD will become better known.

4.6.11 Indoor Aquatic Facility Acoustics

Guidelines

There are several US and international guidelines recommending limiting BACKGROUND NOISE¹⁵⁹ and suggest values for sound insulation, impact noise, REVERBERATION TIME¹⁶⁰ and equipment noise emissions^{161,162,163}. For example ANSI/ASA S12.16 recommends STC 60 for school POOLS. In 1974, a EPA report identified 70 dB over 24 hours (75 dB over 8 hours) as the average exposure limit to environmental noise. Likewise, levels of 55 dB outdoors and 45 dB indoors were identified as the highest average levels of noise that will permit spoken conversation, sleeping, working, and recreation. These are average levels, not peak levels. These limits are not a STANDARD or regulation. They do give state and local governments the basic information they can, and do, use in setting their own STANDARDS. For full information on the EPA 1974 document, visit NPC Online Library: Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety (<http://www.nonoise.org/library/levels74/levels74.htm>). Similarly, the World Health Organization (WHO) recommends that noise exposure levels should not exceed 70 dB over a 24 hour period, and 85 dB over 1 hour period to avoid hearing impairment. For more information on WHO noise publications, visit WHO/Europe | Noise Publications (<http://www.euro.who.int/en/health-topics/environment-and-health/noise/publications>). Local ordinances usually relate to noise annoyance rather than to hearing hazard risks. In certain situations, such as when recreational exposures are loud because of amplified music or at gaming arcades, local ordinances may require the use of hearing protection devices. For example, the City of San Diego noise ordinance does not allow for over 55 dBA one-hour average sound level in multifamily residential facilities during the day; and 65 dBA in commercial facilities <http://docs.sandiego.gov/municode/MuniCodeChapter05/Ch05Art9.5Division04.pdf>. In workplaces, the Occupational Safety and Health Administration (OSHA) requires that average noise exposures not exceed 90 dB for an 8 hour work day. The National Institute for Occupational Safety and Health (NIOSH) and the World Health Organization (WHO) recommend that the highest permissible level of noise exposure in the workplace is an average of 85 dB over an 8 hour day.

Health Effects of Noise

Over time, any sound that is 85 decibels or higher can cause hearing loss or other health problems. The louder a sound is, and the longer you listen to it, the more it can damage your hearing. Hearing loss can also result from a onetime exposure to a very loud sound or blast. The hearing loss progresses as long as the exposure continues. Early damage may not show up on your hearing test, but can create a ‘hidden hearing loss’ which may make it difficult for you to understand speech in noisy environments. In addition to hearing loss, exposure to noise can cause other health problems: Increased stress, anxiety, and fatigue; elevated blood pressure, cardiovascular disease, loss of sleep, and increased heart rate; ringing, hissing, or roaring in the ears (tinnitus) usually occurs immediately, but then it usually, but not always, goes away. It can, however, be an indication of early hearing

damage. Sounds which would otherwise seem normal to most people, may start to sound unbearably loud (hyperacusis). People suffering from this increased sensitivity to sound may experience discomfort or physical pain. Lifeguards need to be especially attentive and vigilant in order to detect early signs of drowning. However, noise has been found to decrease cognitive task performance and vigilance, as well as music itself being distracting to performance of certain tasks¹⁶⁴. Noise during lifeguard scanning constitutes a potential distracting factor for lifeguards as it can hinder attention to signals from peripheral vision¹⁶⁵. Noise-induced hearing loss is permanent, thus prevention is vital. You can use a sound level meter to measure sound around you, including using free sound level meters developed as “apps” for smartphones. Even without a device to measure sound, you can tell if sound is too loud. If you or others need to shout in order to be heard or cannot understand each other even at arm’s length away, the sound is too loud. The three general steps you can take to protect your hearing are turning the noise down, walking away, and using hearing protection. Hearing protection devices are worn to reduce the level of sound entering the ear. Hearing protection that is improperly fitted or not worn at the time of exposure will not protect hearing. Hearing protection devices come with different noise reduction ratings (NRRs). Most hearing protection devices have NRRs that range from 0 dB to 35 dB. NRR is a “best case” rating measured in a laboratory. The actual sound reduction is less than the number listed for the device when worn correctly. As a basic guide, subtract 7 from the NRR number, then divide the result by 2 to see how well the device might reduce your exposure. For example, you might wear earplugs with an NRR of 27 dB to a concert where the sound reaches 100 dB. You calculate the actual noise reduction as $(27 - 7)/2 = 10$. Your earplugs actually reduce the sound by 10 dB, so your exposure (100 dB – 10 dB) is 90 dB. For more information refer to The Occupational Safety and Health Administration Methods for Estimating HPD Attenuation 29 CFR 1910.95 App B (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9737).

The most common types of hearing protection devices include the following:

- 1) Insert type earplugs: These devices provide an airtight seal with the ear canal, and are cheap, effective, and easy to use. They can be pre-molded (pliable devices of fixed proportions), formable (usually made of expandable foam), custom-molded (to fit precisely the size and shape of an individual’s ear canal), and canal caps (earplugs on a flexible plastic or metal band).
- 2) Earmuffs come in many models designed to fit most people. They block out noise by completely covering the outer ear. Some earmuffs also include electronic parts to help users communicate or to block sound impulses and / or BACKGROUND NOISE.

Noise Levels in Indoor Aquatic Facilities

People in indoor AQUATIC FACILITIES can be exposed to various noise sources such as music, HVAC systems, pumps and other noise sources. Although there are numerous complaints found online regarding loud music at POOL parties, there are only few studies measuring sound levels in POOLS. For example, studies have reported high REVERBERATION TIME inside school swimming POOLS (recommended lower than 2.0 sec; measured above 4 seconds). Those studies also reported that although teachers in school swimming POOLS had weekly noise exposures below 80 dBA, the L_{peak} sound levels reached 120 to 124 dBA¹⁶⁶. Music levels in indoor parties and nightclubs have been measured at 95 to 115 dB. Some hearing loss can occur at 100 dBA after 15 minutes, and after just a few minutes at 120 dBA. Consideration was given to adding a requirement for provision of a noise MONITOR with local visual alarming in the natatorium that would be triggered if noise levels above a specific decibel level were exceeded, to alert PATRONS and the QUALIFIED OPERATOR or responsible supervisor. The intent of this requirement would be to alert facility staff of excessive noise levels and limit noise exposure, especially given the negative effects of noise on lifeguard vigilance and communication. The alarm would need to be a visual alarm, such as a strobe, as an audible alarm may not be heard and would add to the excessive noise level, and signage to notify facility management would need to be present adjacent to the visual alarm. A corresponding operational requirement would be that the noise MONITOR with visual alarm be maintained in working condition. The use of such an alarm was determined not to be feasible at this time due to the following factors which need further research and discussion. These issues should be addressed in order to allow for future consideration of this option:

- Can cost be justified? The cost of a sound meter coupled with an alarm is not insignificant; OSHA STANDARDS (29 CFR 1910.95 Appendix G) state that sound level meters cost about \$500 to \$1,000¹⁶⁷.
- Is there justification to require for all facilities? OSHA STANDARDS (29 CFR 1910.95) only require MONITORING when information indicates an employee’s exposure may exceed an 8-hour time-weighted average of 85 decibels or a dose of fifty percent¹⁶⁸. No precedent in building CODE or other STANDARDS was found that requires preemptive use of sound alarms.

- What would be the expected and appropriate follow-up actions if the alarm is triggered? Would single or repeated exceedances require action on the part of the facility? Should any operational steps be taken immediately? Could capacity be reduced? Is retrofitting a viable option? Should next steps include requiring the facility to consult with a professional, industrial hygienist, or noise control engineer to develop a solution? What would be the cost of this, and of implementing engineering and administrative controls? How would PATRONS be informed of the purpose of the alarm, what it indicates, and what to do if it were to go off? Use of sound absorbing materials can reduce the noise created from sound reflection off of facility surfaces (walls, roof, etc.) but it cannot reduce “direct noise.” For example, the noise created by PATRONS in an outdoor POOL could reach 70-85 dB; and sound reflection of the same POOL in a natatorium may be 10-15 dB higher. But, acoustic design and use of sound absorbing materials would only eliminate the 10-15 dB, it would not be able to reduce the noise generated by PATRONS, etc. during use of the facility, so there may be limited options to reduce noise levels if a prescribed noise level were to be exceeded.
- What would the alarm setpoint be? If the AQUATIC FACILITY had lifeguards or other staff present, the alarm setpoint would need to be at least as conservative as the OSHA PEL or NIOSH REL (NIOSH being more protective). Should other guidelines be used, such as EPA’s 1974 recommendations, or those in the WHO Guidelines for Community Noise (<http://apps.who.int/iris/handle/10665/66217>)? NIOSH provides a discussion regarding noise exposure limits for occupational vs. general environmental noise: <https://blogs.cdc.gov/niosh-science-blog/2016/02/08/noise/>. Should the setpoint be for exceedance of an average noise level over a specific duration (a time-weighted average), or for exceedance of a designated level at any time?

Background on Acoustical Issues

It has been documented in the acoustic literature that high levels of noise adversely impact people’s health and wellbeing. It has been shown that “chronic noise exposure increases stress and reduces the quality of life for those exposed”¹⁶⁹. It has also been shown that “noise may tire out the inner ear, causing temporary hearing loss”¹⁷⁰. “In several tests, it has been established that productivity and efficiency can be seriously affected by high noise levels and that fewer mistakes are made when noise levels are reduced”¹⁷¹. Alongside these issues, noise can also present issues to the SAFETY and wellbeing of staff, visitors and guests. It is imperative that emergency broadcast signals played through a Public-Address system be clearly audible above the background sound. It is therefore necessary to provide an environment that controls excessive noise and REVERBERATION¹⁷², and that allows the PA system to maintain clarity and intelligibility. Many industries have recognized the health effects that noise has on its workers and other stakeholders and have developed STANDARDS and regulations to deal with noise through the use of absorbing materials, improving sound transmission between spaces, and limiting building equipment noise. These include STANDARDS for classrooms, offices, healthcare facilities, and limiting of occupational noise exposure through OSHA. Limiting excessive REVERBERATION and loudness through use of absorbing materials to treat the room is useful to:

- 1) “Reduce noise affecting staff below statutory, advised or desired limits.
- 2) To improve communication, i.e. to allow direct speech communication between staff (e.g. for instructions or warning of imminent danger), and to improve attention to P/A, telephone, fire warning bells, or other electroacoustic systems.
- 3) To reduce the sound pressure level incident on the building envelope, thereby reducing the required sound insulation performance of the ENCLOSURE when considering noise breakout. Conversely, in cases where noise breaks in, treatment limits the amplification of the noise by the space itself”¹⁷³.

Sound System/Public Address System

For INDOOR AQUATIC FACILITIES with a sound system or audio/visual system that plays amplified sounds, it is recommended that the sound system be designed so that the loudspeaker coverage will optimize speech intelligibility (STI) to 0.5 to 0.6 or higher and use strategically placed absorbent material in spaces that will optimize speech intelligibility. One major issue in AQUATIC FACILITIES with a public-address system is ensuring that the PA system can be heard clearly, especially when an emergency event is taking place. The Speech Transmission Index (STI) metric predicts the intelligibility of speech transmitted from talker to listener by a transmission channel¹⁷⁴. The STI is a numerical rating system between 0 and 1 representing the transmission quality of speech. An STI rating of 0.5 is considered a “target value for VA systems” and an STI value of 0.6 is

considered to be between “High quality PA systems” and “Good Speech Intelligibility” according to the BS EN 60268-16:2011.

Sound Blocking/Transmission

It is recommended that single or composite wall and floor-ceiling assemblies separating INDOOR AQUATIC FACILITIES and adjacent spaces be designed, constructed and installed to conform to the following minimum STC¹⁷⁵ Ratings. Note that this CODE addresses acoustics in the part of the AQUATIC FACILITY where the water “vessel” is located (natatorium) and not at other areas of buildings (which would be covered by the building CODE). Therefore, since these design recommendations address walls/ceilings/floors between an INDOOR AQUATIC FACILITY and other rooms in a building, they are presented as recommendations in the Annex.

Table 4.6.11: Recommended Minimum STC Ratings for Indoor Aquatic Facilities

Source Space	Receiving Space	Indoor Aquatic Facility STC Rating
Indoor Aquatic Facility	Hygiene Facility or Corridor	45
Indoor Aquatic Facility	Corridor used as ancillary learning space or with lodging/sleeping rooms	55
Indoor Aquatic Facility	Aquatic director’s office or guard/admin room with/without viewing window	60 without window. Composite STC rating of 35 for wall with window
Indoor Aquatic Facility	All other noise sensitive spaces not listed above, including offices, classrooms, conference rooms, and lodging/ sleeping rooms	60
Equipment Room / Mechanical Room	Indoor aquatic facility; all noise sensitive spaces including those listed above	60

*If amplified music, amplified public address announcements, competitions, large crowds of people cheering or other loud sounds are anticipated in the aquatic area, increased STC ratings may be necessary. Analysis should be performed to determine the necessary STC rating of the partition based on typical anticipated sound levels while occupied.

Limiting sound bleed between the INDOOR AQUATIC FACILITY and adjacent spaces is necessary to provide a comfortable acoustic environment. The STC rating of the separating assembly should be selected based on the anticipated level of sound in the natatorium and the maximum desirable level of background sound in the adjoining space. ANSI/ASA S12.60 recommends a minimum STC rating of 55 between an indoor swimming POOL and a corridor used as an ancillary learning space, a minimum STC rating of 60 between an indoor swimming POOL and a music room, and a minimum STC rating of 60 between an indoor swimming POOL and an office or conference room¹⁷⁶. LEED Version 4 requires a minimum composite STC rating of 60 between mechanical EQUIPMENT ROOMS and occupied areas¹⁷⁷.

4.6.11.1 Acoustic Design Criteria

4.6.11.2 Sound Absorption

INDOOR AQUATIC FACILITIES designed to meet a minimum AVERAGE SOUND ABSORPTION COEFFICIENT (*ALPHA BAR* (α^-))^{178,179} of 0.20 would be a space that begins to absorb sound, instead of amplifying it. It is recommended that the INDOOR AQUATIC FACILITY be designed with an ALPHA BAR of 0.25, which provides a reasonable degree of acoustic comfort. It is preferable that an INDOOR AQUATIC FACILITY be designed with an ALPHA BAR of 0.30 to 0.40, which provides the most acoustic comfort and speech clarity.

4.6.11.2.1 Facilities Used Primarily by Specific Hearing Populations

For INDOOR AQUATIC FACILITIES whose main clientele will be young children, the elderly, or any persons with hearing difficulties, a higher ALPHA BAR is necessary. For these facilities, an ALPHA BAR of 0.30 is recommended, and an ALPHA BAR of 0.35 to 0.45 is preferred.

Specific Hearing Populations

It has been documented in the acoustic literature that persons with hearing impairment require higher signal to noise ratios to hear spoken words with clarity and intelligibility than persons of normal hearing sensitivities¹⁸⁰. Children do not typically hear as they would as an adult until they reach the age of 13-15 years old¹⁸¹. The elderly population typically have diminished hearing abilities in the higher frequencies as they age, a condition known as presbycusis, even if they have not had any noise-induced hearing loss or illness resulting in hearing loss¹⁸². It can therefore be concluded that higher signal to noise ratios are needed when young persons and elderly persons use a facility. BACKGROUND NOISE in AQUATIC FACILITIES come from three main sources: 1. Sound people make – talking, splashing, etc. 2. Sound reflections and REVERBERATION, and 3. Building equipment. All three need to be controlled to improve the signal to noise ratio. This can be achieved through the building design by using adequate finish materials and by lowering the NC criteria to effectively make the building equipment noise quieter.

4.6.11.3 Noise

Sounds from air handling system equipment should not be higher than a maximum NOISE CRITERION (NC)¹⁸³ level of 50 because limiting the BACKGROUND NOISE associated with mechanical units aids in reducing overall sound levels in the facility and assists in maintaining clarity and intelligibility of the spoken word. It is recommended that an INDOOR AQUATIC FACILITY be designed to meet an NC of 45, which provides a reasonable sound level. It is preferable that an INDOOR AQUATIC FACILITY be designed with an NC level of 40 which provides an acoustic environment that will help facilitate communication. The ASHRAE Handbook on HVAC Applications recommends limiting the NC level to 45 in natatoriums¹⁸⁴. Noise control and vibration isolation for AQUATIC VENUE equipment, pumps, heaters, filters and other POOL equipment and piping may be necessary to meet the NC level for the space.

4.6.11.4 Sound Absorbing Materials

Special attention should be given to the selection of sound absorbing finishes, especially those that could come in direct contact with water, chemicals, and CHLORINE. The material also shall be able to withstand exposure to humidity. Any acoustical products selected should be verified as intended for use in INDOOR AQUATIC FACILITY environments.

4.6.11.5 Concave Room Surfaces

Concave wall and ceiling surfaces typically result in sound focusing or creep, which are acoustical defects. Surfaces such as domes, circles, ellipses and parabolas cause sound reflections to converge at a focal point thereby producing sound focusing¹⁸⁵. The curving of a dome on a roof or similar roof structure has a tendency to reflect sounds that are propagated in the space back into the space at certain points, with many reflections overlaying on each other. This phenomenon creates excessive loudness and sound buildup in these focal points. Another acoustic issue known as creep may occur with a concave space, whereby sound is reflected many times across the surface of the curved surface and reflected across the room. These acoustic phenomena contribute to overall increases in loudness, REVERBERATION and result in unintelligible speech. To avoid these phenomenon, it is necessary to treat any concave type wall and ceiling areas with sound absorbing material or to consider changing the geometry of the surface or adding elements that can scatter or diffuse the sounds¹⁸⁶.

4.7 Recirculation and Water Treatment

4.7.1 Recirculation Systems and Equipment

4.7.1.1 General

Rationale for Prescriptive Approach

MAHC recirculation and water treatment systems guidance tends to be more prescriptive than performance based because it is difficult and expensive to measure the performance of the filtration and RECIRCULATION SYSTEM with regard to pathogen removal and/or inactivation. Even the measurement of water clarity (*e.g., turbidity*) can be difficult (*due to potential bubble formation, instrument fouling, and instrument calibration procedures*) and can cost more than a thousand dollars to continuously measure turbidity at a single point.

Reasons to Exceed the Minimum Standards

There is no single TURNOVER TIME or one type of filtration system that is optimal for every AQUATIC VENUE. Requiring the most aggressive design for every AQUATIC VENUE is not the intent of the MAHC (*or even necessary*). However, some AQUATIC VENUES, particularly those with high numbers of BATHERS per unit water volume or a BATHER population more likely to contaminate water (e.g., children less than 5 years of age), could need higher recirculation rates and more efficient filtration than the minimum STANDARDS. Since it is not always possible to predict the number of BATHERS in an AQUATIC VENUE, the MAHC recommends a modest overdesign of the RECIRCULATION SYSTEM pipes and thus ample space be left for expansion of pumping and filtration capacities, which will be referred to henceforth as the hydraulic flexibility recommendation. Future editions of the MAHC could have higher minimum STANDARDS that AQUATIC FACILITIES might wish to comply with without having to remove and replace a lot of concrete to accommodate slightly larger pipes.

Hydraulic Flexibility Recommendation

The hydraulic flexibility recommendation made in the section above will also reduce friction losses in the pipes that may lead to energy savings and reduced operating costs. With the formalization of a new turndown system for AQUATIC VENUES, it is hoped that AQUATIC VENUES may be designed for worst-case conditions and then operated according to the demands placed on the system. A turndown system could be used to operate below the minimum operational STANDARDS set by the MAHC when the AQUATIC VENUES is not occupied as an additional cost-saving measure as long as water quality criteria are maintained.

4.7.1.2 Combined Aquatic Venue Treatment

There are some important considerations to take into account when considering treatment of combined AQUATIC VENUES, and this practice is generally discouraged for most installations. First, to respond to a contamination event, it would be necessary to shut down all AQUATIC VENUES and water features on a combined AQUATIC VENUE treatment system since contamination of one AQUATIC VENUE would rapidly contaminate all combined AQUATIC VENUES. Second, including an INCREASED RISK AQUATIC VENUE on a combined system would require SECONDARY DISINFECTION to be installed for all AQUATIC VENUES on the RECIRCULATION SYSTEM. The two scenarios would involve isolating *Cryptosporidium* to a single AQUATIC VENUE (*limiting the number of BATHERS exposed while keeping the concentration high*) or diluting it as much as possible between all AQUATIC VENUES (*to limit the maximum concentration or exposure level while increasing the number exposed*). Based on the infectious dose concept (*i.e., the number of OOCYSTS required to be ingested to cause an infection*), diluting *Cryptosporidium* or other CONTAMINANTS is one way of reducing outbreak potential but the high numbers of *Cryptosporidium* OOCYSTS that may be excreted (*e.g., 10^8 - 10^9 per contamination event^{187,188}*) may overwhelm modest dilution factors while greatly increasing the number of people exposed. While the number of BATHERS exposed may increase, the exposure level will decrease if circulation rates were the same, meaning dilution of a very small AQUATIC VENUE into a large POOL might reduce the *Cryptosporidium* level from 1000's of OOCYSTS per mL swallowed to less than 1 per mL in the combined system. However, smaller AQUATIC VENUES can be circulated at faster rates through the SECONDARY DISINFECTION SYSTEM and therefore can have OOCYSTS loads reduced faster if they are in a small volume, rapidly circulating AQUATIC VENUE. Design modeling is needed to compare the efficacy of these two scenarios under different OOCYST concentrations. The dilution scenario only works if an INCREASED RISK AQUATIC VENUE of small volume is combined with a large volume AQUATIC VENUE. For AQUATIC VENUES similar in size, the impact of dilution is small while the number of people exposed might double or more. There could also be benefits with a combined system that would make it easier to provide more stable water quality parameters (*in terms of pH and CHLORINE level*) because larger water volumes tend to be easier to control. Again, the potential positive impact of combined water treatment is limited to combining small POOLS with much larger POOLS, which is not likely if the DISINFECTION requirements differ between the AQUATIC VENUES. Hydraulically isolating a given AQUATIC VENUE on a combined treatment system with valves is discouraged because doing so necessarily prevents filtration and recirculation of the water. However, ISOLATION capabilities are recommended for maintenance purposes (*as well as separate drain piping*).

4.7.1.3 Inlets

4.7.1.3.1 General

Flow Velocity

The velocity of flow through any INLET orifice (*at between 100% and 150% of the total recirculation flow rate chosen by the designer*) should normally be in the range of 7 to 20 feet per second (*2.1 to 6.1 m/s*). The range of

velocities through the INLETS was selected to balance two competing goals.(1) The velocity should be high enough to push water effectively to the center of the POOL (*or to within the range of the floor INLETS for wider POOLS*), but (2) the velocity should not be so high as to waste an unnecessary amount of energy. The INLETS still being within design range at 150% of the design recirculation flow rate is to accommodate the hydraulic flexibility recommendation discussed previously. This recommendation ensures proper operation at both the current and any future flow rates up to at least 150% of the recirculation flow.

4.7.1.3.2 Floor Inlets

Maintain and Measure

The use of floor INLETS might require additional considerations for draining them when the POOL is not in use. The likelihood of biofilm proliferation in pipes not in use is thought to increase significantly as the FREE CHLORINE RESIDUAL is dissipated. Drinking water distribution pipes are normally coated with biofilm even in the presence of a constant CHLORINE residual^{189,190}. Since it is more difficult to inactivate microorganisms in a biofilm¹⁹¹, there is potentially increased risk of human exposure to pathogens shielded by biofilm once the POOL reopens. Leoni and coworkers found mycobacteria in 88.2% of POOL water samples analyzed and reported that swimming POOLS provided a suitable habitat for the survival and reproduction of mycobacteria¹⁹². Significant damage to the RECIRCULATION SYSTEM pipes and surroundings can result from the expansion of water as it freezes. Both dangers may be alleviated by simply draining water from the pipes when the POOL is not in use. Provisions might also be recommended to prevent the pipes from refilling with water once drained. Floor INLETS are thought to more effectively distribute chlorinated filtered water to the center of the POOL thereby reducing the magnitude or likelihood of dead zones in the center of the POOL. For this reason MAHC 4.7.1.3.1.3.1 requires floor INLETS are required for POOLS greater than 50 feet (*15.2 m*) in width. The designer should take into account climate when designing the INLET system and provide proper drainage instructions.

4.7.1.3.3 Wall Inlets

4.7.1.3.3.1 Effective Mixing

For STANDARD POOLS, since the majority of the water leaving the POOL does so at the surface, locating the INLETS 24 inches (*61.0 cm*) below the design operating water level would reduce short-circuiting of water from the INLETS to the surface removal system.

4.7.1.3.3.3 Inlet Spacing

Wall INLETS have a limited range for how far they can push water out toward the center of the POOL especially as the flow of water is being pulled out of the POOL at the wall via gutters or SKIMMERS. The likelihood of forming regions in the center of the POOL that are not efficiently filtered or chlorinated increases as the width of the POOL increases. For POOLS less than 4 feet (*1.2 m*) in depth, the average velocity of the water is thought to be increased as the volume of water served by a single INLET is expected to decrease assuming equal spacing. Step areas, swim outs, and similar recessed or isolated areas are likely to create a dead zone. Placement of one or more INLETS in these areas will help ensure distribution of chlorinated, filtered water to these areas.

4.7.1.3.3.5 Dye Testing

Dye testing should be performed to determine and adjust the performance of the RECIRCULATION SYSTEM. Dye studies tend to be qualitative in nature. A dye test may not be necessary for "STANDARD" designs previously determined to provide effective mixing. It may be particularly important for irregular shaped POOLS. Some judgment is generally required to determine whether a dye study should be classified as passing or a failing. In general, dead zones (or areas of poor circulation) would indicate a failure that could be fixed by adjusting the INLETS or other system hydraulics. If the POOL does not reach a uniform color within 15-20 minutes, then adjustments are required. Refer to *Appendix 3: Dye Testing Procedure* for additional information.

4.7.1.4 Perimeter Overflow Systems/Gutters

4.7.1.4.1 General

4.7.1.4.1.1 Skimming

Perimeter Overflow/Gutter Systems (*POS*) are intended to remove surface water from the AQUATIC VENUE for treatment and recirculation. The intent of a POS is to remove water from all parts of the POOL equally and preclude "dead spots" from occurring. They need to remove water from all parts of the POOL equally. Much of the dirt, oil, bacteria, floating debris and possibly undissolved chemicals are in the top inch of water. There may also

be less DISINFECTANT due to aerosolization and oxidant demand. Indoors, there is some evidence that DBPs build up in the top layer where they are more likely to aerosolize and contribute to poor air quality and BATHER discomfort. Areas that do not have good circulation due to lack of gutters or return grates (*e.g., zero-depth entries*) or which have gutters that are not level may not have adequate flow in these areas and may develop “dead spots” where the DISINFECTANT is not present at adequate levels to prevent recreational waterborne illnesses or algae growth. The corners of POOLS with SKIMMERS are a case in point. Unightly debris such as “oil slicks”, blowing paper, dead bugs and leaves may also collect in these “dead zones”.

Designs

Novel designs (*e.g., gutters located on only the two longest sides of the POOLS*) should be subject to approval by the local authority with proper engineering justification (*e.g., a computational fluid dynamics (CFD) model of the POOL design demonstrating acceptable hydraulic balance and mixing*).

4.7.1.4.2 Perimeter Overflow System Size and Shape

A value of 125 percent of the total recirculation flow rate chosen by the designer is recommended for hydraulic flexibility.

Oversizing the SKIMMER capacity for point surge. As PATRONS swim, play, dive, and splash, they create waves that exceed the normal recirculation one might see when the POOL is empty. Upsizing the gutter system allows capture of the waves without flooding the gutter, which would make the gutter ineffective. Human body density is approximately equal to water (*fat is less and muscle is more*) at approximately 1 g/mL.

A 200 pound (91 kg) person displaces approximately 24 gallons (90.8 L). ($200 \text{ lbs.} \times 0.454 \text{ kg/lb.} \times 1 \text{ L/kg} \times 0.264 \text{ gal/L} = 24 \text{ gallons}$) The average PATRON is not 200 pounds, so this conservative parameter provides extra capacity in the surge system for more dynamic wave instances.

Surge capacities recommended by state health departments of 1 gallon per square foot (40.7 L/m^2) of POOL water are common. For an average of 24 (*typically 16 to 30*) square feet (2.2 m^2 ; *typically 1.5 to 2.8 m}^2*) of water per person and 24 (90.8 L) gallons per person to be conservative, the net surge capacity is 1 gallon per square foot (40.7 L/m^2) of POOL. This is not new information and was considered over a decade ago. The State of Iowa tried 2 gal/ft² (81.5 L/m^2) for a few years, but found that to be unnecessary. It continues to work well in POOL designs. Once again, the oversized gutter system is recommended to account for how PATRONS enter and displace the POOL water adjacent to the gutter. The 125% gutter capacity and the 1 gallon of surge per square foot of area both continue to work well in practice. The gutter capacity must be even greater for designs relying on AQUATIC FEATURES and SLIDE flow being returned through the gutter.

4.7.1.4.3 Gutter Outlets

A value of 125 percent of the total recirculation flow rate chosen by the designer is recommended for hydraulic flexibility. The design goal is to avoid inadequate outlet spacing in these old gutter channels. The spacing between drain outlets should not exceed 10 feet (3.0 m) for 2 inch (5.1 cm) diameter drains or 15 feet (4.6 m) for 2½ inch (6.4 cm) drains, unless hydraulically justified by the design engineer.

4.7.1.4.4 Surge Tank Capacity

4.7.1.4.4.1 Net Surge Capacity

The net capacity shall be measured from the minimum operating depth required to maintain pump suction to the bottom of the overflow waste outlet.

Draining

Surge tanks should be provided with means for complete draining to allow routine inspections, maintenance, and cleaning. Proper maintenance will reduce the chances of biofilm formation and bio-corrosion. Surge tanks should also have a means of draining for winterization, where applicable. An overflow is recommended to prevent a POOL from flooding DECK areas (*indoor*) if over filled and flooding filter rooms during rainfall events. An air break is recommended to prevent a CROSS-CONNECTION with the POOL water that could introduce CONTAMINANTS into the POOL.

Contain

Surge tanks can contain valves, piping, float controls, heating system manifolds or heat exchangers, makeup water controls and large basket screens for large AQUATIC FACILITIES. They also can act as a settling basin for large

particles and debris coming directly from the main drains and gutters. It is reasonable to drain these tanks to access equipment and remove settled materials.

4.7.1.4.5 Tolerances

Gutter tolerances were chosen to keep water flowing in even proportions from all sections of the POOL and to avoid dead spots and scum lines. Tighter tolerances may be needed for competitive POOLS.

4.7.1.4.6 Makeup Water System

Other BACKFLOW prevention devices may include the following:

- Reduced Pressure principle assembly (RP),
- Pressure Vacuum breaker assembly (PVB),
- Spill-resistant Vacuum Breaker assembly (SVB), or an
- Atmospheric Vacuum Breaker assembly (AVB).

All devices may not be appropriate for all installation conditions.

4.7.1.5 Skimmers and Alternative Gutter Technologies Using In-Pool Surge Capacity

4.7.1.5.1 General

4.7.1.5.1.2 Provided

The use of SKIMMERS could be limited to POOLS with surface areas of less than 1,600 square feet ($149 m^2$), and the maximum width for POOLS using SKIMMERS could be restricted to less than 30 feet ($9.1 m$). The use of SKIMMERS has been limited to smaller POOLS with light BATHER COUNTS since their inception. The limitations of SKIMMERS versus gutters appear to be physical in nature. For example, a 30 feet x 50 feet ($9.1 m \times 15.2 m$) POOL may be served by three SKIMMERS rated at 500 square feet ($46.4 m^2$) each. If each SKIMMER is 1 foot ($30.5 cm$) wide, then all of the SKIMMED water is being drawn off from only 3 foot ($0.9 m$) of the POOL perimeter (*i.e.*, 1.9 % of the total perimeter). This would lead to higher water velocities over the floating weirs and water being collected from a greater depth (*as opposed to actual surface SKIMMING*) relative to a gutter system that extends around the perimeter of the POOL. In this example, 98.1% of the perimeter of the POOL is not being used to skim water and could produce regions of limited flow and scum collection. Theoretically, enough SKIMMERS might be added to produce effective SKIMMING comparable to a gutter system, but the research to demonstrate this in practice could not be found. Practical experience says that having no scum lines or dead zones in corners with stagnant debris are inherent advantages. There could also be practical hydraulic limitations for heavily BATHER loaded POOLS related to use of in-POOL surge as opposed to a surge tank. Equalizer lines are recommended to prevent SKIMMERS from pulling air into the pump and potentially causing loss of prime, flow surges, and interference with proper filter operation.

4.7.1.5.1.3 Hybrid Systems

Hybrid systems that incorporate surge weirs in the overflow gutters to provide for in-POOL surge shall meet all of the requirements specified for overflow gutters. Since the number of BATHERS determines the type of surface overflow system in use, the hybrid systems should be able to meet all CODE requirements regardless of how many BATHERS are present and which components are in active use. When the POOL is inactive (*no BATHERS in the water*) the surge weirs provide surface SKIMMING. The operating water level during the period when there are no BATHERS in the water is designed to be below the rim of the gutter and flows over the surge weirs by gravity. When BATHERS enter the water, the level rises (*in-POOL surge capacity*), the surge weir openings close, and the water flows over the gutter as in STANDARD gutters.

4.7.1.5.1.3.1 Surge Weir

The manufacturers of these gutter systems typically have flow capacities (gpm/surge weir) established for their surge weirs. The number of surge weirs necessary to accommodate the portion of the recirculation rate to be removed from the surface is calculated by using the percentage of the total recirculation rate for surface SKIMMING (*i.e.*, 80 % of total flow) divided by the flow rate for each surge weir. The total recirculation rate must not be used for this calculation, as it will result in a greater number of surge weirs; operationally less water will need to be removed from the surface, which will likely result in inadequate flows over the weirs for effective surface SKIMMING. The required number of surge weirs are to be uniformly spaced around the POOL perimeter in the gutter.

4.7.1.5.1.4 Design Capacity

The 100 percent of the total recirculation flow rate chosen by the designer is recommended as part of the hydraulic flexibility recommendation.

4.7.1.5.3 Skimmer Flow Rate

SKIMMERS should provide for a flow-through rate of 30 GPM (114 L/min), or 3.75 GPM (14 L/min) per linear inch (2.5 cm) of weir, whichever is greater. The AHJ may approve alternate flow-through rates so long as the SKIMMERS are NSF or equivalent CERTIFIED, LISTED, AND LABELED, and manufacturer's design specifications are not exceeded.

Flotation Test Procedure

Materials Needed:

- Yellow wooden stars (55 -110 minimum depending on the POOL's surface area)
- Video camera
- Tripod

Conditions Prior to Test:

- TURNOVER TIME and recirculation flow rate are operated as normal for the POOL
- INLETS and outlets are positioned as normal for the POOL
- SKIMMERS or gutter system is not flooded
- If using SKIMMERS, make sure that the weirs are present
- Water level is at the appropriate height above the weir/gutter (about 1/4 inch or 6.4 mm)
- Set up video camera to record

Test 1: Circulation

1. Determine how many stars are necessary by using the following:
 - POOL surface area < 2,500 square feet (232 m²), use a minimum of 55 stars;
 - POOL surface area > 2,500 square feet (232 m²). use a minimum of 110 stars.
2. Randomly toss the stars into the POOL. Try to toss the stars so that there is an even distribution throughout the surface of the POOL.
3. Record and observe the stars as they travel.
4. Record the motion of the stars in each area of the POOL (e.g., clockwise, counter-clockwise, no movement) and any other observations.
5. Passing criteria may vary, but suggestions include 90% removal within 1 hour.

Test 2: Skimmer/Gutter Draw

1. Stand behind one of the SKIMMERS or the gutter and drop a star into the water at arm's length distance (about 2 feet (61 cm)) in front of it.
2. Record how long it takes for the star to enter the SKIMMER or gutter. Then repeat this process at the same location three times.

4.7.1.6 Submerged Suction Outlet

Note that in the VGB Act, no specific distances are listed. CPSC's question and answer section for implementation indicates 3 feet (0.9 m) measured center to center.

SVRS

SVRS devices are one of several methods to prevent swimmer entrapment on submerged suction fittings. SVRS devices have been on the market since the 1990s and continue to be installed on swimming POOLS because of their value as a SAFETY feature. In addition to CERTIFIED, LISTED, AND LABELED drain covers, the VGB Act required the installation of an SVRS device for POOLS with a single main drain. The MAHC does not address SVRS devices in Section 4 since the MAHC requires two main drains in 4.7.1.6.2), so there should not be a need for a requirement addressing SVRS devices in section 4. ANSI/APSP/ICC-7 has information about SVRS systems and indicates "when used..." and has a caution for incompatible configurations, which lists two or more suction outlets as a potential incompatible configuration. SVRS devices are considered as a secondary line of defense

against drain suction entrapment. This means that an SVRS should be used in conjunction with other suction entrapment preventions methods such as two suction fittings at least 3 feet apart, or single “unblockable” suction fittings.

Currently, there are two general types of SVRS devices; mechanical and electrical.

- Mechanical SVRS devices consist of a separate mechanism installed on the piping on the suction side of the filtration system pump or other pump. In other words, the device is located on the suction piping between submerged suction drain fittings and the pump suction. The device is designed to detect an increase in vacuum in the suction piping near the suction fittings, i.e. detect a suction fitting blockage. When a vacuum is sensed above a set threshold, the device is designed to quickly open to the atmosphere, bringing air into the suction piping, thus causing the vacuum to be broken and the suction fitting blockage released.
- Electrical SVRS devices have a similar function. An electrical sensing device is located as an attachment to the pump control system or is integral with the filtration pump or motor itself. When additional vacuum is sensed over a set threshold, instead of a mechanical device opening to the atmosphere, the electrical SVRS device quickly shuts off the pump motor.

Although there are these two general SVRS types, there are some hybrids and variations from the two types.

- Some SVRS devices may or may not shut off the pump.
- Some SVRS devices may or may not open the suction piping to the atmosphere.

There are some potential problems with SVRS devices.

- Since SVRS devices detect vacuum changes, they may unintentionally be triggered by other system vacuum changes such as during the vacuuming of a POOL.
- Any control valves or check valves installed on the pump suction piping can greatly affect or completely defeat the operation of the SVRS. The SVRS and any valves must be installed strictly according to the manufacturer’s recommendations.
- Although some SVRS devices shut off the pump, the pump may turn back on unexpectedly.

4.7.1.6.4 Flow Distribution and Control

The 125% of the total recirculation flow rate chosen by the designer is recommended as part of the hydraulic flexibility recommendation in MAHC Annex 4.7.1.1. The proportioning valve(s) are recommended to restrict flow by increasing the head loss in the pipe(s) typically on the main drain lines where flow rates are less than those from the surface overflow system lines. The main drain system shall be designed at a minimum to handle recirculation flow of 100% of total design recirculation flow rate. A minimum of two hydraulically balanced filtration system suction outlets are required as protection from suction entrapment. The branch pipe from each main drain outlet shall be designed to carry 100% of the recirculation flow rate so in the event that one drain outlet is blocked the other has the capacity to handle the total flow. Where three or more main drain outlets are connected by branch piping in accordance with MAHC 4.7.1.6.2.1.1 through 4.7.1.6.2.1.3, it is not necessary that each be designed for 100% flow. Where three or more properly piped drain outlets are provided, the design flow through each drain outlet may be as follows:

- Q_{\max} for each drain = $Q(\text{total recirculation rate}) / (\text{number of drains less one})$
- $Q_{\max} = Q_{\text{total}} / (N-1)$

The result is that if one drain is blocked, the remaining drains will cumulatively handle 100% of the flow.

Example:

- $Q_{\text{total}} = 600$ gpm recirculation rate
- $N = 3$ drains
 $600 / (3-1) = 300$ gpm / drain.

4.7.1.7 Piping

4.7.1.7.2 Velocity in Pipes

4.7.1.7.2.1 Discharge Piping

RECIRCULATION SYSTEM piping should be designed so the water velocities should not exceed 8 feet (2.4 m) per second on the discharge side of the recirculation pump. This is a maximum value as opposed to a good design value. The head loss in a pipe (*and hence the energy loss in the RECIRCULATION SYSTEM*) is proportional to the square of the velocity in the pipe (*i.e., if you cut the velocity in half, then you reduce the head loss to 1/4 (25%) of the original value*). In the interest of conserving energy, velocities in the range of 6 to 8 feet (1.8 m to 2.4 m) per second are recommended. Without a minimum INLET velocity, uniform water distribution within the supply piping will not happen.

4.7.1.7.2.2 Suction Piping

The maximum velocity in suction piping is 6 feet (1.8 m) per second. The real limitation in suction piping is NPSH recommended by the pump. NPSH refers to the pressure energy at the suction INLET to the impeller. Pump problems can result from incorrect determination of NPSH. Inadequate NPSH can reduce pump efficiency and capacity and lead to cavitation. If cavitation continues and the pump conditions deteriorate, vibration problems can lead to destruction of the pump impeller and damage to other pump hardware. Failure to provide sufficient NPSH for the pump can result in cavitation, high power usage, and premature failure of the pump and other RECIRCULATION SYSTEM components. The velocities recommended could be lower depending on the size and configuration of the piping as well as the elevation and water temperature. The available NPSH should be at least 20% greater than the recommended NPSH. The available NPSH should be calculated for each AQUATIC VENUE pump and each AQUATIC FEATURE pump. The available NPSH should be compared with the NPSH recommended by each pump manufacturer. Cavitation will occur if the available NPSH is less than the recommended NPSH. The available NPSH is calculated as follows (*all terms in feet*):

- Absolute pressure on the liquid surface
- friction losses in the suction line
- vapor pressure of the water
- + static head of liquid above impeller eye.

Hydraulic calculations for piping and pumps should be prepared by a qualified engineer.

4.7.1.7.2.3 Additional Considerations

Gravity piping must be sufficiently sized to accommodate the recommended flow (*including surges*) without water surcharging above the INLET. Careful consideration of available head, the head losses, and the combined flow from multiple inputs into a single pipe is a necessity. The 2 feet (61.0 cm) per second value is a value derived from common practice with no clearly identifiable theoretical basis.

4.7.1.7.3 Drainage and Installation

Draining Recommendation

The draining recommendation for all equipment and piping serves multiple functions. First, any sediment or rust particles that gather in the pipe can be flushed by means of the drainage system. Since bacteria and biofilms are mostly water, drying out a biofilm can be an effective means of controlling growth. Whereas leaving a pipe full of water during a period of maintenance or no use could lead to dissipation of the CHLORINE residual and proliferation of a biofilm inside of pipes and/or equipment. Biofilms can lead to bio-corrosion of metal components of the RECIRCULATION SYSTEM and serve as protection for microbes and pathogens.

Designed

All equipment and piping should be designed and constructed to drain completely by use of drain plugs, drain valves, and/or other means. All piping should be supported continuously or at sufficiently close intervals to prevent sagging and settlement. All suction piping should be sloped in one direction, preferably toward the pump. All supply and return pipe lines to the AQUATIC VENUE should be provided to allow the piping to be drained completely.

Individual Drain

The individual drain to facilitate emptying the POOL in case of an accidental gross contamination event is intended to prevent further contamination of any pipes, pumps, multi-port valves, filters, or other equipment associated with the RECIRCULATION SYSTEM, which might be more difficult to clean than the inside of the AQUATIC VENUE. In the case of combined AQUATIC VENUE treatment systems, this drain could prevent cross-contamination of multiple AQUATIC VENUES.

4.7.1.7.4 Piping and Component Identification

4.7.1.7.4.1 Clearly Marked

Clearly marking pipes will prevent misidentification that could lead to CROSS-CONNECTIONS and contamination of the AQUATIC VENUE. Pipe marking will also facilitate easier identification of locations for additional equipment installation and/or sample lines.

Color Coding Recommendations: Pipes and valves, when color-coded, may be color-coded in accordance with the following:

- Potable water lines (*Dark blue*),
- Backwash waste (*Dark brown*),
- Filtered water (*Aqua*),
- Sewer (*Dark gray*),
- SKIMMER or gutter return (*Olive green*),
- DECK drains (*Light brown*),
- Main drain (*Black*),
- Alum (*Orange*),
- CHLORINE (*gas/solution*) (*Yellow*),
- Compressed air (*Dark green*),
- Soda ash (*White*),
- Gas (*Red*), and
- Acid (*Pink*).

4.7.1.8 Strainers and Pumps

4.7.1.8.2 Pumping Equipment

4.7.1.8.2.1 Variable Frequency Drives

VFDs may be allowed because the energy savings could be substantial if flow is reduced at night and water quality criteria are continuously maintained. At this time, we are not aware of public health benefits or deficits associated with VFD use so these pumps are allowed but not required. Operators should be aware that VFDs can flatten out a pump curve so if they are installed on a filter pump, operators may want more active control to maintain operations. It is recommended that operators use VFDs with a compatible flow meter with a feedback control to optimize VFD function.

4.7.1.8.2.2 Total Dynamic Head

The recirculation pump should be selected to meet the recommendations of the designer for the system. However, the following guidelines are suggested as starting points for designers. The recirculation pump(s) must be selected to provide the recommended recirculation flow against a minimum TDH of the system, which is normally at least 50 feet (*15.2 m*) for all vacuum filters, 70 feet (*21.3 m*) for granular media and cartridge filters, or 60 feet (*18.3 m*) for precoat filters. A lower TDH could be shown to be hydraulically appropriate by the designer by calculating the total head loss of the system components under worst-case conditions.

4.7.1.8.3 Operating Gauges

Pressure Measurements

A second set of pressure measurement ports could be recommended (*tapped into the pump volute and discharge casing*) to accurately calculate the flow of the pump. These gauges are a way of verifying the pump curve is correct. One can also use the pressure/vacuum gauges and pump curve to verify the flow meter reading and look for differences between the two. During startup, it is possible to shut off a valve on the discharge side of the pump and verify that the maximum discharge pressure measured agrees with the value on the pump curve.

It is recommended that all pumps be located on a base so as to be easily accessible for motor service.

Vacuum Limit Switches

The vacuum limit switch is intended to shut down the pump if the vacuum increases to a point which could cause damage to the pump (*cavitation*).

4.7.1.9 Flow Measurement and Control

4.7.1.9.1 Flow Meters

Over 22% (*approximately 20,000*) of the POOL inspections that led to POOL closures in the state of Florida in 2012 were caused by non-functioning flow meters (State of Florida, unpublished data). This section of the MAHC is intended to improve this flow meter reliability problem (*as well as to address a problem with accuracy*). Since flow rates are critical for proper filtration, sizing, and operational calculations, it is recommended that operators purchase a more accurate flow meter for all systems or when replacing older flow meters on their existing system. Improved accuracy improves an operator's chance of understanding the true flow in their system. Operators should be mindful of flow meter placement by installing according to manufacturer recommendations and adhering to recommended distance parameters. A flow meter or other device that gives a continuous indication of the flow rate in GPM (*L/min*) through each filter should be provided. If granular media filters are used, a device should be provided to measure the backwash flow rate in GPM (*L/min*) for each filter. Flow meters should have a measurement capacity of at least 150% of the design recirculation flow rate through each filter, and each flow meter should be accurate within +/-5% of the actual design recirculation flow rate. The flow measuring device should have an operating range appropriate for the anticipated flow rates and be installed where it is readily accessible for reading and routine maintenance. Flow meters should be installed with 10 pipe diameters of straight pipe upstream and five pipe diameters of straight pipe downstream or in accordance with the manufacturer's recommendations. Acrylic flow meters will not meet the accuracy requirement (*and are prone to fouling/clogging*) and hence should not be installed as the primary flow meter on any RECIRCULATION SYSTEM. However, acrylic flow meters could prove useful as a backup or auxiliary flow meter. A paddle-wheel flow meter, when used, should be located on the effluent side of the filter to prevent fouling.

More accurate flow meters are recommended to conserve energy and increase regulatory compliance. Magnetic and ultrasonic flow meters offer greater accuracy (*typically less than +/- 1% error*) and less potential for fouling, but the aforementioned flow meters tend to be more expensive (*e.g., \$1,000 or more*). An ultrasonic flow meter (*such as clamp-on transit-time models*) can be used to measure flows through the wall of a pipe, so they can be installed and uninstalled without modifying the existing plumbing. One ultrasonic flow meter could be used to routinely verify the flow readings of multiple other flow meters that are more prone to error. An annual cleaning and evaluation of flow meter accuracy could be useful in maintaining compliance with existing regulations.

4.7.1.10 Flow Rates / Turnover

Table 4.7.1.10: Aquatic Venue Maximum Allowable Turnover Times prior to the release of the 2014 MAHC

Type of Pools	Turnover Maximum	States with these Values in their Codes
Activity Pools	2 hours or less	FL, WI
Diving Pools	8 hours or less	IL, KY, MS, OR, UT, MD, MO-KC
Interactive Play*	0.5 hours or less	WI, MT, OH, AL-Baldwin, GA, MO-STL, NE
Lazy River	2 hours or less	MT, IL, IA, WI, MI
Plunge Pools	1 hour or less	IA, MA, MI, MT, NE, NH, WI, AL-Baldwin, OR, SC, TN
Runout Slide	1 hour or less	IA, UT, TN, SC, WI, NE, GA-Fulton, DE
Wading Pools*	1 hour or less	CO, GA, IN, IA, MI, MT, NH, OR, SC, TN, WA, FL, DE, MO-St. Charles, NE, TX, UT
Wave Pools	2 hours or less	IN, IA, SC, WI, AL-Baldwin, MT, NY, SD
All Other Pools	6 hours or less	MOST

*Shall have SECONDARY DISINFECTION SYSTEMS

Spa, Therapy*, & Exercise Pools (from WI; similar to SC)

Temperatures	Load	Turnover Maximum
≤ 72 ^o -93 ^o F (22 ^o -34 ^o C)	> 2500 gals/person (9.46 m ³)	4 hours or less
≤ 72 ^o -93 ^o F (22 ^o -34 ^o C)	> 450 gals/person (1.7 m ³)	2 hours or less
≤ 72 ^o -93 ^o F (22 ^o -34 ^o C)	≤ 450 gals/person (1.7 m ³)	1 hour or less
≥ 93-104 ^o F (34 ^o -40 ^o C)	All	0.5 hours or less

*Shall have SECONDARY DISINFECTION SYSTEMS

4.7.1.10.2 Calculated

A new methodology is being proposed for use in the future that calculates the recommended minimum design recirculation flow rate, which is called the maximum sustainable BATHER load (*MSBL*) calculation. The *MSBL* calculation is based on the values in MAHC Annex Table 4.7.1.10.2 (*below*) and adjusted by all applicable multipliers in MAHC Annex Table 4.7.1.10.3 (*below*) as the maximum *TURNOVER TIME* allowable based on the pathogen load and *CHLORINE* demand imparted by *BATHERS*. Whereas, the traditional *TURNOVER TIME* values (*required in MAHC Table 4.7.1.10 above*) are based on physical transport processes of *CONTAMINANTS* and *DISINFECTANT* in the *POOL*. The *MSBL* design *TURNOVER RATES* should use the adjustment factors provided. For mixed-use *POOLS*, each zone of the *POOL* should individually meet the recommended *TURNOVER TIME* for the zone based on the lesser *TURNOVER TIME* calculated by the procedures already described. All of the maximum *TURNOVER TIMES* provided in MAHC Table 4.7.1.10 are required for *AQUATIC VENUES* as defined in the MAHC. The *MSBL* values calculated might help to identify *POOLS* that could be slightly over-designed to meet the demands placed on the *AQUATIC VENUE*. Furthermore, the *MSBL* approach actually identifies risk factors that might require higher or lower levels of treatment based on the actual system.

- **Zone Volume** (ft³) = Zone Surface Area (ft²) x Average Depth (ft)
- **Zone Bather Load Factor** (BATHERS/ft³) =
1 / {Surface Area per BATHER (ft²/BATHER)} x (Average Depth (ft))
- **Estimated Maximum Number of Bathers Per Zone** =
Zone BATHER load Factor (BATHER/ft³) x Zone Volume (ft³)
- **Raw Recirculation Flow Rate Per Zone** (gal/min) =
Estimated Maximum Number of BATHERS Per Zone x 5.34 (a constant)
- **TURNOVER TIME** (h) =
Water volume (gal) / {Recirculation rate (gal/min) x (60 min / 1 hr)}

Table 4.7.1.10.2: Bather Loading Estimates

Water Depth	Surface Area Per Bather
Under 3 feet (0.9 m)	25 ft ² (2.3 m ²)
3 to 6 feet (0.9 m to 1.8 m)	30 ft ² (2.8 m ²)
6.1 to 10 feet (1.9 m to 3.0 m)	22 ft ² (2.0 m ²)
Over 10.1 feet (3.1 m)	16 ft ² (1.5 m ²)

Table 4.7.1.10.3: Recirculation Rate Multipliers (Adjustment Factors)

Adjustment Reason	Adjustment Factor	Recommendation(s)
Edge Loading (more bathers at edge of larger pools)	1.1	Pools must be greater than 100,000 gallons (378, 541 L) Spas must be greater than 10,000 gallons (37,854 L)
Increased-Risk (diaper-aged patrons present)	0.75	Pool designed for at least 10% of patrons to be diaper-aged.
Activity / Line (attractions increase bather density)	0.5	Any pool/spa with an associated ride or activity (besides swimming) or line to enter
High-Temperature (increased sweat production)	0.5	Pool/Spa with water temperatures routinely exceeding 95 F.
Indoor (protected from some environmental factors)	1.15	Pool/Spa must be located completely indoors year round.
Limited-Use (pools that are frequently lightly loaded)	1.33	Pool must be at an Apartment, Condominium, or Hotel/Motel with no associated attraction or activity.
Showering Recommended (showering reduces bather load)	1.15	Pool/Spa must recommend showering prior to entry.

Example Calculation

For example, here is a set of example calculations for an indoor POOL in a hotel that is 20 feet (6.1 m) wide by 30 feet (9.1 m) long with an even floor slope that goes from 4 feet (1.2 m) at the shallow end to 6 feet (1.8 m) at the deep end.

- **Zone Volume** (ft³)
= 20 ft x 30 ft x 5 ft = 3,000 ft³
- **Zone Bather Load Factor** (BATHERS/ft³)
= 1/(30 ft²/BATHER) x (5ft) = 0.00666 BATHERS/ft³
- **Estimated Maximum Number of Bathers Per Zone**
= 0.00666 BATHER/ft³ x 3,000 ft³ = 20 BATHERS
- **Raw Recirculation Flow Rate Per Zone** (gal/min)
= 20 BATHERS x 5.34 = 106.8 gal/min
- **TURNOVER TIME** (h)
= 3,000 ft³ x 7.48 gal/ft³/(106.8 gal/min) x (60 min/1 hr) = 3.5 h
- **Adjustments for indoor POOL and limited use POOL:**
3.5 h x 1.15 x 1.33 = 5.35 h

Compare the MSBL value of 5.35 h to the value in MAHC Annex Table 4.7.1.10.3 of 5 h and use the lower value = 5 h. Additional example calculations are provided in MAHC Annex Table 4.7.1.10.4.

Shower Required Bather Load Reduction	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Plain Pools Only: Apartment/Condo/Hotel Limited Use Factor	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Final Turnover (Hours)	5.8	1.61	0.99	0.22	0.44	0.22	7.56	4.16
w/ a Required Shower	6.67	1.86	1.14	0.25	0.5	0.25	8.69	4.78
Standard Table Values	4.0-5.0	1.5-2	1-1.5	0.25	0.50	.25-.5	6.0-8.0	5.0

When POOL recirculation rate recommendations are broken down to their essential elements, it is essentially about removing suspended *matter (including microbial CONTAMINANTS)* with the filters and effectively maintaining uniform FREE CHLORINE RESIDUAL at the proper pH. Both the FREE CHLORINE RESIDUAL and the microbial concentrations are a function of the number of BATHERS in a given volume of water. While it is not possible to always accurately predict the BATHER COUNT for a given POOL on a given day, it is generally possible to estimate the maximum number of BATHERS likely to be in any given type of POOL per unit surface area (*since most BATHERS have at least their head above water most of the time and the primary activity in a POOL often dictates the comfort level in regards to BATHERS per unit surface area and hence the likelihood of BATHERS entering or leaving the POOL*). After establishing a maximum sustainable BATHER load (*MSBL; see Annex 4.7.1.10.2 for further explanation and calculation*) or maximum number of BATHERS expected in a POOL, it is possible to calculate the recommended flow of recirculated water necessary to be treated in order to handle the pathogen load and CHLORINE demand imparted by the BATHERS. An empirically-derived multiplier was used by PWTAG¹⁹³ to convert the MSBL to the recommended recirculation rate. The empirical multiplier used in this CODE was derived independently using English units specifically for use in the United States. The value of the U.S. multiplier is approximately 29% smaller than the PWTAG value using equivalent units because POOL design in the UK is more conservative than in the US.

4.7.1.10.2.1 Unfiltered Water

Unfiltered water shall not factor into TURNOVER TIME. This section is to address/clarify water that may be withdrawn from and returned to the AQUATIC VENUE for such AQUATIC FEATURES as SLIDES, features, etc. by a pump separate from the filtration system. That flow rate from the separate pump system shall not be included in the TURNOVER TIME calculation.

4.7.1.10.3 Turnover Times

The recommended design TURNOVER TIME can then be calculated by dividing the volume by the recommended flow. This procedure can be performed for individual sections of a POOL or the entire POOL depending on the number of zones, which are based on depth of the water. Adjustments can then be made to this calculation to account for extraordinary conditions. For example, since a SPA has higher water temperature than a POOL, a PATRON would be expected to sweat more; an indoor POOL might experience less contamination from pollen, dust, and rain than an equivalent outdoor POOL; and a POOL filled with diaper-age children would be considered an increased-risk POOL requiring more aggressive treatment. AQUATIC FACILITIES that enforce SHOWERING prior to POOL entry could reduce the organic load on the POOL by 35-60% with SHOWERS lasting only 17 seconds¹⁹⁴. The BATHER load calculation based on surface area of the POOL has been proposed by PWTAG¹⁹⁵ in 1999 and has influenced the CODES proposed by the World Health Organization¹⁹⁶ and Australia¹⁹⁷. This approach has been adapted for use in the United States by slightly increasing the area recommended per BATHER in shallow waters and decreasing the area in deep POOLS to account for the intensity of deep water activities, the relatively low surface area to volume ratios of deep waters relative to shallow waters, the typically poorer mixing efficiency in

deeper water, the increased amount of time typically spent underwater in deeper water, and the larger average size of BATHERS commonly found in deeper water. These values were empirically derived for the MAHC to match typical U.S. practices and can be changed as necessary to achieve the desired water quality goals.

Effectively handling BATHER COUNT in terms of pathogen removals and CHLORINE demand is a paramount concern for which the above calculations should provide some science-based guidance. However, there are other factors that must be considered when selecting a recirculation rate for an AQUATIC VENUE. For example, effectively distributing treated water to avoid dead spots recommends minimum water velocities to reach the POOL center and extremities. Similarly, effective surface SKIMMING recommends adequate velocities at the surface of the POOL to remove floating CONTAMINANTS. Due to the kinetics of DISINFECTION and CHLORINE decay, CHLORINE must be replenished at some minimum intervals to maintain the recommended FREE CHLORINE RESIDUAL. For these reasons, MAHC Table 4.7.1.10 was developed to provide some maximum TURNOVER TIME limits for AQUATIC VENUES that are not dominantly influenced by BATHER load to help ensure proper physical transport of CONTAMINANTS and DISINFECTANT. Values in this table are derived from historical practice and design experience worldwide. All AQUATIC VENUES must be designed to meet the lesser of the two maximum TURNOVER TIMES.

4.7.1.10.4 Reuse Ratio

This section is intended to address those INTERACTIVE WATER PLAY VENUE designs that remove water from the INTERACTIVE WATER PLAY treatment tank by an AQUATIC FEATURE pump separate from the filtration system pump. The limit/ratio of INTERACTIVE WATER PLAY FEATURE water pump rate to the filtration system water pump rate is to acknowledge the typically high level of contaminants and turbidity introduced to the INTERACTIVE WATER PLAY treatment tank. The introduction and build-up of turbidity can exceed the rate at which it is removed by the filtration system which can result in interference with chemical DISINFECTION and UV treatment.

4.7.1.10.5 Flow Turndown System

The flow turndown system is intended to reduce energy consumption when AQUATIC VENUES are unoccupied without doing so at the expense of water quality. A turbidity goal of less than 0.5 NTU has been chosen by a number of U.S. state CODES (*e.g., Florida*) as well as the PWTAG¹⁹⁸ and WHO¹⁹⁹. The maximum turndown of 25% was selected to save energy while not necessarily compromising the ability of the RECIRCULATION SYSTEM to remove, treat, and return water to the center and other extremities of the POOL. The MAHC does not allow stopping recirculation since uncirculated water would soon become stagnant and loose residual DISINFECTANT likely leading to biofilm proliferation in pipes and filters. This could compromise water quality and increase the risk to BATHERS. Future research could determine that more aggressive turndown rates are acceptable. Some POOLS are already reportedly using the turndown system without a turbidimeter or precise flow rates. The intent of this section is to formalize a system for doing the turndown that does not compromise public health and SAFETY. Additional research in this area could identify innovative ways to optimize and improve this type of system. The likelihood of turbidimeters being cleaned and maintained is likely to be good because turbidimeters tend to give higher reading when not maintained properly. AQUATIC VENUES designed above the minimum design STANDARDS would have the flexibility to increase system flows to maintain excellent water quality during periods of peak activity. The flow turndown system is intended to reduce energy consumption when AQUATIC VENUES are unoccupied without doing so at the expense of water quality. An electronic turbidity and RECIRCULATION SYSTEM flow feedback system would provide a quantifiable means of determining the water quality suitability if a facility desires to "turndown" the recirculation pumps to achieve a flow of up to 25% less than the minimum required recirculation flow rate when the AQUATIC VENUES is not occupied. The integration of feedback from both the flow meter and turbidimeter must be maintained for the VFD to be able to reduce the system flow rate below the level required to achieve the TURNOVER TIME requirement.

Variable Frequency Drives

VFDs offer the benefits of energy savings, operational flexibility, and in most cases the ability to automatically increase the pump flow as the filter clogs by interfacing the VFD with a flow meter (*or potentially a filter effluent pressure transducer*) by means of a proportional-integral-derivative (*PID*) controller. VFDs may also offer the added benefits of protecting piping, pumps, and valves. Energy savings and benefits will vary depending on the design of the system.

4.7.2 Filtration System Design

The filtration system should be designed to remove physical CONTAMINANTS and maintain the clarity and appearance of the AQUATIC VENUE water. However, good clarity does not mean that water is microbiologically safe. With CHLORINE-tolerant human pathogens like *Cryptosporidium* becoming increasingly common in AQUATIC VENUES, effective filtration is a crucial process in controlling waterborne disease transmission and protecting public health. The filtration system of U.S. AQUATIC VENUES has traditionally been designed to remove physical CONTAMINANTS and maintain the clarity and appearance of the AQUATIC VENUE water. Good clarity is important and will help prevent drowning and underwater collisions. Poor clarity can actually compromise the DISINFECTION process as well as leaving CHLORINE-tolerant pathogens suspended in the water for longer periods of time. As a future recommendation for discussion, filtration systems should be capable of removing *Cryptosporidium* OOCYSTS or an acceptable 4.5-micron surrogate particle with an efficiency of at least 90% (*i.e.*, a minimum of 1 log reduction) in a single pass.

Water Quality

If filtration is poor, water clarity will decline and drowning risks increase since swimmers in distress cannot be seen from the surface as well as needed. DISINFECTION will also be compromised, as particles associated with turbidity can surround microorganisms and shield them from the action of DISINFECTANTS. Particulate removal through coagulation and filtration is important for removing *Cryptosporidium* OOCYSTS and *Giardia* cysts and some other protozoa that are resistant to chemical DISINFECTION.²⁰⁰

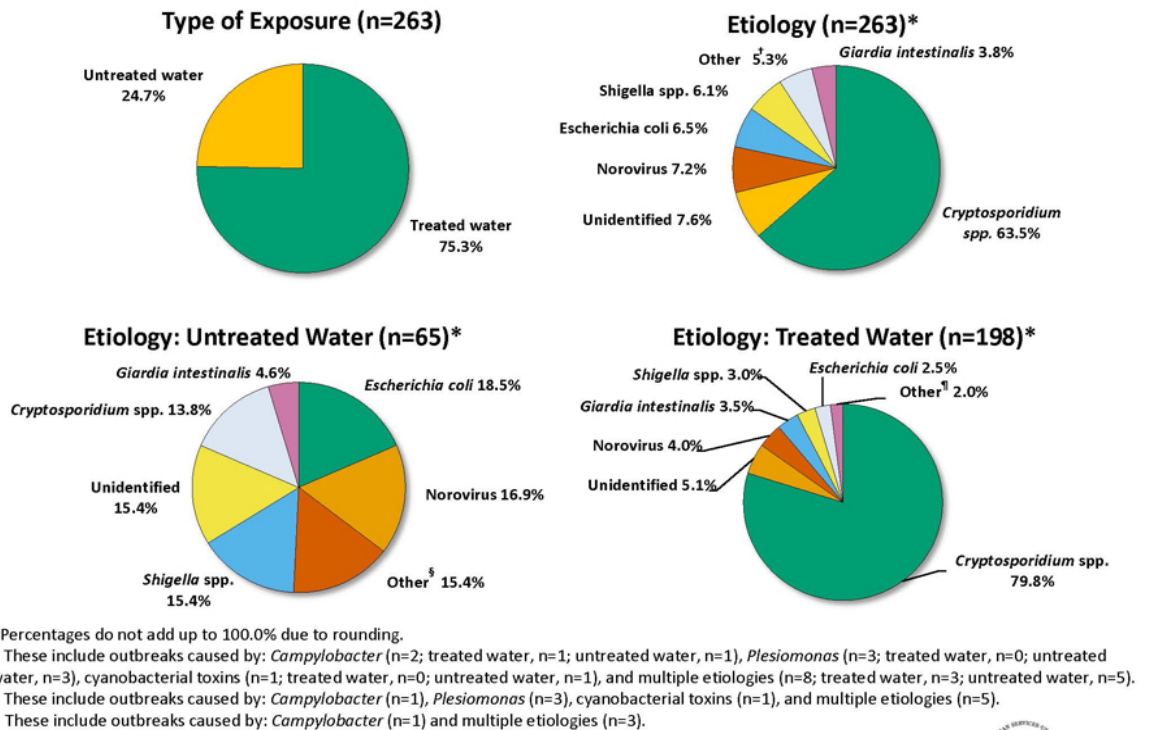
Pathogen Removal

One of the most significant recommended changes of the MAHC is transitioning the filtration system from one that only provides good clarity and appearance to one that efficiently removes waterborne human pathogens from the AQUATIC VENUE water. Water clarity is only an indicator of potential microbial CONTAMINATION, but it is the most rapid indicator of possible high CONTAMINATION levels. CHLORINE residual can be sufficiently high to kill indicator bacteria while leaving protozoa relatively unharmed and infective. Therefore, testing for indicator bacteria may not be useful as a measure of AQUATIC VENUE water quality, and testing for *Giardia* cysts and *Cryptosporidium* is very expensive, time-consuming, and cannot be done in real time. So, both measures are impractical as an operational tool for water quality measurement. *Cryptosporidium* is a widespread threat responsible for causing outbreaks in AQUATIC VENUES each year in the U.S.^{201,202} With CHLORINE-tolerant human pathogens like *Cryptosporidium* becoming increasingly common in AQUATIC VENUES, effective filtration is a crucial process in controlling waterborne disease transmission and protecting public health.^{203,204} Furthermore, an accidental fecal release could overwhelm the DISINFECTANT residual and leave physical removal as the only means of removing pathogens.²⁰⁵ Filtration has been cited as the “critical step” for the removal of *Cryptosporidium*, *Giardia*, and free-living amoebae that can harbor opportunistic bacteria like *Legionella* and *Mycobacterium* species.²⁰⁶

Cryptosporidium

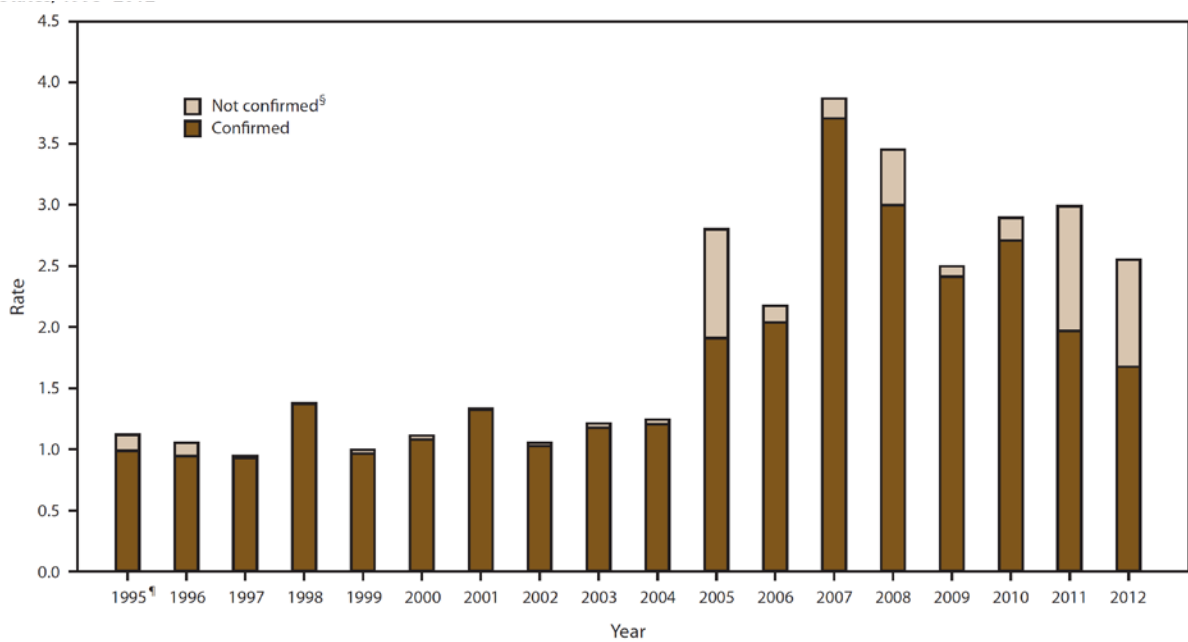
Cryptosporidium is a CHLORINE-tolerant protozoan pathogen that causes the majority of waterborne disease outbreaks in swimming POOLS in the United States as shown in MAHC Annex Figure 4.7.2.1.²⁰⁷ Surveillance for cryptosporidiosis in the United States indicates that the reported incidence of infection has increased dramatically since 2004.²⁰⁸ MAHC Annex Figures 4.7.2.2 and 4.7.2.3 demonstrate the increased cryptosporidiosis incidence post 2004 and total percentage of recreational water–associated outbreaks caused by *Cryptosporidium* since 2003, respectively.²⁰⁹

FIGURE 4.7.2.1: Recreational water-associated outbreaks of acute gastrointestinal illness, by type of exposure and etiology — United States, 2003–2012²¹⁰



Download a CSV file with the data from this figure at <https://www.cdc.gov/healthywater/surveillance/recreational/2011-2012-figures.html>

FIGURE 4.7.2.2: Incidence rate* of cryptosporidiosis, by year and case classification — National Notifiable Disease Surveillance System, United States, 1995–2012^{†‡}

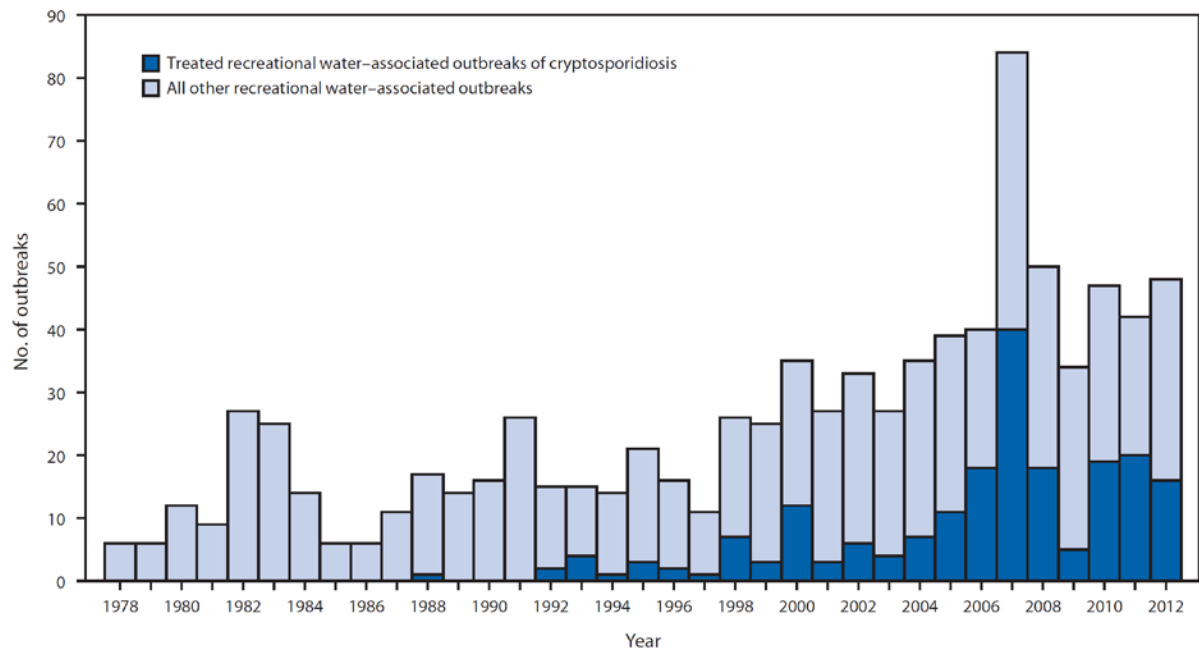


* Cases per 100,000 population.
 † N = 102,835.
 § Not confirmed includes probable, suspect, and unknown cases.
 ¶ First full year of national reporting.

3-Log Reduction

The current CT VALUES for a 3-log reduction in viability of fresh *Cryptosporidium* OOCYSTS with FREE CHLORINE are 10,400 mg/L·min (*Iowa-isolate*)²¹² and 15,300 mg/L·min (*Maine-isolate*) at pH 7.5.²¹³ At a concentration of 1 mg/L, FREE CHLORINE can take more than 10 days to inactivate 99.9% of *Cryptosporidium* OOCYSTS (CT INACTIVATION VALUE = 15,300 mg/L·min), but many people are likely to be swimming in the AQUATIC VENUE during that 10-day period and risk being exposed to infective parasite concentrations. Infected individuals might then return to the AQUATIC VENUE and/or visit other AQUATIC VENUES to amplify the spread of the parasite. Sand filters are commonly used and often serve as the only potential physical BARRIER to *Cryptosporidium* in U.S. AQUATIC VENUES, but sand filters without coagulant typically only remove about 25% of OOCYSTS per passage through the filter²¹⁴. Based on the slow kinetics of CHLORINE inactivation of *Cryptosporidium*, the known inefficiency of sand filter to remove OOCYSTS, and the recent increased incidence of cryptosporidiosis in the United States, additional measures appear necessary to effectively safeguard public health.

FIGURE 4.7.2.3: Number* of outbreaks associated with recreational water, by year — United States, 1978–2012²¹⁵



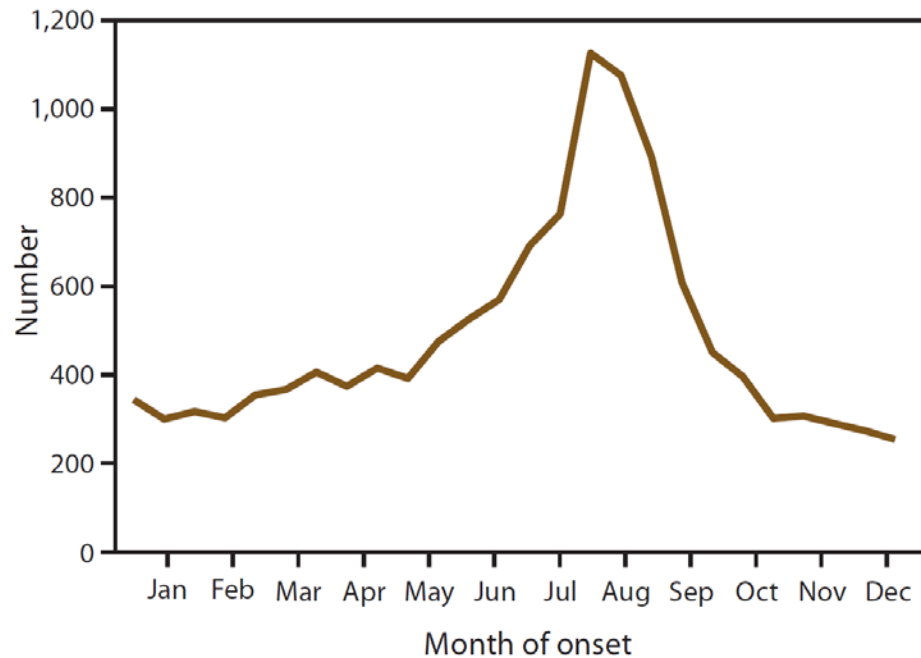
* Total n = 879.

Download a CSV file with the data from this figure at <https://www.cdc.gov/healthywater/surveillance/recreational/2011-2012-figures.html>

Explanation

MAHC Annex Figure 4.7.2.4 (*below*) shows a dramatic increase in the number of cases of cryptosporidiosis during the warmer months of the year when outdoor public POOLS are normally open in the United States. While it is difficult to assess the prevalence of protozoan parasites in public POOLS during normal operation, a study of 160 filter backwash water samples from Atlanta, GA showed that 8.1% (13) were positive for *Giardia*, *Cryptosporidium* or both²¹⁶ while another study of 161 filter backwash samples from metro-Atlanta showed 0.6% (one) and 1.2% (two) were positive for *Cryptosporidium* and *Giardia*, respectively^{217,218}.

FIGURE 4.7.2.4: Number of cryptosporidiosis case reports,* by date of symptom onset† — National Notifiable Diseases Surveillance System, United States, 2011–2012²¹⁹



* Cases per 100,000 population.

† N = 12,581; date of onset for 4,740 patients was unknown.

Review of Recreational Water Filtration Research Findings

Sand Filters

Sand filters often provide the only physical BARRIER to *Cryptosporidium* in U.S. AQUATIC VENUES, but sand filters meeting the recommendations of pre-existing POOL CODES typically only remove about 25% of OOCYSTS per passage through the filter²²⁰. A quantitative risk assessment model of *Cryptosporidium* in AQUATIC VENUES confirmed there is a “significant public health risk” from fecal contamination of recreational water.²²¹ Some changes are necessary to effectively safeguard public health. Recent research in the United States and United Kingdom has shown that sand filters can remove greater than 99% of OOCYSTS per passage when a coagulant is added prior to filtration.^{222,223} The addition of coagulants to swimming POOL filters used to be common practice in the United States with rapid sand filters, but it fell out of favor as high-rate sand filters began to dominate the U.S. POOL market. The importance of coagulant addition to efficient pathogen removal in drinking water is well-documented and recommended in all U.S. surface water treatment facilities for drinking water production by the EPA.^{224,225,226,227,228} The EPA expects drinking water treatment facilities to remove or inactivate a minimum of 99% (2 log) of *Cryptosporidium* OOCYSTS and up to 99.997% (4.5 log) for facilities treating source water with the highest concentration of OOCYSTS.²²⁹ While more research and quantitative risk assessment models will be recommended to determine the safe level of removal in most AQUATIC VENUES, it is clear that the current removal rates of approximately 25% can lead to a significant number of outbreaks each year. Based on the research available for existing AQUATIC VENUE filtration technologies and risk models, a new minimum removal goal for *Cryptosporidium* removal by filters used in new and renovated swimming POOLS is recommended to be at least 90% (1 log) per single pass.

Filtration Systems

Multiple types of AQUATIC VENUE filtration systems have already been shown to achieve removals exceeding 99% depending on the filter design, water quality, and operational variables.

MAHC Annex Table 4.7.2.1 (*below*) contains a summary of pilot sand filtration treatment research on *Cryptosporidium*-sized microsphere removal via filtration. Bench-scale results were not included due to concerns that the laboratory results might not be reproducible at pilot- or full-scale as has been observed in previous studies. MAHC Annex Table 4.7.2.1 is sorted in order of increasing filter removal efficiency, and the data is roughly divided into three groupings (*i.e.*, <90%, 90-99%, and >99% removal). Operating conditions falling into the first group would not be expected to reliably meet the new 90% (*single pass*) removal recommendation that is recommended for all new and renovated AQUATIC VENUES. Coagulant dosage, surface loading rate, and media

depth can significantly impact filtration removals. Careful selection of both design and operating values is essential to achieving excellent pathogen removal with AQUATIC VENUE filters.

Table 4.7.2.1: Pilot-Scale Filter Removal Results for *Cryptosporidium* or Crypto-sized Microspheres in Pool Water²³⁰

Filter Type	Media Depth	Surface Loading Rate	Coagulant Type	Coagulant Dosage	Removal (%)
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	None	n/a	25-46%
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	PACl	0.014 mg/L as A1	54.2%
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	PACl	0.006 mg/L as A1	62.0-64.3%
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	Alum	0.06 mg/L as A1	65-68%
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	PACl	0.76-0.92 mg/L as A1	87.8-98.0%
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	PACl	0.065 mg/L as A1	91.5-97.3%
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	Alum	0.1 mg/L as A1	94-95%
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	Alum	0.3 mg/L as A1	96-97%
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	PACl	0.1 mg/L as A1	99.3-99.7%
Sand	24 in. (60.96 cm)	10 gpm/ft ² (24.4 m/h)	PACl	0.21 mg/L as A1	99.6-99.8%

Filtration Products

At the time of MAHC development, the following filtration products are believed to be untested for *Cryptosporidium*/4.5-micron carboxylated microsphere removal in AQUATIC VENUE water:

- Regenerative media filters,
- Sand followed by cartridge, (with 5-micron absolute or 1-micron nominal rating),
- Macrolite filter media,
- Charged zeolite media,
- Crushed-recycled glass filter media, and
- Any others not listed in MAHC Annex Table 4.7.2.1.

Brief Historical Review of Water Filtration Practices for Aquatic Venues

In the United States in the 1920s, rapid sand filters on swimming POOLS were typically operated at 3-5 gpm/ft² (7-12 m/h) with coagulation prior to filtration, but high-rate sand filters have largely replaced rapid sand filters because they operate at 15-20 gpm/ft² (37-49 m/h) without coagulant.^{231,232} While high-rate sand filters are definitely cheaper and smaller, they are also less effective at removing *Cryptosporidium*-sized particles. The majority of U.S. drinking water treatment facilities still use rapid sand filters with coagulation and typically operate them at 3-5 gpm/ft² (7-12 m/h). The EPA, after an extensive review of peer-reviewed research, decided to give drinking water treatment facilities credit for removing 99% of *Cryptosporidium* OOCYSTS for properly employing this technology (i.e., granular media filtration with coagulation prior to filtration). Research has shown that high-rate AQUATIC VENUE sand filters can only consistently deliver 22 to 48% removal of *Cryptosporidium* OOCYSTS and/or a microsphere surrogate without coagulation²³³.

Increased Headloss Development Rates

Pressure Development

More efficient filtration of AQUATIC VENUE water will, in most cases, lead to higher rates of pressure development in filters and more frequent backwashing of filters. The smaller the pores in the filter media at the surface of the filter, the more rapidly pressure would be expected to increase. Fortunately, there are a number of options available to design engineers that could reduce the rate of pressure development. These options include:

- The use of more uniformly graded filter media,
- SKIMMING fines from filter media prior to startup,
- More efficient backwashing of filters,
- Lowering the flow rate per unit surface area, and
- The use of two types of filter media in filters.

4.7.2.1.2 Certified, Listed, and Labeled

Equipment testing of filters to industry STANDARDS is critically important, but it is only one aspect of performance. A filter certified with the hydraulic capability to pass water at 20 gpm/ft² (49 m/h) does not mean this filter should be operated at 20 gpm/ft² (49 m/h). Granular media filters perform better at removing particles and microbes at lower filter loading rates (*all other factors equal*), and this finding has been repeatedly observed in practice and can be explained theoretically. Filters might need to be held to higher STANDARDS of performance in terms of water quality than the current industry STANDARD. Manufacturers and testing laboratories might need to work together to produce more effective filters and new testing procedures. The maximum filtration rate of 15 gpm/ft² (37 m/h) is the first step toward a change in filter design STANDARDS aimed at improving microbial removal and preventing RWIs. The MAHC is intentionally more restrictive than the current NSF 50 flow requirements.

4.7.2.2 Granular Media Filters

4.7.2.2.1 General

Design Tip: When a single pump feeds two filters at 10 gpm/ft² (24 m/h), redirecting the entire flow through one filter into the backwash line of the other should result in a backwash rate of approximately 20 gpm/ft² (49 m/h). The backwash water would be unfiltered water that would have to be plumbed to bypass the filter. With three filters, it would be possible to redirect water from two filters into the backwash influent pipe of the third filter to provide clean backwash water.

4.7.2.2.2 Filter Location and Spacing

Sufficient floor space should be available to accommodate installation of additional filters to increase the original filtration surface area by up to 50% should it be recommended by future regulations or to meet current water quality STANDARDS. This is part of the hydraulic flexibility recommendation of newly constructed POOLS. The idea is to recommend space for additional filters should they become necessary at some point in the future. The 'extra' space could be utilized to make EQUIPMENT ROOMS safer and more functional. A port and ample space for easy removal of filter media is also recommended. Filter media might be changed every 5 years. This process could be exceedingly difficult if filters are not designed with a port for this purpose or if the filters are installed without proper clearance to access the media removal port.

4.7.2.2.3 Filtration and Backwashing Rates

4.7.2.2.3.1 Operate

High-rate granular media filters shall be designed to operate at no more than 15 gpm/ft² (37 m/h) of filter surface. The minimum depth of filter media above the under-drains (*or laterals*) shall be set by the filter manufacturer. Filters with bed depths less than 15 inches (38.1 cm) shall operate at no greater than 12 gpm/ft² (29 m/h) of filter surface area. A minimum bed depth of 15 inches (38.1 cm) is required for flow rates greater than 12 gpm/ft² (29 m/h) to a maximum of 15 gpm/ft² (37 m/h). *Note:* Allowable filter rate is directly related to bed depth. The granular media filter system should be designed to backwash each filter at a rate of at least 15 GPM per square foot (37 m/h) of filter bed surface area, unless explicitly prohibited by the filter manufacturer. Specially graded filter media should be recommended in filter systems backwashing at less than 20 gpm/ft² (48.9 m/h) to be able to expand the bed at least 20% above the fixed bed height at the design backwash flow rate, which is subject to approval by the local authority. Filtration and backwashing at the same flow rate is likely to lead to poor

performance of both processes. Backwashing at double the filtration rate is not all that complicated with a 3-filter system, where the flow of two filters is used to backwash the third. Further, backwashing with unfiltered water is possible in a 2-filter system by backwashing with the entire recirculation flow through each filter individually. Variable drive pumping systems and accurate flow meters also contribute to the likelihood of successful backwashing as well as effective filtration.

Effective Filtration

Filtration at 10 gpm/ft^2 (24 m/h) is really pushing the envelope for attaining effective filtration and would not be recommended for a municipal drinking water system using sand filters due to doubts about the ability of such a filter to remove particulate CONTAMINANTS reliably. There are instances where multi-media deep bed filters or mono-media filters with large diameter anthracite and 6 foot (1.8 m) deep or greater beds of media are used, such as those owned and operated by the Los Angeles Department of Water and Power. Effective filtration of drinking water at high filtration rates recommends careful and exact management of coagulation. Whereas filtration rates are not explicitly addressed in much of the research on water filtration, the experience of researchers, regulators, and consultants is that high rate filtration recommends extra attention and talent. For example, over 3 decades ago, the State of California allowed the Contra Costa Water District to operate filters at 10 gpm/ft^2 (24 m/h) but other water utilities were not allowed to do this. The exception was permitted because of the design and the high level of operating capability at the plant where the high rate was used. Operation at very high rates either causes very rapid increases of head loss in sand filters (*water utility experience resulted in the conclusion that operating sand filters at rates above 3 or 4 gpm/ft² (7-10 m/h) was impractical*) or very little particle removal occurs as water passes through the sand bed, thus enabling filters to operate for a long time at high rates. For this reason following World War II, the use of anthracite and sand filters became the norm for filters designed to operate at 4 or 5 gpm/ft^2 ($10\text{-}12 \text{ m/h}$) or higher. Finally, in the 1980s, workers in Los Angeles showed that a deep (6 foot (1.8 m)) filter with 1.5 mm effective size anthracite media could effectively filter water at rates of close to 15 gpm/ft^2 (37 m/h). However, for very high rates of filtration to be effective, pretreatment has to be excellent, with proper pH and coagulant dosage, probably use of polymer, and in some cases, use of a pre-oxidant to improve filter performance. This is well understood by filter designers and professors who specialize in water filtration. Articles published on the Los Angeles work done by James Montgomery Engineers showed the importance of proper pretreatment. Papers written by experts on filtration have noted the importance of effective pretreatment (*including proper coagulation*) for dependable filter performance, and those writers were focused on rates employed in municipal filtration plants (*e.g. 3 to 10 gpm/ft² (7-24 m/h)*). As filtration rate increases, water velocity through the pores in the sand bed increases, making it more difficult for particles to attach to sand grains and remain in the bed instead of being pushed on through the bed and into filter effluent. When filters do not work effectively for pathogen removal, the burden is put on DISINFECTION to control the pathogens. For *Cryptosporidium*, the DISINFECTION approach that is typically most cost-effective is UV, so a very high rate filter may need to be followed by UV for pathogen inactivation, and the very high rate filters would just have to clarify the water sufficiently that there is no interference from particulate CONTAMINANTS with the UV inactivation process.

4.7.2.2.3.2 Backwash System Design

For a granular media filter system to be able to backwash at a rate of at least 15 GPM per square foot (37 m/h) of filter bed surface area, the pump(s), pipes, and filters must be designed accordingly. As many professionals have sought to improve water quality by decreasing the filtration rate to values lower than 15 gpm/ft^2 (37 m/h), they have sometimes failed to recognize that while lowering the filtration rate may generally produce a positive change in performance, a similarly lower backwash rate could lead to a total filtration system failure. In cases where a backwash rate of 15 gpm/ft^2 (37 m/h) is explicitly prohibited by the filter manufacturer, the filter may still be used, provided that specially graded filter media is installed that will expand to a minimum of 20% bed expansion at the specified backwash flow rate. Viewing windows are highly recommended in all filters since they will allow direct observation of the bed expansion during backwashing, cleanliness of the media and backwash water, and the depth of the sand in the filter. Croll and coworkers²³⁴ used a backwashing rate of 25 gpm/ft^2 (61 m/h) to achieve 25% bed expansion of their filter.

WHO Recommends

The WHO recommends a backwash rate of $15\text{-}17 \text{ gpm/ft}^2$ ($37\text{-}42 \text{ m/h}$) for sand filters, but the media specifications are not given nor is it clear whether or not air-scour is expected prior to backwashing.²³⁵ Backwashing swimming POOL sand filters with air scour is common in the UK and elsewhere.^{236,237} It has also been reported that air-scour washed AQUATIC VENUE filters are more efficient than filters washed by water

only.²³⁸ It is reasonable that lower backwashing rates would be used for water backwash when following air-scour since the air-scour dislodges most of the particles attached to the media grains (*as opposed to relying on the sheer force of the water passing over the surface of the particles*). It is not feasible to operate sand filters in drinking water treatment plants without an auxiliary backwash system such as air scour.²³⁹ The practice of operating AQUATIC VENUES and filters (*that were not using coagulation*) without air scour has been STANDARD practice in the United States for many years, which has seen mixed results ranging from no problems to total system failures requiring replacement of all filter media. PWTAG recommends air-scouring filters at 32 m/h (13 gpm/ft²) (*at 0.35 bar*).²⁴⁰

Polyphosphate Products

Polyphosphate products are sometimes used to sequester metals in POOLS, but this practice is not recommended when granular media filters are used because polyphosphate is an effective particle dispersant that can reduce the removal efficiency.

Filter Bed Expansion

Sufficient freeboard (*or space between the top of the media and the backwash overflow*) to allow for a minimum of 35% filter bed expansion during backwashing adds a factor of SAFETY when the target bed expansion is 20% to prevent the washout of filter media during backwashing. The regions underneath the lateral underdrains in granular media filters can become stagnant when filled with sand or gravel, which can lead to low DISINFECTANT residuals and ultimately biofilm growth. Filling this area with concrete at the time of installation may prevent this potential problem.²⁴¹ It is fundamentally difficult to suspend (*i.e., fluidize*) and hence clean filter media or gravel that is below the level where the backwash water enters the filter.

4.7.2.2.4 Minimum Filter Media Depth Requirement

The performance of high-rate granular media filters at removing pathogens and particles is contingent upon the depth of the filter media (*as shown in MAHC Annex Table 4.7.2.1*), especially at rates of 15 gpm/ft² (37 m/h), which is why these filters recommend at least 24 inches (*61.0 cm*) of filter media. The WHO recommends filtration at 10-12 gpm/ft² (*24-29 m/h*) for sand filters while the PWTAG recommends 4-10 gpm/ft² (*10-24 m/h*) as the maximum filtration rate for all non-domestic POOLS using sand filters.^{242,243} The STANDARD sand filter bed depth typically varies from 0.55 to 1 m (*22 to 39 inches*) in the UK.²⁴⁴

Minimum Depth

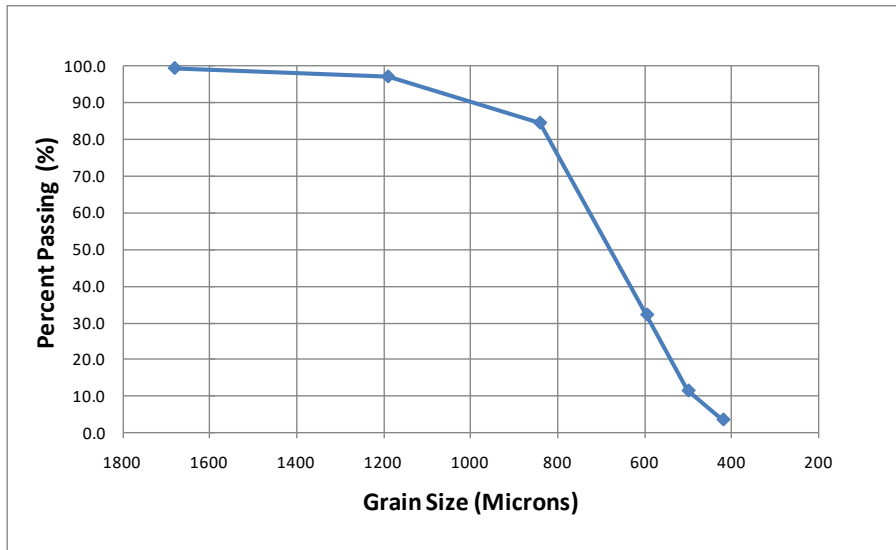
For swimming POOL filters with less than 24 inches (*61.0 cm*) of media between the top of the laterals and the top of the filter bed, lower filtration rates (*e.g., 10 gpm/ft² (24 m/h)*) are recommended to efficiently remove particles and pathogens. Improvements in particle removal with decreasing filtration rates have been documented.²⁴⁵ Drinking water treatment facilities typically limit filtration to less than 4 gpm/ft² (*10 m/h*), which is similar to the filtration rates recommended in AQUATIC VENUES in the 1920s.^{246,247} The minimum depth of sand in POOL filters was 36 inches (*0.9 m*) in 1926.²⁴⁸ Sand filters are typically designed in drinking water treatment for an L/d ratio of 1000 or greater, where “ L ” is the depth of the media and “ d ” is the diameter of the media grain.²⁴⁹ For example, a 0.6 mm effective size sand would recommend a minimum 0.6 m (*23.6 inches*) bed depth, and a 12 inch (*30.5 cm*) deep sand bed with 0.5 mm grains would have an L/d of only 610. The minimum depth of filter media above the underdrains (*or laterals*) is recommended be 24 inches (*61.0 cm*) or greater with sufficient freeboard (*or space between the top of the media and the backwash overflow*) to allow for a minimum of 35% filter bed expansion during backwashing. Sand or other approved granular media should be carefully graded to ensure fluidization of the entire filter bed during backwashing. A design backwash rate of at least 30% higher than the minimum fluidization velocity of the d90 size of the media in water at the larger of 86°F (*30°C*) or the maximum anticipated operating temperature is recommended. A backwash rate higher than the minimum could be necessary to effectively clean the media during backwashing. Variations in the media type, density, water temperature, effective size, or uniformity coefficient may cause changes in the recommended backwash flow rate and/or bed expansion, which should be subject to approval by the local authority provided hydraulic justification by the design engineer. Sand or other approved granular media should be carefully graded to ensure fluidization of the entire filter bed during backwashing. The specifications of POOL filter sand (*or lack thereof*) can lead to filter media being installed that cannot be effectively cleaned during backwashing. Sand that cannot be properly cleaned can lead to filter failures and/or biofilms in the bottom of a filter. Researchers have found nematodes, rotifers, ciliates, zooflagellates, amoebic trophozoites and cysts, as well as bacterial masses in the backwash water of swimming POOL sand filters.^{250,251,252} A design backwash rate of at least 30% higher than the minimum fluidization velocity of the d90 size of the media in water at the larger of 86°F (*30°C*) or the maximum anticipated

operating temperature is recommended, but a backwash rate higher than the minimum could be necessary to effectively clean the media during backwashing. These backwashing recommendations are based on drinking water treatment practice.²⁵³ For a sample of AQUATIC VENUE filter sand examined at University of North Carolina–Charlotte, the d90 size (*i.e.*, 90% of the grains smaller than this diameter) of the media was estimated from the sieve analysis results in MAHC Annex Figure 4.7.2.1.4.1 (*below*) to be 1.06 mm. The calculated minimum fluidization velocity of this sized sand grain in water at 86°F (30°C) was calculated to be 16.7 gpm/ft² (41 m/h). Since this backwash velocity would be expected to leave approximately 10% of the grains in the filter that were larger than the d90 unfluidized, common practice is to recommend a backwashing rate 30% greater than this minimum value (*or* 21.7 gpm/ft²) (53 m/h). The recommended backwash flow for this media by Kawamura²⁵⁴ was graphically estimated to be 20.9 gpm/ft² (51 m/h) at 68°F (20°C). This is the rationale for requiring at least a 15 gpm/ft² (37 m/h) backwashing rate of all swimming POOL sand filters. To ensure compatibility with the minimum recommended backwashing rate of 15 gpm/ft² (37 m/h), filter sand should pass through a number 20 U.S. STANDARD sieve or equivalent (*i.e.*, all sand grains should be smaller than approximately 0.85 mm). While this recommendation of “#20 Silica sand” is common in swimming POOL manuals and by filter manufacturers, it does not appear to be representative of the actual sand that might be installed. Sieve analyses of two brands of commercially available “POOL filter sand” are provided in MAHC Annex Figures 4.7.2.1.4.1 and 4.7.2.1.4.2. Sand can also be specified by an effective size (*E.S.*) of 0.45 mm with a uniformity coefficient (*U.C.*) of less than or equal to 1.45, which is roughly equivalent to a 20/40 mesh sand. A 20/40 mesh sand would pass through a #20 (0.85 mm) sieve and be retained on a #40 (0.42 mm) sieve. In order to reduce the rate of headloss accumulation at the top of the filter bed (*and the frequency of backwashing*), a 20/30 mesh sand could be specified where the smallest grains at the top of the filter would be approximately 0.60 mm (30 mesh) instead of 0.42 mm (40 mesh).

Figure 4.7.2.1.4.1: Grain Size Distribution of Pool Filter Sand – Brand A



Figure 4.7.2.1.4.2: Grain Size Distribution of Pool Filter Sand – Brand B



The depth of the expanded bed during backwashing should be at least 20% greater than the depth of the fixed bed after backwashing. Experiments to determine the backwashing rates recommended to fluidize a bed of POOL filter sand in 3-inch (7.6 cm) and 6-inch (15.2 cm) diameter clear PVC filter columns based on visual observation were conducted. Fluidization is somewhat subjective when observed visually because sand grains could be moving sluggishly prior to fluidization and because the smaller grains at the top of the filter will fluidize long before the larger grains at the bottom. For this reason, bed expansion was measured and recorded along with visual observations of when the bed actually fluidized. Fluidization was visually observed to occur between 20 and 23 gpm/ft² (49-56 m/h), which coincided with 19-23% bed expansion in both sized columns for the unaltered commercial filter media at 68°F (20°C). Expansion data from the 3-inch (7.6 cm) diameter filter column is shown in MAHC Annex Table 4.7.2.1.4.1 (below). The 20/30 mesh fraction of the same filter media was examined under the same conditions, and the experimental results are provided in MAHC Annex Table 4.7.2.1.4.2. The media was observed to be fully fluidized at 19.9 gpm/ft² (49 m/h) with a bed expansion of 21.8% at 68°F (20°C). Calculations based on Cleasby and Logsdon²⁵⁵ indicate that filter backwashing rates should increase by approximately 18% for this media as the temperature is increased from 68° to 86°F (20° to 30°C) due to changes in the viscosity of water with temperature. Fluidization can be somewhat complicated to estimate, but filter bed expansion can be easily measured in the field with granular media filters that use viewing windows. Furthermore, a model exists that can be used to calculate filter bed expansion of sand in a filter during backwashing.²⁵⁶ This model tends to be sensitive to fixed bed porosity, but using a value of 42% porosity with a sphericity of 0.85 and density of 2.65 g/cm³ yielded a bed expansion of 22.7% at 20 gpm for water at 86°F (30°C). This is the rationale for requiring the depth of the expanded bed during backwashing being at least 20% greater than the depth of the fixed bed. PWTAG recommends 15-25% bed expansion following air scouring at 32 m/h (13 gpm/ft²) (at 0.35 bar).²⁵⁷ In a study funded by PWTAG, researchers used a backwashing rate of 25 gpm/ft² (61 m/h) to achieve 25% bed expansion of their filters.²⁵⁸ Variations in the media type, density, water temperature, effective size, or uniformity coefficient may cause changes in the recommended backwash flow rate and/or bed expansion, which should be subject to approval by the local authority provided hydraulic justification by the design engineer.

Table 4.7.2.1.4.1: Pool Filter Sand at 68°F (20° C)

Backwash Flow	Bed Expansion
12.4 gpm/ft ² (30.3 m/h)	3.6%
16.3 gpm/ft ² (39.8 m/h)	11.4%
18.5 gpm/ft ² (45.2 m/h)	16.3 %
20.3 gpm/ft ² (49.6 m/h)	19.3%
22.1 gpm/ft ² (54.0 m/h)	22.5%

Table 4.7.2.1.4.2: Pool Filter Sand Sieved 20/30 mesh at 68°F (20° C)

Backwash Flow	Bed Expansion
12.2 gpm/ft ² (29.8 m/h)	4.8%

15.8 gpm/ft ² (38.6 m/h)	13.0%
17.9 gpm/ft ² (43.8 m/h)	17.4 %
19.9 gpm/ft ² (46.6 m/h)	21.8%
21.5 gpm/ft ² (52.6 m/h)	25.6%
23.9 gpm/ft ² (58.4 m/h)	31.2%

4.7.2.2.6 Coagulant Injection Equipment Installation

To enhance filter performance, a coagulant feed system, when used, should be installed with an injection point located before the filters and, for pressure filters, on the suction side of the recirculation pump(s) capable of delivering a variable dose of a coagulant (e.g., *polyaluminum chloride* or a *POOL clarifier product*) to enhance filter performance. Pumps should be properly sized to allow for continuous delivery of the recommended dosage of the selected coagulant. Products used to enhance filter performance should be used according to the manufacturers' recommendations. The coagulant feed system should consist of a pump, supply reservoir, tubing, ISOLATION valve, and BACKFLOW prevention device. Sand filters used as pre-filters for membranes or cartridge filters with 1-micron nominal or 5-micron absolute size ratings or less should not be recommended to have coagulant injection equipment. Specialized granular filter media capable of removing *Cryptosporidium* OOCYSTS or an acceptable 4.5-micron surrogate particle with an efficiency of at least 90% (i.e., a minimum of 1 log reduction) without coagulation should not be recommended to provide coagulant injection equipment, but this media should be replaced or reconditioned as recommended to sustain the minimum recommended particle removal efficiency stated above. Sand filters located ahead of a UV or ozone DISINFECTION system may be excluded from supplying coagulation equipment with the approval of the local authorities. Local authorities should consider the efficiency of the SECONDARY DISINFECTION SYSTEM process for *Cryptosporidium* inactivation but should also consider that a side-stream system does not have any effect on the *Cryptosporidium* OOCYSTS that bypass the system on each TURNOVER. For example, a UV system that is 99.999% effective at inactivating *Cryptosporidium* that only treats half of the recirculated water flow is on average only 50% effective (per pass) because all of the *Cryptosporidium* in the bypass stream remain unaffected by the UV. Coagulation is the key to effective granular media filtration, which has long been recognized in the drinking water industry.^{259,260,261,262,263} Operation of granular media filters without coagulation is not permitted by EPA regulations for drinking water treatment, with the exception of slow sand filters. Thus, if pathogen removal is a goal of water filtration for swimming POOL sand filters, coagulation would be essential. This is the rationale for recommending future consideration of coagulation in swimming POOLS. A coagulant feed system should be installed with an injection point located ahead of the filters to facilitate particle removal by filtration (instead of settling to the bottom of the POOL), and injection ahead of the recirculation pump(s) will provide mixing to evenly distribute the coagulant among the particles. A variable dose of a coagulant (e.g., *polyaluminum chloride*, or *POOL clarifier*) is recommended because coagulant dosages may vary with BATHER load. Products used to enhance filter performance should be used according to the manufacturers' recommendations since overfeed or underfeed of coagulants is known to impair performance. Although polyaluminum chloride (PACl) is not a widely used coagulant in the United States at present, it has been used extensively abroad.^{264,265} However, recommended dosages abroad may not be optimized for pathogen removal. PWTAG recommends a polyaluminum chloride dosage of 0.005 mg/L as Al, but research has shown that 0.05 mg/L is recommended to exceed 90% removal and 0.21 mg/L or higher could be optimal with filters operated based on U.K. STANDARDS.²⁶⁶

New Challenges: The Impact of Coagulation on Backwashing

Coagulation is likely to make cleaning of sand filters more challenging. Drinking water treatment facilities in the United States employ auxiliary backwash systems such as air-scour to improve the cleaning process. Using water alone for backwashing has not been found to be effective for media cleaning in drinking water treatment applications.²⁶⁷ Air scour systems are common in European AQUATIC VENUE filters and should be investigated further in the United States. More frequent backwashing is recommended with water-only backwash, and the clean-bed headloss (pressure) should be recorded after each backwash to detect early signs of ineffective backwashing and prevent filter system failures.

Initial Headloss and Headloss Accumulation Rate

Increased headloss (or pressure buildup) in filters is expected with coagulation as particles are likely to be removed faster (more efficiently) and closer to the top of the filter thereby clogging the top of the filter more

quickly. This is actually a sign that the coagulation/filtration system is working effectively. The initial headloss after backwashing should remain relatively constant however. Coagulants have been used successfully in the United States in the past and are currently being used in POOLS abroad.^{268,269,270,271} In systems not properly designed to backwash with filter effluent from other filters, the coagulant feed system should not be operated during backwashing so as to prevent introduction of coagulant into the backwash water.

4.7.2.3 Precoat Filters

4.7.2.3.1 Filtration Rates

The design filtration rate of 2.0 GPM per square foot (4.9 m/h) might be overly conservative and is the same upper limit on filtration rate typically used in drinking water treatment applications.²⁷² However, drinking water applications typically use finer grades of precoat media at application rates of 0.2 lbs/ft^2 (1 kg/m^2).³² Lange and coworkers²⁷³ have used filtration rates up to 4 gpm/ft^2 (10 m/h) with no adverse effect on *Giardia* cyst removal although the removal of turbidity and bacteria were decreased. Ongerth and Hutton²⁷⁴ found better removals at 2 gpm/ft^2 (5 m/h) than at 1 gpm/ft^2 (2.4 m/h) for *Cryptosporidium* OOCYSTS under drinking water treatment conditions (*i.e.*, 0.2 lbs/ft^2 (1 kg/m^2) of DE with body-feed).

4.7.2.3.2 Precoat Media Introduction System Process

The precoat process shall follow the manufacturer's recommendations and requirements of NSF/ANSI Standard 50.

Separation Tank

Precoat filter media has the potential to settle out of suspension in sewer pipes depending on the flow velocities, which could lead to fouling or clogging of sewer pipes. Local authorities may recommend removal of precoat media prior to discharge in sewer systems so POOL operators should check the AHJ.

4.7.2.3.3 Continuous Filter Media Feed Equipment

Filter performance can be significantly impacted by the selection of the precoat filter media, which could alter water clarity, pathogen removal, and cycle length. Multiple grades of precoat media are available in the marketplace. Precoat media can be specified by median particle size of the media or by permeability of the media.²⁷⁵

4.7.2.4 Cartridge Filters

Cartridge filters have not been demonstrated to remove pathogens like *Cryptosporidium* efficiently using the STANDARD swimming POOL cartridges, but the non-STANDARDIZED manual cleaning methods for cartridges may lead to pathogen and/or chemical exposure risks to PATRONS and employees at AQUATIC VENUES while the fouling of cartridges may lead to AQUATIC VENUES exceeding their maximum recommended TURNOVER TIMES. Poor use of PPE and non-STANDARD cleaning of SPA cartridge filters led to non-tuberculosis mycobacterial infections in SPA workers²⁷⁶. Due to these health and SAFETY concerns, cartridge filter use is not recommended in AQUATIC VENUES. Cleaning procedures for cartridges are not well-established and education in proper cleaning procedures is likely necessary to avoid contaminated cartridges being reinstalled into filters potentially providing a protected region for proliferation of biofilm bacteria the could lead to an outbreak. Cartridge filter elements are typically cleaned manually, usually by hosing them down with a water hose and replacing them. Exposure concerns exist since concentrated streams containing *Legionella*, *Mycobacteria*, *Cryptosporidium*, and other pathogens can potentially be sprayed or splashed on the operator/lifeguard as well as the surrounding environment perhaps even including the inside of the filter or the surfaces surrounding the AQUATIC VENUES. An extensive survey of manufacturers' cleaning recommendations was conducted after there was a legionellosis outbreak in a facility with cartridge filters. *Legionella*, *Pseudomonas*, and biofilms were found in the filters. The cleaning procedure employed was to take them outside, rinse them with a water hose, and replace them. Operators reported that they would occasionally degrease or bleach them. Further investigation revealed that this cleaning procedure was common at other facilities. Filter manufacturers were surveyed for cleaning procedures and most often did not have a cleaning process and simply deferred to the cartridge manufacturer since many filter manufacturers do not make the cartridges. The cartridge manufacturers also did not have a cleaning procedure or a very minimal one that did not account for biofilms or heavy organic loads commonly encountered in SPAS. CHLORINE is generally ineffective at inactivating bacteria in a biofilm or removing particulate or organic filter foulants. One effective way to control the biofilms is to completely dry them out.

Based on the known poor performance in removing pathogens increasing the likelihood of waterborne disease outbreaks and the potential for dangerous microbial (*and perhaps chemical*) exposures to the operators during routine maintenance and cleaning, cartridge filters are not currently recommended. This is not to say that all of the current issues and/or concerns with cartridge filters could not be resolved.

4.7.2.4.1 Filtration Rates

Cartridge filter elements should have a listed maximum flow rate of 0.375 GPM per square foot (0.26 L/s/m^2), but the design filtration rate for surface-type cartridge filter should not exceed 0.30 GPM per square foot (0.20 L/s/m^2). Cartridges don't recover 100% capacity when cleaned after fouling. Systems designed to the maximum limit cannot sustain performance (*or minimum POOL TURNOVER requirements*) over time. For example, if a filter only recovers to 80% of the original flux after cleaning, then a filter flow rate of 0.375 GPM per square foot (0.26 L/s/m^2) would become 0.30 GPM per square foot (0.20 L/s/m^2). Cartridge replacement would be necessary following fouling levels greater than 20% of the maximum rated capacity.

4.7.2.4.2 Supplied and Sized

The pore size and surface area of replacement cartridges should match the manufacturer's recommendations.

4.7.2.4.3 Spare Cartridge

An extra set of elements, with at least 100 percent filter area, and appropriate cleaning facilities and equipment should be provided to allow filter cartridges to be thoroughly cleaned. Two sets of filter cartridges should be supplied to allow for immediate replacement and cleaning procedures that involve complete drying of the filter elements.

4.7.3 Disinfection and pH Control

Disinfection and Indoor Air Quality

To provide for a healthy and safe swimming environment in INDOOR AQUATIC FACILITIES, it is important to consider a number of issues that could impact health. Proper ventilation and humidity control are important in removing excess heat, moisture, noxious odors, and harmful DBPs.²⁷⁷

Proper Chemical Use

In addition, improper usage of chemicals and inadequate ventilation can also decrease the quality of the indoor air environment and cause affect health.^{278,279,280}

High Chloramines

High levels of chloramines and other volatile compounds in the air can increase the possibility of health effects such as upper respiratory illnesses and irritation of the mucous membranes including eyes and lungs.^{281,282} Furthermore, these CONTAMINANTS can also cause metal structures and equipment to deteriorate.

Shock Oxidizer

While proper ventilation is critical for INDOOR AQUATIC FACILITIES, water chemistry also can dramatically affect air quality. Levels of chloramines and other volatile compounds can be minimized by reducing CONTAMINANTS that lead to their formation (*e.g., urea, creatinine, amino acids, and personal care products*), as well as by supplemental water treatment. Effective filtration, water replacement, and improved BATHER hygiene can reduce CONTAMINANTS and chloramine formation. Research has shown that the use of non-CHLORINE shock OXIDIZERS is selective in OXIDATION and may not prevent nor reduce inorganic chloramines though they may reduce some organic chloramines.²⁸³ The EPA final guidelines state that manufacturers of "shock OXIDIZERS" may advertise that their "shock OXIDIZER" products "remove," "reduce," or "eliminate" organic CONTAMINANTS. Shock dosing with CHLORINE can destroy inorganic chloramines that are formed. SECONDARY DISINFECTION SYSTEMS such as ozone and UV light may effectively destroy inorganic as well as some organic chloramines.

Swimmer Education

In addition, swimmers should be educated that their behavior (*e.g., failing to SHOWER, urinating in the POOL*) can negatively impact air quality by introducing nitrogen-containing CONTAMINANTS that form volatile compounds.²⁸⁴

Reduce and Minimize Impact

These steps can help reduce the chemical role in creating poor indoor air quality, and help maintain an environment that minimizes health effects on BATHERS as well as decrease deterioration of AQUATIC FACILITIES and equipment.

4.7.3.2 Feed Equipment

4.7.3.2.1 General

If recirculation pumps stop but chemical feed pumps continue to pump chemicals into the return lines it can result in a high concentration of acid and CHLORINE being mixed so that eventually when concentrated solutions of CHLORINE and acid are mixed, CHLORINE gas will be formed. The CHLORINE gas could then be released into the AQUATIC VENUE when the recirculation pump is turned on again or in the pump room if there is an opening in the line as has been documented in CDC's Waterborne Disease and Outbreak Surveillance System^{285,286}. To prevent the hazardous release of CHLORINE gas, the chemical feed system shall be designed so that the CHLORINE and pH feed pumps will be deactivated when there is no or low flow in the RECIRCULATION SYSTEM.

4.7.3.2.2 Sizing of Disinfection Equipment

The CMAHC established a Chlorinator Sizing Ad Hoc Committee in 2015 (<https://cmahc.org/ad-hoc-committees.php>) to address chlorinator sizing by collecting and analyzing actual CHLORINE consumption at operating POOLS since the existing chlorinator sizing requirements were not based on data analysis. Analysis of CHLORINE use data from over 6000 POOLS underscored that existing MAHC dosing requirements are likely excessive in non-SPA AQUATIC VENUES, may be inadequate for SPA operation and, that all AQUATIC VENUES in a given venue type cannot be adequately represented by a single dosing value. In addition, actual CHLORINE consumption at each AQUATIC VENUE appears to be non-linear making it difficult to derive a single dosing rate value. As a result, the Ad Hoc Committee recommended performance-based sizing with consideration of the actual POOL/SPA CHLORINE demand factors such as BATHER load, exposure to vegetation and airborne debris, aeration, volume, water temperature, sunlight (UV), and CYA. This performance based language places the burden on the design professionals and equipment suppliers to properly size dosing equipment. Further data collection and analyses are needed to better understand if CHLORINE use can be more accurately modeled to make chlorinator sizing more data-based.

4.7.3.2.5 Types of Feeders

All UV units shall be installed into the system by means of a bypass pipe to allow maintenance on the UV unit while the AQUATIC VENUE is in operation.

4.7.3.2.7 Feeders for pH Adjustment

It is recommended that the solution's reservoir supply be sized to hold a minimum of 1 week's supply.

4.7.3.2.8 Automated Controllers

Constant and regular MONITORING of key water quality parameters such as the DISINFECTANT level and pH are critical to prevent recreational water illness and outbreaks. AUTOMATED CONTROLLERS are more reliable as a MONITORING device than personnel and hand feeding chemical. Automated chemical controllers are therefore required for use on every AQUATIC VENUE with a time of 1 year built in for facilities to become compliant after adoption of this requirement. The use of AUTOMATED CONTROLLERS does not negate the requirements for regular water testing. Automated units require verification of proper function and the probes do fail or slip out of calibration. This can only be detected by MONITORING the water quality.

4.7.3.3 Secondary Disinfection Systems

4.7.3.3.1 General Requirements

4.7.3.3.1.1 ANSI Listing and Labeling

EPA regulates the labeling of pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (<https://www.epa.gov/laws-regulations/summary-federal-insecticide-fungicide-and-rodenticide-act> accessed April 21, 2018). According to EPA requirement 40 CFR 156.10, the establishment registration number may appear in any suitable location on the pesticide label or immediate container. More information on pesticide establishment registration numbers can be found here at <http://www2.epa.gov/pesticide-registration/pesticide-registration-manual-chapter-13-devices> (accessed April 21, 2018).

4.7.3.3.1.2 Required Facilities

Due to the risk of outbreaks of RWIs associated with the DISINFECTANT tolerant parasite *Cryptosporidium*, it is strongly recommended that all AQUATIC FACILITIES include SECONDARY DISINFECTION SYSTEMS to minimize the risk to the public associated with these outbreaks.

Increased Risk Aquatic Venues

However, there are some AQUATIC VENUES where the risk of acquiring a RWI is elevated (*INCREASED RISK AQUATIC VENUES*) due to either the use of the AQUATIC VENUE, or the users. THERAPY POOLS, for example, are often utilized by individuals with compromised immune systems and/or open wounds. The risk of acquiring an RWI is substantially increased under such circumstances. WADING POOLS are utilized by small children who may be in diapers. Incontinent infants and small children are likely to increase the contamination burden (*e.g.: urine and feces*) in the water, thereby creating an increased risk of disease to other users. In addition, cryptosporidiosis is more prevalent in younger children.²⁸⁷ INTERACTIVE WATER PLAY VENUES such as spray pads, fountains, and similar features are most often used by smaller children who are likely to increase the risk of water contamination occurring. They also may be more likely to suffer from more severe illness when they become infected.

Intent

The intent of requiring a SECONDARY DISINFECTION SYSTEM is to limit the length of time of exposure to agents that cause diarrheal illness, in particular *Cryptosporidium*, after a fecal release in INCREASED RISK AQUATIC VENUES.

Facilities

These facilities include THERAPY POOLS, and WADING POOLS, water ACTIVITY POOLS, INTERACTIVE WATER PLAY AQUATIC VENUES (*e.g., spray pads*), and other AQUATIC VENUES with no standing water designed primarily for young children, including children less than 5 years of age. In these facilities, the potential of diarrheal illness is elevated due to the population mix of the BATHERS and the design of the facility. The pathogens of concern in such facilities are *Cryptosporidium*, *Giardia*, *Shigella*, *E. coli* O157:H7, and norovirus. *Shigella* and *E coli* O157:H7 are very sensitive to traditional CHLORINE DISINFECTION. However, the seriousness of illness caused by highly (*Cryptosporidium*) and moderately (*Giardia, norovirus*) CHLORINE tolerant pathogens is the reason a SECONDARY DISINFECTION SYSTEM is **required** for all new or SUBSTANTIALLY ALTERED construction of these types of AQUATIC FACILITIES after the adoption of this CODE. When older facilities are SUBSTANTIALLY ALTERED, they must retrofit to meet this treatment requirement.

4.7.3.3.2 Log Inactivation and Oocyst Reduction

4.7.3.3.2.1 Log Inactivation

Examples of SECONDARY DISINFECTION SYSTEMS include but are not necessarily limited to UV DISINFECTION and ozone DISINFECTION. Due to circulation hydraulics, there is no significant advantage to having 3-log inactivation instead of 2-log inactivation. Allowing either 2-log or 3-log inactivation per pass, as specified, will provide more flexibility to POOL operators in choosing systems (*e.g., filtration, ozonation, or UV*) that will still provide a 3-log reduction of *Cryptosporidium* in the POOL within seven TURNOVERS. Using Gage-Bidwell's law of dilution, MAHC Table 4.7.3.3.2.1 shows the log reduction of *Cryptosporidium* in the POOL vs. the number of TURNOVERS for secondary systems that provide 2-log and 3-log reductions per pass through the SECONDARY DISINFECTION SYSTEM.

Table 4.7.3.3.2.1 Turnovers Required to Achieve 2-log and 3-log Removal of *Cryptosporidium* in Pools with Secondary Systems

Turnover	Log removal in pool with 2-log secondary system	Log removal in pool with 3-log secondary system
0	0.00	0.00
1	0.43	0.43
2	0.86	0.87
3	1.29	1.30
4	1.72	1.74
5	2.15	2.17
6	2.58	2.60
7	3.01	3.04

The table clearly shows that the 2-log secondary system and 3-log secondary systems provide virtually the same log reductions in the POOL. Both are capable of providing a 3-log reduction of crypto in the POOL after 7 TURNOVERS. The values in the table were calculated using the following equation:

Log removal in the POOL = $\text{Log}(e^{(\text{efficiency} \times \text{turnover})})$ where the efficiency of a 3-log reduction system is 0.999 and the efficiency of a 2-log system is 0.99. For example, with a 2-log secondary system and one TURNOVER, log removal in the POOL = $\text{Log}(e^{(0.99 \times 1)}) = 0.43$.

4.7.3.3.2.2 Installation

SECONDARY DISINFECTION SYSTEMS are located in the treatment loop (*post-filtration*) and treat a portion (*up to 100%*) of the filtration flow prior to return of the water to the AQUATIC VENUE or AQUATIC FEATURE. For INTERACTIVE WATER PLAY AQUATIC VENUES, the SECONDARY DISINFECTION SYSTEM is also to be installed on the filtration system loop and not a separate AQUATIC FEATURE line. The filtration system operates continuously, which is necessary to achieve the intended reduction of *Cryptosporidium* in the treatment tank in the specified time period. Installation on an AQUATIC FEATURE loop will not ensure that the intended treatment outcome will be met, especially since the feature pumps do not typically operate continuously throughout the entire day (*24 hours; typically turned off at night*).

4.7.3.3.2.4 Minimum Flow Rate Calculation

The SECONDARY DISINFECTION SYSTEM is to be designed to reduce an assumed total number of infective *Cryptosporidium* OOCYSTS in the total volume of the AQUATIC VENUE from an assumed 100 million (10^8) OOCYSTS to a maximum concentration of one infective OOCYST/100 mL by means of consecutive dilution.

4.7.3.3.2.5 Equation

In considering the potential for outbreaks, it was decided that a treatment system should be designed to limit the outbreak to a reasonable period of time, preferably to a single day of operation. By this, it is meant that all pathogens of concern that may still be present at infective concentrations at the close of operations are reduced to below a level of infectivity by the opening time of the following day. This approach has been recommended because numerous multi-day outbreaks have been well documented.^{288,289,290} In order to design a treatment system that can reduce the duration of exposure to a single day, the MAHC Committee made the following assumptions:

- The target of concern is *Cryptosporidium*. Based on known CT INACTIVATION VALUES, all other pathogens will be inactivated within an hour if the facility is maintaining at least 1 ppm of FREE CHLORINE.
- At a concentration of 1 ppm FREE CHLORINE, any *Cryptosporidium* OOCYSTS left circulating in the water may be infective for up to 15,300 minutes (*>10 days*) after introduction.
- A single contamination event (*e.g. diarrheal incident*) of ~100 mL could introduce 10^8 *Cryptosporidium* OOCYSTS into the water.^{291,292}
- Reducing the amount of *Cryptosporidium* below the level at which there is one infectious OOCYST per average volume swallowed by swimmers (*16-128 mL*) would be a reasonable target for overnight remediation of the water to reduce the risk of transmission beyond the day of initial contamination.^{293,294,295} The concentration chosen was one OOCYST/100mL.
- The only effective means currently to reduce the concentration of OOCYST in an AQUATIC VENUE while open for bathing is by dilution (*this does not include HYPERCHLORINATION that requires closure of the water to BATHERS*). Accomplishing this through the introduction of sufficient makeup water is not practical. Instead, the solution is to remove a portion of the water, treat it to reduce the concentration of infectious OOCYSTS, and then return that water to the AQUATIC VENUE.
- SECONDARY DISINFECTION SYSTEMS can practically achieve a 3-log (99.9%) reduction in the number of infective OOCYSTS per pass through the SECONDARY DISINFECTION SYSTEM.
- Due to imperfect mixing and other real work constraints, a SAFETY factor of 1.33 has been applied to the maximum dilution time, as defined as the time it will take for 10^8 OOCYSTS introduced into an AQUATIC VENUE (*e.g. a diarrheal event*) to be reduced to a maximum concentration of one OOCYST per 100 mL.
- A reasonable expected overnight closure time for an AQUATIC VENUE is 12 hours (*e.g. 8 p.m. to 8 a.m.*). Therefore 9 hours has been established as the maximum dilution time ($12 / 1.33$ or 12×0.75) to be used when sizing a SECONDARY DISINFECTION SYSTEM. If the actual expected closure time of a venue is less than 12 hours, then 75% of that value shall be used for the dilution time.

- Following is the derivation of the equation for Q found in MAHC 4.7.3.3.2.5.

C = needed resulting concentration after a given time period = 1 OOCYST per 100 ml (37.85 OOCYSTS per 1 gallon)

C_0 = initial concentration = 10^8 OOCYSTS / V

r = efficiency = 0.999 for 3-log reduction per pass, or 0.99 for 2-log reduction per pass

t = time (minutes)

V = volume (gallons)

Q = flow rate (gpm)

T = number of TURNOVERS = Qt/V

e = Euler's mathematical constant whose value is approximately 2.71828.

$C = C_0 * e^{-rT}$

$C/C_0 = e^{-r(Qt/V)}$

$\ln C/C_0 = -r(Qt/V)$

$\ln C - \ln C_0 = -rt(Q/V)$

multiply both sides by $-1/rt$

$(\ln C - \ln C_0)/-rt = Q/V$

$(\ln C_0 - \ln C)/rt = Q/V$

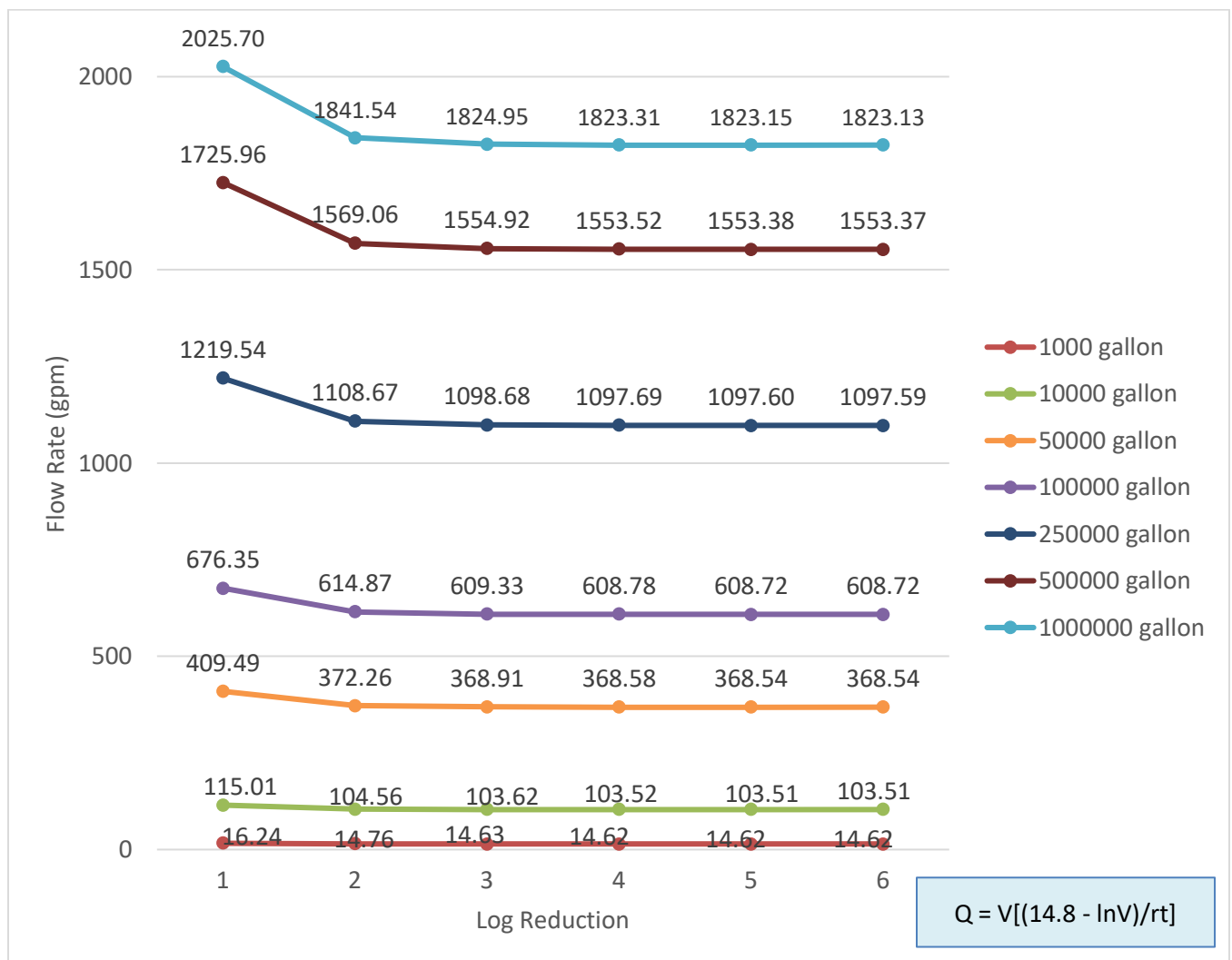
$Q = V[(\ln C_0 - \ln C)/rt]$

$Q = V\{[\ln(10^8/V) - \ln 37.85]/rt\}$

$Q = V[(18.42 - \ln V - 3.63)/rt]$

$Q = V[(14.79 - \ln V)/rt]$
- If a 9 hour (540 minute) dilution time is assumed, this equation can be used to calculate the data displayed in the following graph.

Figure 4.7.3.3.2.5: Flow Rate per Volume for a Given Log reduction, 9 hour Dilution Time



Any treatment system that demonstrates this reduction in *Cryptosporidium* OOCYSTS specified herein is suitable for use. It is not the intent of the MAHC to limit technology only to UV and ozone as discussed in the code, but rather to specify the outcome of the treatment.

Purpose

The purpose of SECONDARY DISINFECTION is to reduce the viable *Cryptosporidium* OOCYSTS to a number below that which is considered an infective dose (number/volume swallowed), should the parasite be introduced into an AQUATIC VENUE. While 100% UV treatment of recirculated water is an option, it is important to note that this will not ensure the SAFETY of the BATHERS immediately following a fecal event, but it will reduce the time required for the system to get below an infective dose. While this is beneficial, mandating UV on 100% of the recirculated water flow may lead owners and designers to minimize the total recirculated flow so as to not incur the additional capital and operating cost of the required additional UV, ozone, or other SECONDARY DISINFECTION SYSTEMS. *Cryptosporidium* control is not the only consideration when designing an INCREASED RISK AQUATIC VENUE, and it is important that this requirement does not negatively influence other design considerations—such as amount of filtration needed for particulate removal and control of turbidity. Consideration was therefore given to what should be the maximum time a system takes to reduce the viable OOCYST concentration to below an effective dose. Because a fecal event can release 100 million OOCYSTS and an infective dose is as little as one OOCYST per 100 mL, it is not possible with available technology to ensure the SAFETY of BATHERS in the AQUATIC VENUE both at the time the fecal event occurs and in the immediate aftermath. A reasonable and logical maximum time for reducing the OOCYST concentration to below one OOCYST/100mL was determined to be the lesser of 9 hours or 75% of the time an AQUATIC VENUE is closed in a 24-hour period. The goal of this is to ensure an AQUATIC VENUE is free of viable *Cryptosporidium* OOCYSTS, or at least have the number below an infective concentration every day the AQUATIC VENUE opens to the public.

Example of Equation

The actual calculation used to determine the amount of needed SECONDARY DISINFECTION is based upon the understanding that the treatment of recirculated AQUATIC VENUES involves serial dilution, whether we are talking about particulate removal or rendering *Cryptosporidium* OOCYST ineffective. Assuming an initial concentration of 10^8 OOCYSTS, recognizing the limit of an infective dose is one OOCYST/100 mL, and allowing for a 99.9% reduction in infective OOCYST by the SECONDARY DISINFECTION SYSTEM, it can be derived that needed flow through the SECONDARY DISINFECTION SYSTEM is as given in the MAHC.

An example of how to calculate for the needed flow is as follows:

$Q = V \times \{ [14.8 - \ln(V)] / (60 \times T) \}$, where:

- Q = SECONDARY DISINFECTION SYSTEM flow rate (*gpm*)
- V = Total water volume of the AQUATIC VENUE or AQUATIC FEATURE, including surge tanks, piping, equipment, etc. (*gals*)
- T = Dilution time (*hrs.*)
- For a 100,000 gallon (*378,541 L*) AQUATIC VENUE which is closed 12 continuous hours out of every 24 hours, 75% of which is 9 hours:
- $100,000 \times \{ [14.8 - \ln(100,000)] / (60 \times 9) \} = 609 \text{ gpm}$

Therefore, the 100,000 gallon (*378,541 L*) AQUATIC VENUE would require a SECONDARY DISINFECTION SYSTEM which has a flow rate of at least 609 gpm. If this AQUATIC VENUE is designed with a 2 hour filtration TURNOVER RATE, the flow through the filters would be 833 gpm. An owner or designer can choose to size the SECONDARY FILTRATION SYSTEM to be 609 gpm, 833 gpm, or anything in between. If the owner or designer chooses to size the SECONDARY DISINFECTION SYSTEM equal to the filtration flow rate (*833 gpm*) the time it would take to reduce 10^8 OOCYST to 1 OOCYST/100 mL would be 6.6 instead of 9 hours.

4.7.3.3.2.7 Flow Rate Measurements

Consideration was given for simplifying the sizing of the SECONDARY DISINFECTION SYSTEM and having the flow rate through the SECONDARY DISINFECTION SYSTEM equal to the overall treatment system flow rate. While this was initially recommended by the MAHC, ultimately this approach was rejected. A basic premise of the MAHC is to establish performance-based STANDARDS supported by data and science whenever possible. Sizing the SECONDARY DISINFECTION SYSTEM equal to the overall treatment system flow rate, while simplifying the design and operation of the facility, does not meet any defined criteria for reducing or eliminating risk to the PATRONS using the AQUATIC FACILITY. It was felt that establishing specific criteria for sizing the SECONDARY DISINFECTION SYSTEM independent of the criteria for sizing other treatment system processes (*e.g. filtration flow rate*) was the approach most likely to protect the public's health.

Maximum Concentrations

In developing this approach, the MAHC considered establishing maximum permissible concentrations of OOCYSTS, which would be MONITORED and verified, but the MAHC rejected that approach as impractical since this would require actual laboratory testing. Establishing a concentration based STANDARD for the water cannot readily be implemented because:

- There is no practical method to rapidly determine the number of OOCYSTS in the water and thus no method to enforce the STANDARD.
- There are multiple and interrelated biological variables in exposure estimations. These include the number of OOCYSTS released per fecal incident, the number of incidents per day, strain differences in pathogenicity, the amount of water swallowed, and differences in individual susceptibility.
- The circulatory patterns in facilities are complex and unique to each AQUATIC FACILITY.

Requiring that the SECONDARY DISINFECTION SYSTEM deliver a treatment that ensured the OOCYST concentration was reduced to a specified level would require multiple biological assumptions and computer modeling that exceed those currently required for any other water parameter.

4.7.3.3.3 Ultraviolet Light Systems

UV DISINFECTION is a SECONDARY DISINFECTION SYSTEM and must meet the minimum requirements of all SECONDARY DISINFECTION SYSTEMS as defined in MAHC 4.7.3.3. The minimum requirements must be read in conjunction with the clarifications and additional information as detailed below.

Mercury clean-up procedures for broken UV lamps can be found in Section E.1.2 of EPA 815-R-06-007 Appendix E: <http://goo.gl/edykzN>. The MAHC agrees that knowledge of appropriate mercury clean-up is essential for operator SAFETY. If this is considered for inclusion in the MAHC then additional guidance on training requirements should be included. Guidance should include who should be trained (e.g., owner, operator, manager), the type of training required (e.g., on the job, classwork), and how inspectors should verify operators are trained (e.g., completion certificate, demonstration of knowledge?). Such guidance can be found in Section E.1.2 of EPA 815-R-06-007 Appendix E.

4.7.3.3.3.1 Third Party Validation

Validation to a recognized national STANDARD is carried out by a recognized and capable third party. Such validation needs to take into consideration lamp life, UV MONITORING, and optical water quality. Typical POOL water qualities vary, but a design UV TRANSMISSIVITY assumption of better than 94% T10 should not be used. T10 is the ability of an object to transmit UV. Where possible, transmissivity tests should be obtained for existing facilities.

4.7.3.3.3.1.1 Validation Standard

Validation is a process by which any UV unit is tested against a surrogate microorganism in order to determine its performance. Validation is required because there is no on-line test of a UV unit's ability to DISINFECT and, due to the relatively short contact time, it is impossible to size units accurately based on just calculations. It is important to note that evidence of testing is not the same as validation. Validation must adhere to the following criteria:

- Follow one of the approved validation systems, preferably the EPA 815-R-06-007,
- Have been carried out by a genuine third party, and
- Include all the required validation factors and RED BIAS.

The validated performance is based on the flow and transmissivity of the water to be treated. Therefore it is essential that the system is used within its validated performance range. A system operated outside its validated range is NOT acceptable.

Validation Factor

The validation factor is used to account for statistical variations in the recorded data during third party testing. The validation factor is required to ensure that the equipment's actual performance will always be equal to or better than its validated performance. This figure can be between 15% and 35% depending on the quality of the testing and must be included in any validated performance curve.

Transmissivity (Transmission)

The transmissivity (*often called transmission*) of the water to be treated is an important design factor in sizing a UV system. The transmissivity is normally quoted as a % value in either a 1 cm, 4 cm, or 5 cm cell. It is measured in a UV Spectrophotometer. In many water treatment applications, this value will vary considerably but AQUATIC VENUES are for the most part consistent, due to the bleaching effect of the CHLORINE used as a residual DISINFECTANT. Typically AQUATIC VENUES will have a transmission of between 94% and 95% in a 1 cm cell, with splash pads and other INTERACTIVE WATER PLAY VENUES between 92% and 94%. The installation of a UV unit itself will increase the transmission by perhaps 2% due to the improvement in the POOL water quality so the values noted above refer to a situation where a UV unit is installed and operational. Design transmissions over 94% are not recommended, and exceptionally heavily loaded AQUATIC VENUES may consider using a lower number as a design basis. It is also important to understand that as transmission is reduced, the performance of the equipment is reduced and the RED BIAS increases, requiring the UV to deliver more performance. For this reason, the performance difference between any equipment's validated performance at 98% transmissivity and actual field performance at 94% transmissivity can be 40% lower. When presented with validated performance data at 98% transmission, operators should therefore be aware that the equipment may only deliver half the performance when installed.

Validation Range

A validated system will have different performance levels at different water qualities and flows. The relationship between these is traditionally represented as a performance curve where the performance can be noted at any point on this curve. However the lowest transmission test point and the highest flow tested are normally considered the extents of the validated range. This means that any UV unit tested at 95% and above is NOT validated at transmissions lower than 95%. For the same reason, a unit tested at a maximum flow of 500 gpm is

NOT validated for any flow over 500 gpm. Validation factors can reduce equipment validated performance by 30%, so it is essential that systems without validation factors built into performance curves are not considered validated. The performance of a UV system in the field is measured by a combination of flow and intensity readings from the UV sensors. Performance in the field can be verified on inspection by regulators who will compare actual sensor readings with those indicated on the performance charts, so these charts must be retained at the AQUATIC FACILITY for each validated system. UV equipment is utilized for its ability to DISINFECT CHLORINE-tolerant pathogens and for its ability to reduce combined CHLORINES in the POOL water. For the latter, typically a calculated dose of 60mJ/cm² is utilized based on the total UV-C and UV-B spectrum. This is similar to the validated dose requirements of the SECONDARY DISINFECTION SYSTEMS. Where UV is fitted as a SUPPLEMENTAL TREATMENT SYSTEM the CODE allows some operational and equipment concessions. Operators should note that the regulations as stated represent BEST PRACTICE; but where specific circumstances dictate, then the equipment specifications may be reduced. For a SUPPLEMENTAL TREATMENT SYSTEM, the operator may consider reducing the dose applied to the process. This will reduce performance accordingly and operators should consider carefully such reduction in performance, and assure themselves that the equipment will still provide a beneficial level of performance.

4.7.3.3.4.1 Alarm/Interlock Setpoint

This requirement is intended to ensure that UV sensor placement is taken into account when determining the minimum setpoint to alarm/interlock. UV equipment validated through the UV Intensity Setpoint Approach relies on UV intensity readings by UV sensors to account for changes in UV transmittance (UVT), and therefore UVT is not MONITORED separately during operations to confirm dose delivery. However, proper positioning of sensors is necessary to accurately relate a given UV intensity to a specific level of dose delivery, irrespective of changes in UVT or lamp output. Refer to EPA 815-R-06-007 Chapter 3 Section 3.5.2.1 and Appendix D Section D.2 for a discussion of the importance of ideal placement of sensors and the impact of sensor positioning on UV dose MONITORING. This requirement is not intended to specify sensor placement, which is addressed in the validation process. However, if a UV sensor is not placed as close as possible to the “ideal” location (i.e. positioned so that the UV intensity reading is proportional to the UV dose, irrespective of changes in UVT and lamp output), it is necessary to adjust the alarm/interlock setpoint accordingly. This adjustment should account for the disproportionate impact of changes in UVT or lamp output on the measured intensity as a result of sensor positioning to ensure that the minimum dose is delivered at the specified flow rate. EPA 815-R-06-007 Appendix D. Section D.2.1 items 1-3 and their respective examples (D.2, D.3, and D.4) and figures (D.5 (a), (b) and (c)) provide a detailed discussion of the impact of UV sensor positioning on the relationship between UV dose and intensity readings.

4.7.3.3.9 Minimum RED

The EPA identifies the required dose for various organisms to achieve 3- or 4-log reduction. This dose must be modified by the RED BIAS in order to ensure delivery of validated performance. Depending on the quality of the water, this RED BIAS can be between 35% and 70%.

4.7.3.3.4 Ozone Disinfection

4.7.3.3.4.1 Log Inactivation

Ozone is a SECONDARY DISINFECTION SYSTEM and must meet the minimum requirements of all SECONDARY DISINFECTION SYSTEMS as defined in MAHC 4.7.3.3. Ozone is an antimicrobial OXIDIZER. Its use as a SECONDARY DISINFECTION SYSTEM in commercial swimming POOLS in the United States dates back to the 1930s. Ozone is proven to kill *Cryptosporidium*²⁹⁶, *Giardia*²⁹⁷, *E. coli*²⁹⁸, and *Pseudomonas aeruginosa*²⁹⁹, along with any other microorganism potentially found in AQUATIC VENUES, and is a strong OXIDIZER. Exposure to ozone gas can result in irritation to the eyes and respiratory tract if not generated and handled correctly. Therefore OSHA has identified a time weighted average (TWA) of 0.1 ppm (0.1 mg/L) as the PEL for ozone.

4.7.3.3.4.2 Third Party Validation

Validation is a process by which any ozone unit is tested against a surrogate microorganism in order to determine its performance. Validation is required because there is no on-line test of an ozone unit's ability to DISINFECT and, due to the relatively short contact time, it is impossible to size units accurately based on just calculations. It is important to note that evidence of testing is not the same as validation. NSF/ANSI Standard 50 now includes the ozone/*Cryptosporidium* validation STANDARD; it is no longer in an Annex but is now a portion of the ozone section in the whole STANDARD that was published in 2013.

4.7.3.3.4.3 Suitable for Use

All materials must be ozone resistant. The strong oxidizing power of ozone shall be considered when choosing materials for pipes, valves, gaskets, pump diaphragms, and sealant. Materials for water piping, tanks, and other conveyance shall be nearly inert. For generators that produce ozone under pressure and utilize a negative pressure (*Venturi*) ozone delivery system, or introduce ozone under pressure (*such as a pressurized diffuser into an atmospheric holding tank*), any leak or break in the system will immediately cause the release of ozone gas.

Suitable materials and their uses are:

1. Ozone/Air or Ozone/Oxygen:

- Concentrations above 2500 ppm (*mg/L*) (*0.4 % wt*)
 - PTFE, FEP (*Teflon*®) – tubing, O-rings, or ozone cell materials
 - PVDF (*Polyvinylidene Fluoride*), Kynar® (*Pennwalt patent*) – tubing, injection, check valves
 - Stainless Steel, grade 316L – tubing or ozone cell materials
 - Glass and most ceramics – ozone cell materials
 - Aflas® – seals, O-rings, gaskets
- Concentrations below 2500 (*in addition to those above*)
 - Viton® – tubing, seals, O-rings
 - Kel-F® – seals & O-rings

NOTE: *Stainless steel tubing shall only be used when the feed-gas is dried to a dew point below –76 °F (-60° C), and where no chance of water ingress exists. CORROSIVE acids formed in moist air will corrode the pipes from the inside.*

2. Dissolved Ozone in Water (in addition to all those listed above):

- PVC or CPVC (*schedule 40 or 80*)
- EPDM (*Ethylene - propylene terpolymer*)
- PVDF (*Polyvinylidene Fluoride*), Kynar® (*Pennwalt patent*)

3. Gaskets and O-rings

- Aflas®, Kalrez®, and Teflon® are acceptable gasket materials for both gas and aqueous seals.
- Viton®, EPDM, and “Red Silicon” do not provide sufficient resistance to deterioration at ozone concentrations above 1.5% (*gaseous*) but work well in aqueous ozone solutions. If used for gaseous application, these shall only be used in static seals and replaced regularly.

4. Joint Sealing

Properly applied Teflon tape may be used successfully for sealing joints; however, threaded fittings shall be avoided where possible. Hypalon® and silicone sealers which do not contain rubber filler are also successful.

4.7.3.3.4.7 Installation and Injection Point

4.7.3.3.4.7.2 Gas Monitor / Controller

For generators that produce ozone under pressure and utilize a negative pressure (*Venturi*) ozone delivery system, or introduce ozone under pressure (*such as a pressurized diffuser into an atmospheric holding tank*), any leak or break in the system will immediately cause the release of ozone gas.

4.7.3.4 Supplemental Treatment Systems

4.7.3.4.1 General Requirements

4.7.3.4.1.1 Optional

AQUATIC VENUES that do not require SECONDARY DISINFECTION SYSTEMS have the option to utilize SUPPLEMENTAL TREATMENT SYSTEMS. These systems may not afford DISINFECTION protection against *Cryptosporidium*, and may not remove chloramines as effectively as SECONDARY DISINFECTION SYSTEMS. However, if sized within supplementary treatment system requirements in MAHC 4.7.3.4, a SUPPLEMENTAL TREATMENT SYSTEM may be of benefit in maintaining air quality at indoor facilities, reducing the *Cryptosporidium* burden over an extended period of time, and reducing the amount of DISINFECTANT needed to

maintain required DISINFECTANT levels. Although SUPPLEMENTARY TREATMENT SYSTEMS are optional, it should be noted that this CODE, as written, represents BEST PRACTICE.

4.7.3.4.2 Ultraviolet Light

Refer to information presented in MAHC Annex 4.7.3.3.3.

4.7.3.4.3 Ozone

Refer to information presented in MAHC Annex 4.7.3.3.4.

4.7.3.4.4 Copper / Silver Ion System

The scientific data available on efficacy of these systems is predominantly for bacterial inactivation and usually includes FAC.^{300,301} There is limited scientific literature that documents the efficacy of these systems on viruses and parasites. Given the importance and frequency of RWIs associated with these other microorganisms (*viruses and parasites*), it is essential that DISINFECTION chemicals / systems are also effective against such microorganisms as well.

4.7.3.4.5 Ultraviolet Light / Hydrogen Peroxide Systems

UV/peroxide systems have not been registered by the EPA as primary DISINFECTANT systems for recreational water. Although UV is a DISINFECTANT, it does not impart a persistent residual DISINFECTING property to water. To overcome this, UV/peroxide systems claim, or in some cases, imply that the inclusion of hydrogen peroxide in the system supplies a DISINFECTANT in the bulk water in the AQUATIC VENUE. Hydrogen peroxide is used as a hard surface DISINFECTANT and has been granted registration for this purpose by the EPA. When used as a hard surface DISINFECTANT, hydrogen peroxide is normally used at around 3%. When used in recreational water, hydrogen peroxide is used at 27 to 100 ppm (mg/L), which is 1111 and 300 times, respectively, more dilute than that used on hard surfaces. At these low concentrations hydrogen peroxide is not an effective DISINFECTANT. Thus, UV/peroxide systems do not provide a persistent DISINFECTANT in the bulk of the water in the AQUATIC VENUE. Further, hydrogen peroxide is not registered by the EPA for use as a DISINFECTANT in recreational water. Since it is not EPA-REGISTERED, the use of hydrogen peroxide as a DISINFECTANT, or any market claims that implies hydrogen peroxide provides any biological control, is a violation of FIFRA. UV/peroxide system should not be used as a SUPPLEMENTAL TREATMENT SYSTEM on CHLORINE treated AQUATIC VENUES. The addition of hydrogen peroxide to a CHLORINE-treated POOL will inactivate the HOCl. If sufficient hydrogen peroxide is added, the HOCl will be completely eliminated and no DISINFECTANT for inactivation of pathogenic organisms will remain.

4.7.3.5 Water Quality Testing Devices and Kits

WQTDs should be stored as specified by the manufacturer's instructions. Failure to properly store WQTDs will result in incorrect readings. NSF/ANSI 50 for WQTDs in 2013 currently contains specified precision and accuracy requirements for measuring pH, free & total CHLORINE, and free & total bromine. There are three levels of accuracy and precision deemed level 1, 2 and 3, with the highest accuracy and precision in level 1 devices. The test water specifications include alkalinity, calcium hardness, and TDS. It is important for a QUALIFIED OPERATOR to use equipment that is easy to read and as objective as possible. The current, common means of testing AQUATIC VENUE water using colorimetric test kits is subjective because the color and intensity must be compared. Titration testing for free and combined CHLORINE is an objective test, which is accurate to 0.2 mg/L with an easily recognizable start and end point. Therefore, titration testing is recommended over colorimetric testing. Due to the use of inconsistent concentration gradations (*i.e., the difference in concentration between adjacent color blocks*) and the subsequent rapid darkening of the color blocks (*e.g., above 1.5 mg/L*), the accuracy of colorimetric test methods is likely to be lower than for titration test methods. Visual colorimetric methods are accurate only to +/- half the difference between the adjacent color blocks, and thus the confidence limits for these methods are wider at higher concentrations (*e.g., above 1.5 mg/L*). Where portable colorimeter test kits are affordable, these are the most accurate kits available for use at POOLSIDE. Most water tests involve color development. Interferences in the water can cause them to produce a different color, or produce the wrong color intensity, or be unable to produce the expected color. Color matching tests for CHLORINE/bromine provide accuracy equal to approximately half the difference between known values of the color STANDARDS. As the CHLORINE/bromine concentration rises, the greater the difference will be between the known color STANDARDS. Thus, the readings become subjective as the difference increases. The following MAHC Table 4.7.3.5 summarizes some common interferences and how they impact the test color in DISINFECTANT tests.

Table 4.7.3.5: Water Tests and Interference

<i>Test</i>	<i>Interference</i>			
	High Chlorine	Metals: Cu, Fe, Mn	High Calcium	Monopersulfate
Chlorine	At approximately 10 ppm, may cause partial or total bleaching of the DPD reagents, resulting in lower pink color intensity, or no pink color at all.	None	May cause the sample to turn cloudy white when adding DPD #1.	Will cause a false positive (more intense pink color) for combined chlorine at any level and for free chlorine at high levels (over 25 ppm).
pH	May create a different indicator, chlorphenol red, that is purple at pH 6.6 and higher.	None	None	None
Total Alkalinity	May cause the beginning color to be light blue and the end-point to be yellow, rather than the expected starting green color and red (pink) endpoint.	None	None	None
Calcium Hardness	None	Expected blue color never fully develops, and the endpoint approaches blue, but fades to a light purple.	None	None

High Chlorine Effects on Chlorine Testing:

If the water sample indicates high CHLORINE levels, usually over 10 ppm (*10 mg/L*), the DPD reagents may partially or totally bleach out, resulting in a false low or zero CHLORINE reading. The addition of double the quantity of DPD reagent during testing may minimize this interference or the analyst can use a smaller sample size or dilute the sample with distilled or deionized water (*DI*) water. Reference the WQTD's use instructions to guard against false readings and interferences.

High Chlorine Effects on pH Testing:

If the CHLORINE reading is high, the tester must wait until it is lowered to a normal level before retesting the pH, to assure an accurate reading. Some analysts neutralize the DISINFECTANT first by adding a drop of CHLORINE neutralizer (*i.e., sodium thiosulfate*). This is not recommended since the reaction between thiosulfate and CHLORINE can change the pH of the sample and give an inaccurate reading.

High Chlorine Effects on Total Alkalinity Testing:

High CHLORINE will affect the Total Alkalinity reading. Some reagents will bleach out and the color change will be from blue to yellow instead of the expected green to red/pink. Refer to the WQTD's instruction manual to prevent false readings and interferences.

Metals:

Be sure to identify the source of the metal in order to remove the problem for the AQUATIC FACILITY owner. Likely sources are copper from algacides or corroded pipes, or iron and manganese from the fill water.

Effect of Metals on Calcium Testing:

For the calcium test, copper, iron, and manganese dissolved in the water may prevent the expected blue color (*indicating the end of the test*) from fully developing. As the end of the test approaches blue, it fades to a light purple instead, which results from the metals in the water. Repeat the test, but before proceeding with the test instructions, add 5 or 6 drops of titrant. Remember to add the 5 or 6 drops to your final drop count when finished to determine the calcium concentration.

High Calcium Effects on Chlorine Testing:

When high calcium levels are in the water, the sample may turn cloudy with the addition of DPD #1 liquid reagent, which is alkaline. Addition of DPD #2 liquid reagent may not clear up the cloudiness. With high calcium water, adding DPD #2 prior to adding DPD #1 will acidify the sample, turning it slightly pink, and the cloudiness will not appear. Add DPD #1 to complete the test and obtain the proper pink color for the amount of CHLORINE in the water.

Potassium Monopersulfate Shock:

Potassium monopersulfate produces a false high combined CHLORINE reading whenever it is present in the water. Monopersulfate will also produce a false positive FREE RESIDUAL CHLORINE reading when the monopersulfate concentration is high (*over 25 ppm*). Monopersulfate interference can be removed by a variety of products found in the market place. Refer to the WQTD's instruction manual to prevent false readings and interferences.

4.7.3.6 Microbiological Testing Equipment

Microbiological testing equipment and methods should be EPA-REGISTERED, conforming Standard Methods for the Examination of Water and Wastewater, 23rd Edition, 2017,³⁰² existing professional guidelines, or other recognized international guidelines or STANDARDS. At this time, routine microbiological testing for POOLS, SPAS, and other AQUATIC VENUES is not recommended in the MAHC. Routine MONITORING of chemical levels (*e.g., pH, DISINFECTANT concentration*) and proper operation and maintenance of the AQUATIC VENUE have historically been considered to be sufficient to ensure that proper BARRIERS are maintained to minimize potential infectious disease risks from CHLORINE sensitive pathogens. Currently, routine MONITORING for CHLORINE-tolerant microorganisms (*e.g., Cryptosporidium spp.*) is not a feasible or cost-effective disease prevention approach. Chemical tests such as FREE RESIDUAL CHLORINE, pH, CT INACTIVATION VALUES, and others provide a good indication of operational control of an AQUATIC VENUE. However, while these tests provide an indication of DISINFECTION potential, they may not provide complete assurance of the microbial quality of AQUATIC VENUE water. While agencies such as the World Health Organization³⁰³, the South Australia Environmental and Public Health Service³⁰⁴, and the United Kingdom Health Protection Agency³⁰⁵ have established STANDARDS for routine MONITORING of public and semi-public AQUATIC VENUES for microbial parameters including enteric bacteria (*fecal organisms or E. coli*), *Pseudomonas aeruginosa*, and *Legionella*, there is insufficient scientific data for the purposes of the MAHC to indicate that these routine MONITORING STANDARDS provide an increased level of public health protection beyond adherence to current BEST PRACTICES. The routine MONITORING recommendations in the MAHC can be reconsidered to potentially include routine MONITORING for microbial parameters if compelling scientific data indicate that such testing provides additional, measurable public health protections beyond use of BEST PRACTICES for DISINFECTION in AQUATIC VENUE operation and maintenance. It should be noted that this section of the Annex is a minimum guideline for microbiological MONITORING. AQUATIC VENUE operators wishing to achieve additional microbial water quality characterization are encouraged to use the references in this Annex regarding water quality MONITORING techniques and STANDARDS established by the United States and in other countries. Microbial water quality STANDARDS established for AQUATIC VENUES by United States and international agencies include:

- **Alberta Public Health**, Alberta Regulation 293/2006 (2006) Swimming Pool, Wading Pool and Water Spray Park Regulation; Alberta, Canada
 - Excerpt, Page 10, Bacterial Limits: Heterotrophic Plate Count less than 100/mL; *Pseudomonas aeruginosa* 0/100 mL, coliforms 0/100 mL
- **Code de la Santé Publique, France**, (2007) Arrêté préfectoral en date du 15 juin 2007 fixant les upermens du contrôle sanitaire de la qualité des eaux des piscines (*Prefectural order dated June 15, 2007 establishing STANDARDS for the control of swimming POOL water quality*)
 - Excerpt: Determination of the parameters to be analyzed in the field or laboratory:

Standards for Bacteriological Analytical Parameters

- | | |
|---|-----------|
| • Viable aerobic bacteria at 37°C | <100/ml |
| • Total coliforms | <10/100ml |
| • Fecal coliforms (E. coli) | 0/100ml |
| • Pathogenic staphylococci | 0/100ml |
| • <i>Pseudomonas aeruginosa</i> (in SPAS) | 0/100ml |
- **New Jersey Department of Health and Senior Services** (2009) New Jersey State Sanitary Code, Chapter IX, Public Recreational Bathing N.J.A.C 8:26
 - Excerpt: pages 20 – 21; Heterotrophic plate count do not exceed 200 colonies per 1 milliliter sample; Coliforms to be less than one colony per 100 milliliter sample, *Pseudomonas aeruginosa* not to exceed one colony per 100 milliliter sample.

Although routine microbial testing is not recommended by the MAHC at this time, microbiological testing can be useful as supporting data for evaluating the need for (*or effectiveness of*) troubleshooting activities, remediation activities, and AQUATIC FACILITY upgrades. As indicated by WHO³⁰⁶ recommendations, microbiological testing of water samples from AQUATIC VENUES can be useful for the following reasons:

- Before an AQUATIC VENUE is used for the first time,
- Before it is put back into use after it has been shut down for repairs or cleaning,
- If there are difficulties with the treatment system, or
- As part of any investigation into possible adverse effects on BATHER or PATRON health.

It is known that certain microorganisms, because of their ecology and/or structure, can be tolerant of chemical DISINFECTANTS (*e.g., CHLORINE, bromine*). *Legionella pneumophila*, *Pseudomonas aeruginosa*, *Cryptosporidium parvum*, *Entamoeba histolytica* cysts, and *Mycobacterium avium* complex are a few examples of pathogenic microbes that have been reported to show some tolerance to chemical DISINFECTANTS. In addition, sessile (*in the biofilm*) microorganisms in biofilm are likely to receive additional protection from OXIDIZERS (*such as CHLORINE*) when the exposure concentration of these OXIDIZERS is reduced at the interface with the biofilm due to reaction with biofilm material. Biofilm is a complex community of microorganisms which attach to the sides, piping, and filters of AQUATIC VENUES³⁰⁷. Even at elevated concentrations, oxidizing and non-oxidizing chemicals have reduced effectiveness in controlling biofilm when their concentrations and contact times are not sufficient for penetrating the biofilm³⁰⁸. Biofilm formation in AQUATIC VENUES is also a concern because microorganisms in the biofilm or the biofilm itself can detach and multiply³⁰⁹. Following BEST PRACTICE guidelines for AQUATIC VENUE cleaning and continuous DISINFECTION is critical to avoid biofilm growth and expansion problems^{310,311}. If biofilm-related problems arise, it can be useful to incorporate biofilm sampling to develop a comprehensive evaluation of the risk factors for water quality impairment and potential solutions to identified problems³¹². MAHC Annex Table 4.7.3.6 (*below*) identifies microorganisms for which chlorination may have, or is known to have, reduced efficacy^{313,314,315}. MAHC Annex Table 4.7.3.6 also identifies methods that may be used to detect these microbes in AQUATIC VENUE systems, but the methods identified are not necessarily rapid. Additional research is needed to evaluate the benefits of microbiological testing data for AQUATIC VENUES, especially for improving public health protection. This is particularly important for the protozoans, amebas, and sessile bacterial pathogens that co-exist in biofilms. It should be noted that the use of fecal indicator organisms for AQUATIC VENUE water quality evaluation may not be sufficient for certain AQUATIC VENUE operation, maintenance, and public health investigations, especially in public health investigations related to inhalation, skin breaks, or ocular exposure routes. Since health risks in AQUATIC VENUES and similar environments may be fecal or non-fecal in origin, investigation of fecal indicators and non-fecally-transmitted microorganisms (*e.g. P. aeruginosa, S. aureus, and Legionella spp.*) may be warranted. It is not feasible or cost effective to test for all infectious organisms. Therefore MAHC Annex Table 4.7.3.6 identifies those organisms which have readily available test methods and/or cause illnesses that are common, very serious, or fatal. It is important to note that these test methods may not allow for rapid remediation, decision making, or public health intervention on a timely basis. The Heterotrophic Plate Counts (*HPC*) method has not been included in the list of microbial water quality tests in MAHC Annex Table 4.7.3.6. While HPC data are generally a good indicator of microbial water quality and efficacy of POOL operations (*e.g., water treatment*), this parameter has been reported to show no correlation to the presence of *Legionella*³¹⁶, planktonic pathogens³¹⁷, or the presence of biofilm³¹⁸. HPC tests (*as do all culture tests*) under-report the actual concentration of viable bacteria. Therefore, it is recommended that the use of this test be restricted for assessing the level of planktonic, non-pathogenic bacteria only. HPC data are not sufficient to assess the public health risk of POOLS, SPAS, and waterparks³¹⁹. Since the MAHC is intended to be a living document with changes anticipated as our knowledge increases, it is prudent to acknowledge that a paradigm shift is occurring in the world of microbiology that likely will impact how pathogen testing will be conducted and interpreted in the future. Culture tests are gradually being replaced with culture-independent test methods such as Polymerase Chain Reaction (*PCR*) testing and microarray testing. Years ago when PCR was first used commercially, the cost of the tests was prohibitively expensive. Now test costs have decreased and are competitive with culture dependent tests. A recent development is the commercialization of microarray testing which can screen for the presence of a wide variety of bacterial and viral pathogens without the need for an isolation step. However, the costs associated with microarray testing are prohibitively expensive as of this MAHC publication. In addition to the use of STANDARD culture-based fecal indicator bacteria (FIB) tests in recreational water testing (*i.e., total and fecal coliforms, E. coli and Enterococcus*), EPA provides recommended criteria values for states that want to use a quantitative polymerase chain reaction (qPCR) method for *Bacteroides* and *Enterococcus* testing as a possible replacement for these culture tests. In addition, EPA has developed a qPCR

method for *E. coli* which is being tested at Great Lakes Beaches. Two of the most compelling reasons for why some states would consider the use of the qPCR method are::

- Incubation times for culture tests prevent quick decision-making to minimize public exposure to water with a potentially elevated disease risk, and
- Molecular tests are generally considered to have higher specificity (*lower false positive rates*) than traditional culture tests.

Table 4.7.3.6: Known Pathogenic Organisms of Concern in Chlorinated Aquatic Venues (continued on next page)

<i>Organism</i>	<i>Illness</i>	<i>Route of Infection</i>	<i>Resistant To Chlorine</i>	<i>Environmental Biofilm Amplification</i>	<i>Test Method</i>
<i>Pseudomonas aeruginosa</i> ¹	<ul style="list-style-type: none"> • Hot Tub Folliculitis • Conjunctivitis • Pneumonia • Swimmer's Ear 	<ul style="list-style-type: none"> • Skin • Eyes • Inhalation • Ears 	<ul style="list-style-type: none"> • Yes when planktonic^{320,321} • Yes when sessile in biofilms 	Yes	<ul style="list-style-type: none"> • APHA Standard Method 9213 E-F • APHA Standard Method Rapid PCR test available
Enteric Bacteria	<ul style="list-style-type: none"> • Gastroenteritis • Hip and Knee joint replacement infections, replacement heart valve infections • Conjunctivitis • Pneumonia 	<ul style="list-style-type: none"> • Fecal/Oral • Skin breaks • Eyes • Inhalation 	<ul style="list-style-type: none"> • No when planktonic • Yes when sessile in biofilm 	Yes	<ul style="list-style-type: none"> • APHA Standard Method for Coliforms 9221 A-F • APHA Standard Method 9260 A-L for specific pathogens • APHA pathogen specific PCR test • Bacteroides/Enterococci PCR tests under investigation by EPA to replace Coliforms
<i>Legionella</i>	<ul style="list-style-type: none"> • Legionnaires' Disease, Pontiac Fever • Hip and Knee joint replacement infections, replacement heart valve infections 	<ul style="list-style-type: none"> • Inhalation • Skin breaks 	<ul style="list-style-type: none"> • Yes when planktonic^{322,323} • Yes when sessile in biofilm 	Yes	<ul style="list-style-type: none"> • APHA Standard Method 9260 J • CDC/ISO Method is Gold Standard • APHA Standard Method • Rapid PCR test
<i>Mycobacterium avium complex (MAC)</i>	<ul style="list-style-type: none"> • Hypersensitivity pneumonitis • Dermatitis 	<ul style="list-style-type: none"> • Inhalation • Skin Breaks 	<ul style="list-style-type: none"> • Yes when planktonic • Yes when sessile in biofilm 	Yes	<ul style="list-style-type: none"> • APHA Standard Method 9260 M • Rapid PCR
<i>Staphylococcus aureus</i> & Methicillin resistant <i>Staphylococcus aureus</i> (MRSA)	<ul style="list-style-type: none"> • Conjunctivitis • Antibiotic resistant skin infection possibly fatal 	<ul style="list-style-type: none"> • Eyes • Skin Breaks 	<ul style="list-style-type: none"> • No when planktonic • Yes when sessile in biofilm 	Yes	<ul style="list-style-type: none"> • APHA Standard Method 9213 B 6 and 7 • Rapid PCR test
<i>Naegleria fowleri</i>	<ul style="list-style-type: none"> • Primary amoebic meningoencephalitis (<i>uncommon but high mortality rate</i>) 	<ul style="list-style-type: none"> • Water accidentally inhaled in nose or pharynx 	<ul style="list-style-type: none"> • Yes when planktonic 	Yes	<ul style="list-style-type: none"> • APHA Standard • Method PCR test
<i>Acanthamoeba</i>	<ul style="list-style-type: none"> • Conjunctivitis and Keratoconjunctivitis (<i>may cause blindness particularly in contact lens wearers</i>) 	<ul style="list-style-type: none"> • Eye, skin, mucous membranes 	<ul style="list-style-type: none"> • Yes when sessile in biofilm 	Yes	<ul style="list-style-type: none"> • APHA Standard Method 9711 C

<i>Organism</i>	<i>Illness</i>	<i>Route of Infection</i>	<i>Resistant To Chlorine</i>	<i>Environmental Biofilm Amplification</i>	<i>Test Method</i>
<i>Cryptosporidium and Giardia</i>	<ul style="list-style-type: none"> • Gastroenteritis • Biliary Tract Infections • Reactive Arthritis 	<ul style="list-style-type: none"> • Fecal/Oral • Inhalation • Inhalation 	<ul style="list-style-type: none"> • (Oo)cysts are resistant in planktonic and sessile forms 	Yes	<ul style="list-style-type: none"> • Standard Method 9711 B • APHA PCR test
Adenoviruses	<ul style="list-style-type: none"> • Conjunctivitis • Gastroenteritis 	<ul style="list-style-type: none"> • Eyes • Fecal/Oral 	<ul style="list-style-type: none"> • No 	Unknown	<ul style="list-style-type: none"> • Cell culture • PCR
Enteroviruses	<ul style="list-style-type: none"> • Gastroenteritis • Viral meningitis 	<ul style="list-style-type: none"> • Fecal/Oral 	<ul style="list-style-type: none"> • No 	Unknown	<ul style="list-style-type: none"> • APHA Standard Method 9510 • EPA Method 1615
Noroviruses	<ul style="list-style-type: none"> • Gastrointestinal 	<ul style="list-style-type: none"> • Fecal/Oral 	<ul style="list-style-type: none"> • No 	Unknown	<ul style="list-style-type: none"> • EPA Method 1615 • RT-PCR Methods
Helminths and Roundworms	<ul style="list-style-type: none"> • Ascariasis • Baylisascariasis 	<ul style="list-style-type: none"> • Fecal/Oral 	<ul style="list-style-type: none"> • Cysts are resistant in planktonic and sessile forms 	Yes	<ul style="list-style-type: none"> • APHA Standard Method 10750 • PCR tests available for species identification
Fungi	<ul style="list-style-type: none"> • Ringworm 	<ul style="list-style-type: none"> • Skin 	<ul style="list-style-type: none"> • Spores are resistant 	Yes	<ul style="list-style-type: none"> • Culture and PCR tests

Table 4.7.3.6 Notes:

1. **NOTE**

- a. Many elderly and/or immuno- compromised people use SPAS making them more susceptible to disease;
- b. *P. aeruginosa* can be tolerant of CHLORINE and is found in biofilm;
- c. Hot tub folliculitis is the most common illness associated with hot tubs; and
- d. Coliform testing is not an indication of *P. aeruginosa* contamination;
- e. Since this is a non-reportable disease, we have no information on the incidence of disease.

PCR can be a good method for investigating whether pathogenic microbes were present in AQUATIC VENUES (*e.g., sampling filter backwash*) since the technique detects the DNA of pathogens regardless of whether they are live, dead, or viable-but-not-culturable. Another benefit is that PCR culture tests can be completed in hours versus days. However, while PCR can be effective for determining whether pathogens have been present in an AQUATIC VENUE, the technique is less effective as a measure of DISINFECTION effectiveness since it detects DNA from both viable and non-viable organisms. New techniques, such as the use of propidium monoazide (*PMA*) have been reported to enable PCR to characterize the viability status of microorganisms, so in the future PCR may be an effective option for DISINFECTION studies³²⁴.

4.7.4 Water Replenishment System

A WATER REPLENISHMENT SYSTEM allows for POOL water to be removed from the POOL and properly disposed of so that it can be replaced with fresh water containing lower concentrations of dissolved CONTAMINANTS. A WATER REPLENISHMENT SYSTEM should be used to control the dissolved organic CONTAMINANT concentrations (*e.g., sweat, oils, chlorination by-products, and urine*) and dissolved inorganics (*e.g., salts and metals*) because POOL filtration systems are not effective at removing dissolved CONTAMINANTS.

4.7.4.1 Discharge and Measure

A means of intentionally discharging and measuring or calculating the volume of discharged POOL water (*in addition to the filter backwashing system*) should be provided and designed to discharge a volume of water of up to 4 gallons (*15 L*) per BATHER per day per facility through an air gap. Knowing pump GPM and knowing how much time one is backwashing can be used to calculate the volume discharged. Water replacement or replenishment at a rate of 8 gallons (*30 L*) per BATHER per day per AQUATIC VENUE^{325,326,327} have been widely used. PWTAG³²⁸ states that as much as half of the recommended amount could be associated with filter backwashing. There does not appear to be any research to support the use of the 30 L/day/BATHER number used abroad. So, since 4 gal/day/BATHER is roughly half of this amount (*and typically met by filter backwashing alone*), it seems like a reasonable place to start incorporating this practice into operations. A requirement could be made once the science is there to support a higher or lower value. With a WATER REPLENISHMENT SYSTEM in place, AQUATIC FACILITY operators will be able to experiment with higher WATER REPLENISHMENT rates to obtain improved water (*and indoor air*) quality. It should also be easy to comply with any future regulations related to WATER REPLENISHMENT as only the flow rate would require adjustment. WATER REPLENISHMENT for a large AQUATIC FACILITY would be based on the number of BATHERS in the entire AQUATIC FACILITY (*not the total number swimming in a particular AQUATIC VENUE on a given day since most BATHERS are expected to distribute the BATHER COUNT over a range of AQUATIC VENUES and/or rides on a given day*). However, WATER REPLENISHMENT should be proportional to the number of BATHERS in each individual treatment system. It would not be allowable to send to waste all of the water from the WAVE POOL and none from the other attractions (*unless the water was shared through a combined AQUATIC VENUE treatment system*).

4.7.4.1.1 Alternate Systems

The CODE allows for use of alternate systems to meet the intent for removal of turbidity, organic carbon, and nitrogen-based compounds. Discharging POOL water serves to remove compounds of public health interest (*e.g., chloramines, particles/pathogens, TDS, UVT, and organic compounds attached to particles*). While most alternate systems that remove dissolved organic compounds (*e.g., nanofiltration and reverse osmosis*) also remove particles, there are a number of treatment systems (*e.g., granular activated carbon or ion exchange*) that would target organics without removing particles, pathogens, TDS, or chloramines.

4.7.5 Spas

4.7.5.1 General

Portable SPAS are not excluded from use in public settings. However, the design, operation, and maintenance of portable SPAS must conform to this CODE.

4.8 Decks and Equipment

4.8.1 Decks

4.8.1.1 General Standards for All Decks

4.8.1.1.2 Lifeguard Placement and Safety Considerations

See MAHC 4.6.5.1 and 6.3.3.1.1 for operational considerations in design.

4.8.1.1.2.1 Deck Clearance

Four feet (*1.2 m*) of clearance would allow for safe movement of a roaming QUALIFIED LIFEGUARD or for extrication in case of an emergency. This is consistent with the design guidance of the MAHC.

4.8.1.1.2.2 Access Points

In locations where PERIMETER DECK is non-contiguous and the clearance is not at least 4 feet (*1.2 m*), such as where fencing is provided around elevated POOL edges and LAZY RIVERS, locations for lifeguards to safely access the POOL edge should be required. This facilitates a safe entry rather than climbing over any fence or other obstruction.

4.8.1.1.2.3 Bather Zone Surveillance

Designers have historically added AQUATIC FEATURES that are not readily visible on a site plan nor are their effects self-evident until installed during construction. This could result in additional lifeguards to facilitate zone coverage or create small blind spots. For this reason, this line item was added for the designer to consider.

4.8.1.1.6 Concrete Decking

See ACI 302.1R-15, Guide for Concrete Floor and Slab Construction.

4.8.1.2 Standards for Perimeter Decks

The term “PERIMETER DECK” refers to the area around and immediately adjacent to the POOL. This area is the wettest area of the DECK and extends out from the edge of the POOL a maximum of 4 feet (*1.2 m*) or out to DECK drains, whichever is farther. Finish materials for the PERIMETER DECK must be suitable for the POOL environment, non-toxic, and substantially impervious. See MAHC 4.8.1.4.

4.8.1.3 Drains

4.8.1.3.1 Slope

Table 4.8.1.3 Minimum Slopes for Drainage

Surface	Minimum Slope
Smooth finishes; such as tile, hand-finished concrete & lightly-broomed concrete	$\frac{1}{8}$ inch per foot (3.2 mm/30.5 cm)
Moderately textured finishes; such as exposed aggregate or medium-broomed concrete	$\frac{1}{4}$ inch per foot (6.4 mm/30.5 cm)
Heavily textured finishes; such as brick (where permitted)	$\frac{3}{8}$ inch per foot (9.5 mm/30.5 cm)

MAHC Table 4.8.1.3 was created after reviewing and refining information from existing state CODES and established STANDARDS. Fundamentally, these sources all seek to eliminate standing water from the DECK, typically recognizing that smoother surfaces convey water more efficiently than rougher ones. Relating slopes to texture, rather than specific materials, provides the ability for any otherwise suitable DECK material or finish to be considered by the adopting jurisdiction. There is an inherent conflict in sloping of DECKS. Steeper slopes provide more construction tolerance and surety in conveying water, particularly in active soil conditions. Shallow slopes are required to meet accessibility guidelines – particularly for cross-slopes. It is the intent of this section to encourage positive and proper drainage without running afoul of accessibility guidelines.

4.8.1.3.3 Cross-Connection Control

Consult local AHJ regarding specific chemical handling and use to properly dispose, including discharge to the watershed or sanitary sewers where appropriate.

4.8.1.3.3.2 No Drain

This requirement prevents sewage from backing up into the AQUATIC VENUE water. This isolates the treated system and does not allow mixing of other sources of water that could contaminate.

4.8.1.4 Materials / Slip Resistance

4.8.1.4.2 Slip Resistance

Industry STANDARDS have changed to reflect a more accurate method for determining slip resistance which has been adopted by the Tile Council of North America (TCNA). Historically, “slip resistance” has been defined as having a minimum coefficient of friction of 0.6 for all wet surfaces and 0.8 for ramped surfaces. This static coefficient of friction is often linked to ADAAG. However, ADAAG did not set a requirement but rather referenced accessibility guidelines in the appendix that recommended (*not required*) a value of 0.6, but failed to specify a means of measurement. The recommended 0.6 value is all but meaningless without a testing method. The test method previously called for in the industry was ASTM C1028 in ANSI A137.1. The C1028 method was affected by a phenomenon called “stiction” when measuring two very smooth surfaces. This led to false expectations of slip resistance when the rubber sensor used to test for SCOF was in the presence of moisture. In Section 9.6 of ANSI A137.1, the dynamic coefficient of friction, or DCOF, is now measured. The DCOF is essentially the resistance or force that must be overcome to keep one object, already in motion, moving over another object. The test is called the DCOF AcuTest and the aforementioned “stiction” effect is eliminated. The DCOF AcuTest is also more repeatable than the 1028 method. The TCNA tested over 300 surfaces and found that on average a 0.60 SCOF correlated to a DCOF of 0.38. There have also been a number of studies done in Germany determining that the COF for reliable traction is 0.2 to 0.3, depending on the individual. When factoring in different “slippery” conditions and how different people can move on the surface, it has been determined that a minimum DCOF of 0.42 is appropriate and is now included in ANSI 137.1 for level INTERIOR SPACES expected to be walked upon when wet.

4.8.1.4.3 Carpet

Carpet and artificial turf have been found to be inappropriate finish materials for the wettest area immediately around the POOL, i.e. PERIMETER DECK. Although the materials that carpet is manufactured from are durable and do not support mold growth, when they are installed over a relatively impermeable surface, water flows very slowly through the carpet. Soil and CONTAMINANTS entering into the carpet are not easily removed. Since the carpet stays wet longer, soil and CONTAMINANTS remain in the carpet, and mold and algae growth can occur. Therefore carpeting is not an acceptable finish material in the wet PERIMETER DECK. Finish materials for the PERIMETER DECK should not block DECK drains or impair water flowing to DECK drains. Carpeting may be installed beyond the DECK drains, i.e. DRY DECK.

4.8.1.4.4 Wood

Properly treated or composite wood materials may be a suitable material for DRY DECKS provided all other DECKING requirements are maintained. Fasteners must be regularly inspected to ensure structural integrity and that all heads are flush or recessed into the DECK surface.

4.8.1.4.5 Dry Deck

Regional materials, local practices, and particular facility design intentions vary widely with respect to DRY DECK. This section intends to provide the opportunity for regulatory oversight of DRY DECK, without limiting these variables best understood by AHJ.

4.8.1.4.6 Landscaping

It is acknowledged that landscaping near AQUATIC VENUES is not an uncommon practice in enhancing an AQUATIC VENUE environment. Landscape materials themselves and the design of special AQUATIC VENUES vary so widely as to require special consideration with respect to landscaping. This section intends to provide the opportunity to allow landscaping, but only through the lens of the AHJ. The landscaping materials are not intended to be placed in the wet PERIMETER DECK area. It is assumed here that the POOL DECK will be designed and sloped to prevent drainage from landscaping materials from reaching the POOL. For an outdoor AQUATIC VENUE, it is not possible to prevent wind from moving dirt, bugs, plant material, etc. around and perhaps into the AQUATIC VENUE. The landscape designer must consider the type and location of landscape materials placed inside or outside of an outdoor AQUATIC VENUE ENCLOSURE.

Textured Surface

The walking surface should not be rough so as to cause injury or discomfort to BATHERS. ANSI defines where a trip hazard is considered as a level change that is greater than ¼ inch (6.4 mm). Other definitions include an abrupt or unexpected level change in surfaces.

4.8.1.5 Deck Size/Width

Traditional AQUATIC VENUES should be surrounded by clear DECK space to allow for operational flow (*foot traffic*) as well as space to perform in the event of an emergency situation. Non-traditional AQUATIC VENUES such as LAZY RIVERS, WAVE POOLS, etc. are not required to have clear space around due to the need to control access by providing a BARRIER to block access into unapproved entry areas. Both guarded and unguarded AQUATIC VENUES should have the same clear space requirements.

4.8.1.5.1 Perimeter Deck

4.8.1.5.1.1 Width

The 4 foot (*1.2 m*) unobstructed DECK area is intended to ensure a minimum clear area for emergency access and care around the POOL. Examples of obstructions include but are not limited to INFINITY EDGES, ADAAG transfer walls, and curbs.

4.8.1.5.1.2 Perimeter Decking

Most POOLS require continuous DECKS in order to safely accommodate circulation of all BATHERS in the AQUATIC VENUE.

4.8.1.5.1.3 Unguarded Aquatic Venues

Unguarded AQUATIC VENUES require special consideration for DECK access.

- Option 1 assures the entire perimeter is available for assistance.
- Option 2 allows for incorporation of leisure amenities and AQUATIC VENUE features such as “INFINITY EDGES” and landscaping, while maintaining assurance that the entire AQUATIC VENUE can be reached with STANDARD SAFETY equipment.

Individual requests for variance could accommodate different designs.

4.8.1.6 Wing Walls or Peninsulas

4.8.1.6.1 No Perimeter Deck

A WING WALL or PENINSULA is intended to provide separation of different areas in a POOL. The separated areas may have differing uses, flow rates, currents, or water depths.

4.8.1.6.2 Perimeter Overflow System

The MAHC Committee defines WING WALLS as interior elements of the POOL and interior to the POS, so the MAHC did not feel it was appropriate to say that WING WALLS longer than some specified length should require POSS. It would be a function of the width of the WING WALL as to whether or not it can be properly constructed. If the POOL has a gutter system, it would probably need 4 feet (*1.2 m*) of width to get a normal trough on either side. SKIMMERS could be achieved for narrower walls because they could be staggered.

4.8.1.6.3 Pool Perimeter

WING WALLS do not contribute to the overall POOL perimeter so should not be included in AQUATIC VENUE perimeter calculations that are used as part of multiple critical design calculations.

4.8.1.6.5 Deck Drainage

The MAHC did not feel that DECK drains should be required on WING WALLS since they are considered part of the POOL and not subject to regular foot traffic. As for DECK level POOLS, the WING WALLS would be at or below water level making drains impractical.

4.8.1.7 Islands

A 7 foot (*2.1 m*) minimum clearance overhead is required since it is consistent with requirements of building CODE minimum ceiling clearances.

4.8.1.8 Heated Decks

Heated DECKS are occasionally used in cold climates to provide pedestrian paths to and around outdoor heated AQUATIC VENUES. This section provides that when heated DECKS or snow-melt systems are provided, a minimum slope must be uniformly provided. Clear delineation is required because icy areas and/or pathway edges near otherwise DRY DECK poses an unsafe condition.

4.8.2 Diving Boards and Platforms

4.8.2.1 Diving Envelope

When diving boards or diving platforms are installed, it is important for the SAFETY of the diver to have a diving envelope that minimizes the possibility of a diver striking any surface of the POOL structure (walls, bottom, upslope). The diving envelope requirements consist of a set of minimum water depths and dimensions that a POOL is designed and constructed to which has been determined to be acceptable for the specified height of the diving board above the water surface. All minimum dimensions are established based on the diving board or diving platform plummet point. The plummet is a plumb and vertical line passing through the end of a diving board or diving platform at its centerline. Minimum dimensions set the distance and water depth from the plummet back to the POOL end wall, the water depth and overhead clearance at the plummet, the distance and depths from the plummet to walls or slopes at the side, the distance and depths ahead of the plummet before the POOL bottom may slope up, the maximum slope up, and distances ahead to the closest POOL wall. Diving from diving boards and diving platforms is divided into two categories;

- Competitive Diving utilizes springboard heights of 1 meter and 3 meters above the water surface and diving platform heights of 5 meter, 7.5 meter, and 10 meter, with 10 meter being the most common. Competitive divers range from school-age through adults, with various sanctioning bodies setting the rules for the competition.
- Non-Competitive or Recreational Diving can utilize any diving board or diving platform height, but jumpboard or springboard heights 1 meter or less above the water surface are typically used, with $\frac{1}{2}$ meter and $\frac{3}{4}$ meter boards the most common. Recreational boards less than 1 meter above the water surface are shorter in length and less flexible than 1 meter springboards. Although non-competitive boards could be between 1 meter and 3 meters in height, since manufacturers only make 1 meter and 3 meter boards, boards between these heights are not common.

Note concerning diving from a pool DECK: Because of the danger of catastrophic spinal cord injury due to the lack of a safe diving envelope, no head first dive should ever be attempted from a POOL DECK where the water is less than 5 feet deep. See MAHC 4.5.19.4 No Diving Markers and MAHC Annex 4.5.19.4.1 discussion. This CODE is designed to encourage POOLS to be built to the STANDARDS of the agency that will certify the diving at the AQUATIC FACILITY. The CODE dimensions are purposely a compilation of the most conservative STANDARDS of diving envelope dimensions and are in no way intended to supersede the certifying agencies dimensions, but instead are intended to be used only when there is no certifying agency for the AQUATIC FACILITY. Since NCAA, USA Diving, and FINA do not have STANDARDS for diving boards less than 1 meter in height, the State of Michigan table (Public Swimming Pools R 325.2133 Diving areas and facilities; “plummet” defined, Table 1), shown below as MAHC Table 4.8.2.2, was revised to the most conservative STANDARD found for 0.5-meter and 0.75-meter diving boards. These minimum dimensional requirements were then dictated to be more conservative in certain instances based largely on interpolations. Concerning use of diving boards higher than 1-meter, these diving boards are not recommended for non-competitive use. However, if the diving boards are constructed to this CODE or NCAA STANDARDS, then non-competitive use can be allowed under careful adult supervision or with QUALIFIED LIFEGUARDS on duty. However, non-conformance with these STANDARDS is unsafe for recreational diving purposes.

4.8.2.1.1 Competitive Diving

The diving envelope STANDARDS for various competitive diving board and platform heights is well established by certifying agencies such as NCAA, FINA, and USA Diving. When POOLS are designed to these competitive diving envelope, STANDARDS, POOL bottom contact injuries are very rare however, injuries due to contact with the board or platform do happen.

4.8.2.1.2 Non-competitive Diving

Aquatic venues with non-competitive or recreational diving from boards or platforms, typically have boards that are less than 1 meter, such as $\frac{1}{2}$ meter or $\frac{3}{4}$ meter installed. There may also be boards greater than 1 meter installed. Since the certifying agencies only certify 1 meter and 3 meter boards for competition only, the diving envelope STANDARDS in MAHC tables 4.8.2.2 and 4.8.2.3 and MAHC Figures 4.8.2.2.1 and 4.8.2.2.2 must be used with non-competitive height boards.

4.8.2.2 Steps and Guardrails

Diving boards and diving platforms are accessed from the POOL DECK by ladders and stairways. Just as providing a safe diving envelope protects the diver once they have left the board, it is essential that a diver can safely access the diving board elevation above the POOL DECK. There have been significant injuries and numerous deaths associated with falls from the ladder to, or from 3 meter boards onto concrete deck below. Guardrails and/or protective barriers that are properly designed and provided on each side of a diving board, prevent a person from falling off a board and landing on the POOL DECK. In addition, the guard rail/ handrail design must address the ability of the diver to grip and maintain a sufficient grip to prevent a fall from the ladder. Studies regarding handhold designs and the impact on breakaway strength (the maximum force that can be exerted on an object before it is pulled or slips from the grasp of the hand) for children and adults have been conducted and indicate that the diameter of the handhold and vertical orientation significantly impact the breakaway strength.^{329,330} Using a stairway instead of a ladder is an alternate way to provide for safe access. Change Requests (CRs) were submitted for the 2015 and 2017 MAHC update cycle to require use of stairs instead of ladders to access diving boards or platforms greater than 1 meter in height when used for recreation. The CRs did not pass primarily due to the concern over availability of manufacturers of diving board stairs, associated cost of stairs, and the impact on aquatic venue space design due to the larger footprint. Although the CRs did not pass, the supporting information regarding injuries and handrail design to accommodate sufficient grip for SAFETY, is relevant and included in this Annex discussion and for consideration for future CRs for improvement of SAFETY when accessing diving boards/platforms. Supporting documentation submitted includes the Public Playground Safety Handbook, Consumer Product Safety Commission, December 29, 2015; Standards Australia AS 1657-2013 Fixed platforms, walkways, stairways and ladders – Design, construction and installation; and several research publications detailing the abilities of children to grasp handholds of various diameters, orientations, and friction.^{331,332,333,334,335}

4.8.3 Starting Platforms

4.8.3.1 Conform to Standard Codes

The intent is to require a minimum 4 foot (1.2 m) water depth under the starting platform and the oversight of an aquatics governing body (e.g. FINA, USA Swimming, NCAA, NFHS, YMCA, etc.) or a coach or instructor. FINA, USA Swimming, NFHS, and the NCAA allow 4 feet (1.2 m) at starting platforms. Although there are some national data on SCIs in general, data on diving-specific SCIs are limited, particularly for SCIs involving public POOL-related competition diving.

General Data on Spinal Cord Injuries and Other Diving Injuries: For SCIs in general, approximately 40 SCIs/million population occur each year in the US (about 12,400 injuries for 2010) with approximately 4.5% related to diving injuries.³³⁶ SCIs are a catastrophic public health problem leading to disability and decreased life expectancy³³⁷ with a large economic and social burden for those who suffer the injury^{338,339}. In a study of U.S. emergency department (ED) data from 2006-2014, an estimated 83,000 ED visits for injuries occurred as a result of diving into swimming POOLS. The majority were male and significantly more patients were in the 15-24 age category. Spinal cord injuries were more common in those over age 25, whereas intracranial injuries occurred more frequently in younger patients. The total charges for the six-year period approached \$620 million.³⁴⁰

Non-DECK Level Diving, Competition Diving, and SCIs: Data related to SCIs occurring as a result of competition diving off starting platforms are limited. Since starting platforms are several feet above the POOL, the entering velocity of swimmers is greater than for DECK level diving making it more difficult to alter trajectory once executed³⁴¹. One large study investigated 74 SCIs in non-competitive divers occurring with use of springboards and/or jumpboards; 45% of the POOLS were public³⁴². Of these injuries, 12.2% occurred in water less than 4 feet (1.2 m); 66.2% occurred in water less than 5 feet (1.5 m); 94.6% occurred in water less than 6 feet (1.8 m). All SCIs occurred in water of less than 7 feet (2.1 m). The MAHC requires that starting blocks be removed, if possible, or blocked off to prevent recreational divers from using them when not in use by competitive swimmers. Data demonstrates that competitive swimmers can be trained to perform shallow water dives from starting blocks to reduce the risk of SCIs^{343,344,345}. As a result, competitive aquatics governing bodies (e.g., FINA, U.S.A. Swimming, NCAA, NFHS, YMCA) allow starting blocks to be placed over water as shallow as 4 feet (1.2 m) in depth as long as competition is conducted under the auspices of the governing body or by a coach or instructor. A progressive training regimen can be used so that diver training is conducted in deeper water until the diver has mastered the technique before the certified personnel approve their starting block entries into shallower depths³⁴⁶. However, further data are needed on the adequacy of an intervention, like training, that relies on correctly performing a technique to prevent injury; aquatics governing bodies state they have not documented injuries since

this progressive training regimen has been adopted. However, it is noted that high speed video of competing athletes during competition dives from starting platforms illustrates the following:

- About 3% of athletes diving into 4 feet (1.2 m) of water³⁴⁷ (*the POOL had the minimum depth recommended for athletes using starting blocks*) touched the bottom;
- Nearly half approach within 0.5 meters (1.6 ft) of the bottom;
- Over half exceeded head speed thresholds deemed possible to cause severe head trauma; and
- There was some anecdotal information suggesting some divers touched intentionally.

Conversely, filming of athletes diving into 7.5 feet (2.3 m) of water (*the POOL studies exceeded Olympic competition depths of 6.5 feet (2.0 m) below starting platforms*) showed that very few swimmers approach to within even 1 meter (3.3 ft.) of the POOL bottom³⁴⁸. These data suggest that injury risk from using starting platforms is likely to be higher for older, presumably heavier, or inexperienced divers, particularly when diving into shallower depths.

Future Directions and Research

The MAHC recommends that these national data be re-analyzed with aquatics in mind to gather more detailed information on SCIs and other injuries related to diving in treated AQUATIC VENUES, particularly public AQUATIC VENUES to further inform this discussion. Future analysis of national data should be undertaken, if possible, to assess the occurrence of SCIs in competitive swimmers and platform heights and water depths at which the injury occurred. Analysis of data in peer-reviewed publications or reports collected by aquatics governing groups on SCIs and other diving injuries would also be important to understand POOL-specific diving injuries occurring in competitive swimmers and the efficacy of current progressive training or other interventions.

4.8.4 Pool Slides [N/A]

4.8.5 Lifeguard- and Safety-Related Equipment

4.8.5.2 Safety Equipment Required at all Aquatic Facilities

4.8.5.2.1 Emergency Communication Equipment

A communication device is required in the Operations (*MAHC 5.0*) section of the MAHC, but it also needs to be considered in the design so the designer can plan for the wiring for such devices. Consider larger facilities or other types of facilities who may have a phone in the nearby building. Consider a telephone labeled with location of phone/address. Some facilities may be so equipped to properly respond to an event and phones may not be required. Large AQUATIC FACILITIES with lifeguard/trained response may not need phones installed everywhere. The intent is for BATHERS to have access to a phone to call for help when help is not necessarily part of the AQUATIC FACILITY operation. QUALIFIED LIFEGUARDS or other emergency response staff are to be trained and may have communication devices such as whistles or radios which initiate their emergency response which includes the ability to contact outside emergency personnel when necessary. Often AQUATIC VENUES can be at a distance from support personnel and the designer should consider methods for personnel to communicate whether via radio, telephone, intercom, or other method. For alternate communication systems or devices, the intent is that an emergency phone or communications system or device is immediately available to PATRONS from all AQUATIC VENUES within an AQUATIC FACILITY. Some alternate communication systems might include a handset or intercom system to a location that is constantly manned whenever the AQUATIC VENUE is open for use (*e.g. a front desk at a hotel, the check in desk at a fitness club, or other continuously manned location*); a commercial emergency contact device that connects to a MONITORING service, or directly to 911 dispatch; or devices that alert multiple staff on site when activated (*e.g. pagers systems, cellular telephone systems and radio communication alert systems*). Also see MAHC 5.8.5.2.1 for additional requirements.

4.8.5.3 Safety Equipment Required at Facilities with Lifeguards

4.8.5.3.1 Lifeguard Chair and Stand Placement

This section refers to only those chairs that are permanently installed and does not indicate that a permanent chair or stand is required. The location of the chairs must give the QUALIFIED LIFEGUARD complete visibility of all parts of the zone of PATRON surveillance. The number of chairs is determined by the ability to provide surveillance of the AQUATIC VENUE by creating zones of PATRON surveillance. It is intended that the designer should be working with an aquatic consultant or the owner/operator to make sure the location of chairs and stands allows for clear line of sight.

4.8.5.3.2 Lifeguard Chair and Stand Design

Chairs and stands are exposed to elements; therefore, they should be made to withstand the environment. The intent for such a chair is to facilitate better surveillance and such the chair should be elevated sufficiently above the heads of BATHERS to have a better view and combat glare. Considerations for the SAFETY of QUALIFIED LIFEGUARDS using these chairs should include access and egress as well as BARRIERS to unauthorized access if installed at an elevation.

4.8.5.3.3 UV Protection for Chairs and Stands

Protection from UV radiation exposure can include a shade attached to the stand, a shade structure external to the stand, or other types of shade such as surrounding features. The designer should consider which method will be employed to provide UV protection for the stand.

4.8.6 Barriers and Enclosures

4.8.6.2 Construction Requirements

4.8.6.2.1 Discourage Climbing

Many POOL CODES refer to a 4 inch (10.2 cm) sphere in the body of the CODE. From a building CODE perspective, this is not consistently enforced and these CODES don't regulate that small of an opening. Building CODES allow STANDARD 2 ¼ inch (5.7 cm) mesh fencing and is not necessarily specific for AQUATIC VENUES. Building CODES typically dictate minimum height and proximity to property lines - unless it's a fall issue. With AQUATIC FACILITIES, we are mainly concerned with discouraging unauthorized entry / break-ins.

4.8.6.2.2 Emergency Exit Paths

It is the intent of this section to prevent emergency egress routes from exposing building occupants to unguarded AQUATIC VENUE areas. It is not the intent of this section to permanently segregate multiple AQUATIC VENUES on the same site. Temporary or seasonal ENCLOSURES (*properly maintained and employed*) may be used to segregate paths of egress from a building or adjacent AQUATIC VENUE to SAFETY. For example, where a seasonal outdoor AQUATIC VENUE is operated in conjunction with a year-round indoor AQUATIC VENUE, a seasonal exit pathway separation ENCLOSURE may be used to maintain exiting in the off-season. During the outdoor swim season (*when the outdoor AQUATIC VENUE is in operation*), it is acceptable to egress via the AQUATIC VENUE DECK to EXIT GATES.

4.8.6.2.4 Height

The MAHC discussed this issue at length. The prevailing "BEST PRACTICE" in the industry is for 4 foot (1.2 m) high fencing around unguarded AQUATIC FACILITIES. However, the MAHC decided to make the BARRIER height the same for all AQUATIC FACILITIES (6 feet or 1.8 meters) since 4 foot fences are scalable even with smaller mesh. Generally, even unguarded AQUATIC FACILITIES have some hours of use and these POOLS also need to discourage use outside of operational hours by youth and others. The MAHC's collective logic was that if an AQUATIC FACILITY is designed for unsupervised use at all times then there is no real advantage to a fence higher than 6 foot (*i.e., 8 foot or taller*).

4.8.6.2.4.3 Other Barriers Not Serving as Part of an Enclosure

The 42 inch (1.1 m) BARRIER height is consistent with STANDARD building CODE requirements for a guardrail, which serves substantially similar purposes. This height provides for consistency across CODES for like appurtenances.

4.8.6.3 Gates and Doors

This section is intended to address large AQUATIC FACILITIES where there may either be multiple AQUATIC VENUES, multiple grade elevations, or both. EXIT GATES must be provided to permit adequate emergency egress. For example, an AQUATIC FACILITY with ten AQUATIC VENUES split between different grade elevations should have the required number of exits spaced reasonably around the perimeter and not all at one grade elevation.

4.8.6.3.1 Self-Closing and Latching

4.8.6.3.1.1 Self-latching Device Height

The NCHS's Anthropometric Reference Data for Children and Adults³⁴⁹ demonstrates the mean height of a 6-year old child in the United States is 47 inches (119.3 cm) and the mean height for a 5-year old is 44.8 inches (113.7

cm). If one adds the reach height of a 5- to 6- year old child above the head this is approximately 54 to 57 inches. Raising latch heights from 3.5 ft (42 inches, 1.1 m) to 4.5 ft (54 inches, 1.4 m) will put the latch out of the average 5-year old child's reach. Exception 2 of Section 404.2.7 of the 2010 ADAAG allows for an increase in the maximum height of operable parts (defined in Section 106.5 as "a component of an element used to insert or withdraw objects, or to activate, deactivate, or adjust the element") of gate and door hardware from 48 inches (1.22 m) maximum above the finish floor or ground to 54 inches (1.37 m) maximum above the finish floor or ground, for operable parts of the release of latch on self-latching devices of access gates in BARRIER walls and fences protecting POOLS, spas, and hot tubs, provided the self-latching devices are not also self-locking devices and operated by means of a key, electronic opener, or integral combination lock.

4.8.6.3.1.6 Exceptions

The exceptions in MAHC 4.8.6.3.1.6 are intended to provide flexibility for design with an equivalent means of PATRON SAFETY. It is recommended that during the design phase the AQUATIC FACILITY consider and plan for operation of the AQUATIC FACILITY to meet the exemption, including an assessment of the need for additional personnel for staffing or supervision.

- **Exception 1:** MAHC 4.8.6.3.1.6.1 is intended to provide relief from MAHC 4.8.6.3.1 at locations where there is a staffed entrance which is locked when the AQUATIC FACILITY or AQUATIC VENUE is not open to the public. If Exception 1 is used, the AQUATIC FACILITY should clearly outline in the Staffing Plan (*part of the SAFETY PLAN required in 6.3.3*) the necessary staffing of any gate or door designed per the Exception and operate in accordance with the approved SAFETY PLAN. Use of video surveillance is not considered an acceptable alternative to having staff physically present at such entrances.
- **Exception 2:** MAHC 4.8.6.3.1.6.2 is intended to provide relief from MAHC 4.8.6.3.1 in instances where a required AQUATIC FACILITY or VENUE ENCLOSURE surrounds one or more AQUATIC VENUES where a QUALIFIED LIFEGUARD(s) is provided to conduct PATRON surveillance at all times the AQUATIC VENUE(s) is open, and where the gate or door is locked at all times the AQUATIC FACILITY or AQUATIC VENUE is closed to the public. Note that to comply with Exception 2, all AQUATIC VENUES within the AQUATIC FACILITY or VENUE ENCLOSURE must have a QUALIFIED LIFEGUARD present, even if not otherwise required per MAHC 6.3.2. If an AQUATIC FACILITY is not otherwise required to provide a QUALIFIED LIFEGUARD(s) at all AQUATIC VENUES within the ENCLOSURE, to meet Exception 2, any AQUATIC VENUE within the ENCLOSURE not provided with a QUALIFIED LIFEGUARD(s) would need to have a separate ENCLOSURE with gates or doors designed per MAHC 4.8.6.3.1 or 4.8.6.3.1.6.1. If Exception 2 is used, the AQUATIC FACILITY must clearly outline in the Staffing Plan (*part of the SAFETY PLAN required in MAHC 6.3.3*) any additional supervision provided by a QUALIFIED LIFEGUARD(s) to meet Exception 2 and operate in accordance with the approved SAFETY PLAN.

4.8.6.4 Indoor Aquatic Venues

4.8.6.4.3 Indoor and Outdoor Aquatic Venues

If a seasonal AQUATIC VENUE is on the same property as an AQUATIC VENUE operated outside of that same season, PATRONS need to be prevented from accessing the closed AQUATIC VENUES.

4.8.6.4.4 Wall Separating

A minimum overhead clearance of 6 feet 8 inches (2.0 m) is required since it is consistent with requirements of building CODE minimum doorway clearances. Materials that do not pose a possibility of physical injury may be suspended from the structure to help contain the INDOOR AQUATIC FACILITY environment.

4.8.6.5 Multiple Aquatic Venues

Rationale of 24 inch (61.0 cm) deep rule is that if adjacent water is not substantively deeper than the WADING POOL, there is no need to segregate the two. If it is the only AQUATIC VENUE within the facility, then normal fencing and perimeter ENCLOSURE requirements would apply. If WADING POOLS are a part of a larger facility with other types of AQUATIC VENUES, then the requirements proposed in MAHC 4.12.9.2 would apply.

4.8.7 Aquatic Venue Cleaning Systems

The MAHC encourages draining SPAS for cleaning. A vacuum likely would not be required for very small AQUATIC VENUES, such as SPAS less than 75 square feet (7.0 m²). A simple wall brush with pole can adequately and efficiently clean the floor.

4.8.7.1 No Hazard

Pumps shall not exceed three horsepower because the suction hydraulic of a larger pump through the small vacuum tubing would force the pump to operate at unacceptable hydraulic conditions. Strong suction forces provide a greater risk for bodily harm in the event of a vacuum system mishap. POOL vacuum systems must use suitably-sized pumps, proper diameter vacuum hoses, and reasonable hose lengths to provide optimum hydraulics for vacuuming operations. Conventional suction requirements call for a maximum 15 feet (4.6 m) of water at a flow of 4 gpm per lineal inch of suction cleaner head for the total suction head loss.

4.8.7.6 GFCI Connection

Not allowing extension cords prevents the possibility that the high voltage power supply unit has enough cord to potentially be dragged into the POOL causing a potential SAFETY risk. The power cord length needs to be shorter than the distance between the receptacle and the edge of the POOL in order to prevent the power supply from accidentally entering the POOL water while connected.

4.9 Filter/Equipment Room

4.9.1 Equipment Room

4.9.1.1 General Requirements

Building CODE speaks to minimum door widths from an egress standpoint which is typically narrower. The height is consistent with building CODE requirements.

4.9.1.2 Construction

- See IMC Section 304.1.
- See NEC Article 110-26 : *Minimum Clearances*.
- See NFPA 54 Section 8.1.2.

4.9.1.4 Ventilation

- See IMC Section 502.

4.9.1.5 Markings

Pipes may be color coded according to use with either labels or a reference chart; directional arrows with permanent labeling on the pipes; or by other means deemed suitable by the AHJ.

4.9.1.6 Equipment Rooms Containing Combustion Equipment

Due to the CORROSIVE nature of chemicals being used in the water treatment process, it should be expected that all equipment, especially combustion equipment and any ancillary components, experience corrosion. A breach in the combustion chamber or failure of the combustion air damper could lead to carbon monoxide release into the EQUIPMENT ROOM which can prove fatal to occupants. The carbon monoxide detectors, CERTIFIED, LISTED, AND LABELED in accordance with UL 2075, should be tested, at a minimum, semiannually to ensure their operability. All combustion chambers, combustion dampers, and ancillary items associated with the combustion system, should be inspected annually to ensure they are intact, operating correctly, and not in danger of corroding through. Inspections should be carried out by qualified parties. Where local health inspectors do not have the proper training or knowledge to perform these tests and boiler inspections, operators should contract for the required tests and inspections by qualified parties. Health inspectors should review the facility's paperwork to confirm that they have had the required tests and inspections completed.

Installed

No CODE language exists for this section since the MAHC defers to other CODES but the rationale for some of it is still included in the Annex. No items should be installed, nor shall STORAGE be planned for any items, within the minimum clearances of a COMBUSTION DEVICE, as defined by the manufacturer, or within the minimum clearances as defined the National Fuel Gas Code or other applicable CODE, whichever are greater.

- See IMC Section 304.1.
- See NFPA 54 Sec. 8.1.2.

Increased Ventilation

Rooms containing combustion equipment may be subject to requirements for increased ventilation and combustion-air intake, as specified by the National Fuel Gas Code or other pertinent CODES. The EQUIPMENT ROOM should be so constructed as to allow for the planned equipment, or should be modified as necessary. Where an EQUIPMENT ROOM contains combustion equipment which uses equipment-room air for combustion, no other equipment should be so installed as to reduce the room air pressure beyond the acceptable air-intake pressure range for the combustion equipment.

- See IMC Section 701.

Noxious Gasses

All practical flames produce carbon monoxide or nitrous oxides. There is very little chance of being rid of both of them at the same time. Neither is good for human health. The key is to dilute combustion products and send them up the flue. This does not always work where equipment-room air pressure is lower than outdoor air pressure. Some COMBUSTION DEVICES work by natural draft (*buoyancy of hot gases*) and cannot tolerate any pressure difference. Other COMBUSTION DEVICES have higher pressure differences which they can overcome. Where an EQUIPMENT ROOM contains combustion equipment which uses EQUIPMENT ROOM air for combustion, air-handling equipment should not use the room as a plenum. Exceptions may include where the combustion equipment is CERTIFIED, LISTED, AND LABELED for the expected use, such installation shall be acceptable where approved by the AHJ.

- See IMC Section 701.

Plenum Room

A plenum room uses the EQUIPMENT ROOM as the intake duct for HVAC equipment. Thus, it will have a low air pressure while the HVAC equipment is operating. For an INDOOR AQUATIC FACILITY, the incoming air would contain halogen compounds, e.g. chloramines, and thus should never be used as combustion air. Where an EQUIPMENT ROOM contains combustion equipment which uses a draft hood, air-handling equipment should not use the room as a plenum. Exceptions may include where the combustion equipment is CERTIFIED, LISTED, AND LABELED for the expected use, such installation shall be acceptable where approved by the AHJ.

- See IMC Section 701.

Lowered Room Pressure

In this situation, there is a tendency for the lowered room pressure to pull combustion products back down the flue into the room, and thus spread them everywhere. Rooms containing combustion equipment are also subject to requirements for separation from CHEMICAL STORAGE SPACES.

4.9.1.7 Separation from Chemical Storage Spaces

Largely, building STANDARDS do not speak to AQUATIC VENUES; for example, the dangers that chemical fumes pose to combustion equipment.

4.9.1.7.1 Equipment

4.9.1.7.1.1 Contaminated Air

Combustion equipment, air-handling equipment, and electrical equipment should not be exposed to air contaminated with CORROSIVE chemical fumes or vapors.

- See ANSI/ACCA 10 Manual SPS Section 1-6.
- See Chimney Safety Institute of America (*Plainfield, IN*): *Proper Venting of Gas Fueled Appliances*, 2010.
- See NFPA 54 Section 8.1.6.
- See Propane Council (*Washington, D.C.*): *Instruction Sheet IV - Identifying and Correcting Burner Problems*.

4.9.1.7.1.2 Equipment Restrictions

Spaces containing combustion equipment, air handling equipment, and/or electrical equipment and spaces sharing air distribution with spaces containing such equipment shall not at the same time be used as CHEMICAL STORAGE SPACES. Exceptions may include equipment CERTIFIED, LISTED, AND LABELED for use in that atmosphere shall be acceptable, where approved by the AHJ.

- See: ANSI/ACCA 10 Manual SPS Section 1-6.

- See: IMC Section 304.1

4.9.1.7.1.3 Isolated

Spaces containing combustion equipment, air-handling equipment, and/or electrical equipment and spaces sharing air distribution with spaces containing such equipment shall be isolated from CHEMICAL STORAGE SPACE air.

- See ANSI/ACCA 10 Manual SPS Section 1-6.
- See IMC Section 304.1.

4.9.1.7.2 Doors and Openings

4.9.1.7.2.1 Between Equipment and Chemical Storage Spaces

A door or doors should not be installed in a wall between such EQUIPMENT ROOMS and an interior CHEMICAL STORAGE SPACE.

- See ANSI/ACCA 10 Manual SPS Section 1-6.
- See IMC Section 304.1.

4.9.1.7.2.2 No Openings

CHEMICAL STORAGE SPACE door(s) must not be left open. This is important to controlling air pressure ratios, keeping CORROSIVE gases out of COMBUSTION DEVICES, and keeping children away from hazards. There should be no ducts, grilles, pass-throughs, or other openings connecting such EQUIPMENT ROOMS to CHEMICAL STORAGE SPACES.

- See ANSI/ACCA 10 Manual SPS Section 1-6.
- See IMC Section 304.1.

4.9.1.7.2.3 Indoor Aquatic Facility Air

Spaces containing combustion equipment, air-handling equipment, and/or electrical equipment and spaces sharing air distribution with spaces containing such equipment should be isolated from INDOOR AQUATIC FACILITY air. Exceptions may include equipment listed for the atmosphere, which may be acceptable.

- See ANSI/ACCA 10 Manual SPS Section 1-6.
- See Chimney Safety Institute of America (*Plainfield, IN*): *Proper Venting of Gas Fueled Appliances*, 2010.
- See NFPA 54 Section 8.1.6.
- See Propane Council (*Washington, D.C.*): *Instruction Sheet IV - Identifying and Correcting Burner Problems*.

Combustion equipment cannot be allowed to intake halogen compounds, because acids will form in the flue and destroy it, allowing carbon monoxide and other combustion products to enter the occupied space.

4.9.1.7.2.4 No Openings

There should be no ducts, grilles, pass-throughs, or other openings connecting such spaces to an INDOOR AQUATIC FACILITY. Exceptions may include HVAC equipment which is rated for INDOOR AQUATIC FACILITY atmosphere and which serves only that INDOOR AQUATIC FACILITY shall be acceptable.

Note: Ducts which connect the INDOOR AQUATIC FACILITY to the duct connections of air handlers should not be construed as connecting the air-handler space to the INDOOR AQUATIC FACILITY.

- See ANSI/ACCA 10 Manual SPS Section 1-6.
- See IMC Section 304.1.

4.9.1.7.2.5 Openings / Gaps

Where building construction leaves any openings or gaps between floors and walls, or between walls and other walls, or between walls and ceilings, such gaps should be permanently sealed against air leakage.

- See ANSI/ACCA 10 Manual SPS Section 12-3.

4.9.1.7.3 Indoor Aquatic Facility Access

4.9.1.7.3.1 Floor Slope

Where a door or doors must be installed in a wall between an EQUIPMENT ROOM and an INDOOR AQUATIC FACILITY, the floor of the EQUIPMENT ROOM should slope back into the EQUIPMENT ROOM in such a way as to prevent any equipment-room spills from running under the door into the INDOOR AQUATIC FACILITY. Exceptions may include:

- This may be met by a floor all of which is at least 4 inches below the level of the nearest part of the INDOOR AQUATIC FACILITY floor.
- This may be met by a continuous dike not less than 4 inches high located entirely within the EQUIPMENT ROOM, which will prevent spills from reaching the INDOOR AQUATIC FACILITY floor.

Note: Equipment-room floor drains may be required and all designs shall be compliant with ADAAG as they may be applicable.

Cleaning Supplies

Even if POOL chemicals and cleaning supplies are not in the EQUIPMENT ROOM, there is a very good chance that other fluids may be present (*e.g. ethylene-glycol heating fluids, petroleum refrigeration oils, polyol-ester refrigeration oils, alkyl-benzene refrigeration oils, other lubricants, caustic or acidic coil cleaners, etc.*).

4.9.1.7.3.2 Automatic Closer

Such door or doors should be equipped with an automatic closer. The door, frame, and automatic closer shall be installed and maintained so as to ensure that the door closes completely and reliably without human assistance.

4.9.1.7.3.3 Automatic Lock

Such door or doors should be equipped with an automatic lock. Such lock shall require a key or combination to open from the INDOOR AQUATIC FACILITY side. Such lock should be so designed and installed as to be opened by one hand from the inside of the room under all circumstances, without the use of a key or tool.

4.9.1.7.3.3.1 Restrict Access

Such doors should be equipped with permanent signage warning against unauthorized entry.

4.9.1.8 Other Equipment Room Guidance

4.9.1.8.1 Access Space

Where ventilation, air filtration, or space dehumidification, heating, or cooling for an INDOOR AQUATIC FACILITY is by mechanical equipment located in an EQUIPMENT ROOM, adequate access space should be provided to allow for inspection and service.

- See IMC Section 304.1.
- See NFPA 70 Article 110-26 : *Minimum Clearances*.
- See NFPA 54 Section 8.1.2.

4.9.1.8.1.1 Size Requirements

The access spaces should be the greater of:

- Those required by OSHA, NEC, National Fuel Gas Code, or other official requirements; or
- The equipment manufacturer's recommendations.

4.9.1.8.2 Adequate Space

Where ventilation, air filtration, or space heating or cooling for an INDOOR AQUATIC FACILITY is beside mechanical equipment located in an EQUIPMENT ROOM, adequate space for required straight lengths of duct shall be provided as the greater of those described in AMCA 201, SMACNA HVAC Systems Duct Design, ANSI/ACCA 10 Manual SPS, or the equipment manufacturer's recommendations.

- See ANSI/ACCA 10 Manual SPS Sections 1-6 and 13.
- See AMCA 201.
- See SMACNA HVAC Systems Duct Design.

4.9.1.8.3 Minimize Hazards

- See 29 CFR 1926.1053 Ladders.
- See ANSI/ACCA 10 Manual SPS Section 1-6.

4.9.1.8.4 Refrigeration Equipment

Most refrigerants are heavier than air. When released from containment, most will evaporate rapidly, expanding greatly in the process. If a large enough amount is released, it could displace air to above head-height. For this reason mechanical CODES usually require refrigerant-release to the outdoors when the amount of refrigerant exceeds some fraction of the occupied volume.

4.9.2 Chemical Storage Spaces

POOL-chemical associated injuries have been routinely documented.^{350,351,352,353,354} For 2007-2008, 32 POOL chemical--associated health events that occurred in a public or residential setting were reported to CDC by Maryland and Michigan. These events resulted in 48 cases of illness or injury; 26 (81.3%) events could be attributed at least partially to chemical handling errors (*e.g., mixing incompatible chemicals*). ATSDR's HSEESS received 92 reports of hazardous substance events that occurred at AQUATIC FACILITIES. More than half of these events (55 [59.8%]) involved injured persons; the most frequently reported primary contributing factor was human error. Estimates based on CPSC's NEISS data indicate that 4,876 (95% confidence interval [CI]: 2,821–6,930) emergency department (ED) visits attributable to POOL chemical--associated injuries occurred in 2012; the most frequent diagnosis was poisoning (2,167 ED visits [95% CI: 1,219–3,116]). CDC has developed recommendations to reduce the risk of chemical-associated injuries at AQUATIC FACILITIES.³⁵⁵ Designers and aquatics staff should read and consider findings and recommendations developed from investigations related to POOL chemical-related injuries. The design for CHEMICAL STORAGE SPACE was included in the initial version of the MAHC Ventilation and Air Quality module AIR HANDLING SYSTEM design posted for public comment. It was removed in the revised indoor AIR HANDLING SYSTEM design area of the MAHC as part of revising the definition of an INDOOR AQUATIC FACILITY for which the AIR HANDLING SYSTEM does not include CHEMICAL STORAGE SPACE or other space outside the negative pressure zone around the AQUATIC VENUE. However, the building of an INDOOR AQUATIC FACILITY will still require consideration of the ventilation of CHEMICAL STORAGE SPACES using separate AIR HANDLING SYSTEMS. Chemicals, typically stored in AQUATIC FACILITIES for the purpose of maintenance and water treatment, can create ventilation hazards for PATRONS and staff. IMC and IFC 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 ASHRAE Standards or STANDARDS such as NFPA 5000, or IBC Section 307.
- Separate the AIR HANDLING SYSTEMS for the CHEMICAL STORAGE SPACE 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 SPACE 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 SPACE, pump room, and AQUATIC VENUE area are well-ventilated.
- Ventilate the CHEMICAL STORAGE SPACE, pump room, and AQUATIC VENUE area to the outside.

4.9.2.1 Outdoor / Indoor Storage

4.9.2.1.3 Dedicated Space

The number of required CHEMICAL STORAGE SPACES should be as necessary to allow safe STORAGE of the chemicals present.

Additional Space

Where the listing, labeling, or SDS of chemicals indicates incompatibility of STORAGE with other chemicals present, other CHEMICAL STORAGE SPACE(S) should be provided.

- See ANSI/ACCA 10 Manual SPS Sections 1-6 and 12-3.
- See Calcium Hypochlorite, Sodium Hypochlorite, Muriatic Acid, BCDMH, etc., have NFPA 704 health rankings of 3

- See CDC. Recommendations for Preventing Pool Chemical-Associated Injuries accessed at <http://www.cdc.gov/healthywater/swimming/pools/preventing-pool-chemical-injuries.html>.
- See EPA OSWER 90-008.1 *Chemical Emergency Preparedness and Prevention Advisory SWIMMING POOL CHEMICALS: Chlorine*.
- See IMC Sections 502.8.4 and 502.9.2.
- See NFPA 704.

4.9.2.1.4 Eyewash

It is the intent to allow re-fillable eyewash bottles and not require plumbed emergency eyewashes and SHOWERS unless required by the AHJ.

4.9.2.1.4.1 AHJ Requirements

The intent is to allow some flexibility since installation in the CHEMICAL STORAGE SPACE may be prone to failure due to corrosion. External eye wash stations should be close and easily found such as in a location outside the door that all staff must walk past. The MAHC will continue to look for data supporting a maximum distance from the door.

4.9.2.2 Construction

As applicable, the STANDARDS of NFPA 400, the IFC, and the IBC shall prevail. This STANDARD is not intended to provide relief from these other regulations, but to provide BEST PRACTICE where these regulations are not adopted or enforced. The more stringent STANDARD shall prevail as applicable.

4.9.2.2.3 Floor

The floor or DECK of the CHEMICAL STORAGE SPACE should be protected against substantial chemical damage by the application of a coating or sealant capable of resisting attack by the chemicals to be stored.

4.9.2.2.6 No Openings

Other than a possible door, there should be no permanent or semi-permanent opening between a CHEMICAL STORAGE SPACE and any other INTERIOR SPACE of a building intended for occupation.

- See ANSI/ACCA 10 Manual SPS Sections 1-6 and 12-3.
- See IMC Section 502.
- See NFPA 704.
- See SDS for calcium hypochlorite, hydrochloric acid, muriatic acid, and sodium hypochlorite.

4.9.2.3 Exterior Chemical Storage Spaces

As applicable, the STANDARDS of NFPA 400, the IFC, and the IBC shall prevail. This STANDARD is not intended to provide relief from these other regulations, but to provide BEST PRACTICE where these regulations are not adopted or enforced. The more stringent STANDARD shall prevail as applicable.

4.9.2.3.2 Fencing

Such part of an outdoor space as does not join a wall of a building should be completely enclosed by fencing that is at least 6 feet (1.8 m) high on all other sides.

4.9.2.4 Chemical Storage Space Doors

As applicable, the STANDARDS of NFPA 400, the IFC, and the IBC shall prevail. This STANDARD is not intended to provide relief from these other regulations, but to provide BEST PRACTICE where these regulations are not adopted or enforced. The more stringent STANDARD shall prevail as applicable.

4.9.2.4.1 Signage

Given the high TURNOVER RATE or potential for employees to travel between workplaces at some AQUATIC FACILITIES, it would seem prudent to require a posting of the SDS location. Specifying the location of the SDS on the actual entry door to the chemical space may help reduce time for a response to an event. It further strengthens the requirements of OSHA 1910.1200(g)(8), 1910.1200(g)(9), and 1910.1200(g)(10)

- See NFPA 704 “Hazard Identification System”.

4.9.2.4.2 Emergency Egress

This usually takes the form of a kick-out panel in the door. When trapped, a person can sit down and kick out the panel, creating an opening usually about 6 inches (15.2 cm) narrower than the door and about 28 inches (71.1 cm) high. Since these are used in most ENCLOSURES where a person can be trapped (e.g. walk-in freezers) the volume is high enough for additional expense to be minimal. Trapping could happen in several ways, but the most common is binding of the door to the jamb. Corrosion products can build up inside a metal door between the jamb and the wall, forcing the jamb away from the wall and toward the door. At some point the door will either fail to open or fail to close.

4.9.2.4.3 Interior Door

- Safety Data Sheets for sodium hypochlorite, calcium hypochlorite, hydrochloric acid, and muriatic acid.

4.9.2.4.4 Equipment Space

- See ANSI/ACCA 10 Manual SPS Sections 1-6 and 12-3.
- See Canadian Standards Association C22.2.
- See Chimney Safety Institute of America, Plainfield, IN
 - Proper Venting of Gas Fueled Appliances, 2010
- See NEC Art. 110.11: *Deteriorating Agents*.
- See NEMA 250.
- See NFPA 54 Section 8.1.6
- See Propane Council (Washington, D.C.). Instruction Sheet IV: *Identifying and Correcting Burner Problems*.
- See UL 50 and UL 508.

4.9.2.4.4.1 Corrosive

Combustion equipment cannot be allowed to intake halogen compounds, because acids will form in and destroy the flue. Air-handlers have strong negative air pressures inside them. This will draw in any CONTAMINANTS around the cabinet and distribute throughout the ducted system.

4.9.2.4.5 Interior Opening

4.9.2.4.5.2 Automatic Locks

Most locks for employee-only doors in public buildings would qualify, since such locks must lock automatically from the outside, but cannot require a key or tool for exit. Examples of suitable lock types would include, but not be limited to, the locks on hotel-room doors, the lock on the door of a personnel-file STORAGE room, the lock on a janitor's closet, etc.

- See ANSI/ACCA 10 Manual SPS Sections 1-6, 4-4, and 12-3.

4.9.2.5 Interior Chemical Storage Space

As applicable, the STANDARDS of NFPA 400, the IFC, and the IBC shall prevail. This STANDARD is not intended to provide relief from these other regulations, but to provide BEST PRACTICE where these regulations are not adopted or enforced. The more stringent STANDARD shall prevail as applicable.

4.9.2.5.1 No Air Movement

- See ANSI/ACCA Manual SPS 2010 Section 4-4.

4.9.2.5.2 Electrical Conduit System

An interior CHEMICAL STORAGE SPACE that shares any building surface (*wall, floor, ceiling, door, etc.*) with any other INTERIOR SPACE or that shares an electrical-conduit system with any other space should be equipped with a ventilation system that maintains the air pressure in the CHEMICAL STORAGE SPACE below that of any other INTERIOR SPACE by 0.05 to 0.15 inches (1.3 to 3.8 mm) of water pressure, or by such greater pressure difference as should be necessary to ensure that all air movement through building surfaces or conduits should be toward the CHEMICAL STORAGE SPACE.

Note 1: This can usually be accomplished by maintaining the air pressure in the CHEMICAL STORAGE SPACE at least 0.05 I.W.C. to 0.15 I.W.C. below that of any adjoining space and below that of any space connected to the

CHEMICAL STORAGE SPACE by an electrical conduit system. Larger pressure differences may be needed in special cases.

Note 2: Where:

- All conduits passing through the CHEMICAL STORAGE SPACE use only threaded joints within the CHEMICAL STORAGE SPACE, and
- All conduits terminating in the CHEMICAL STORAGE SPACE
 - Are effectively sealed, and
 - Use only threaded joints within the CHEMICAL STORAGE SPACE, the specified air-pressure difference need not include the air pressures of INTERIOR SPACES which do not share a building surface with the CHEMICAL STORAGE SPACE.

4.9.2.5.2.2 Pressure Difference

This pressure difference should be maintained by a continuously operated exhaust system used for no other purpose than to remove air from that one CHEMICAL STORAGE SPACE.

4.9.2.5.2.4 Alarm

- See ANSI/ACCA 10 Manual SPS Sections 1-6, 4-4, and 12-3.
- See *ASHRAE Handbook: HVAC Applications, 2011, Places of Assembly, Natatoriums*, Section 4.6: *Ventilation Requirements*.
- See IMC 502.1.
- See Safety Data Sheets for calcium hypochlorite, hydrochloric acid, muriatic acid, and sodium hypochlorite.

4.9.2.6 Air Ducts in Interior Chemical Storage Spaces

4.9.2.6.1 No Air Movement

- See IMC Section 502.1.
- See ANSI/ACCA 10 Manual SPS Sections 1-6 and 4-4.

Ducts should not be shared between spaces. Should the blower stop or fail, there would be cross-contamination.

4.9.2.8 Combustion Equipment in Interior Chemical Storage Spaces

- See NFPA 54 Section 8.1.6
- See Chimney Safety Institute of America, Plainfield, IN; *Proper Venting of Gas Fueled Appliances*, 2010
- See Propane Council, Washington DC; Instruction Sheet IV: *Identifying and Correcting Burner Problems*

4.9.2.11 Gaseous Chlorination Space

Many current jurisdictions closely regulate the use of gas CHLORINE from a disaster preparation and response standpoint. This can make CHLORINE gas use prohibitive from a regulatory standpoint to the point that its use is difficult to justify.

4.9.2.12 Windows in Chemical Storage Spaces

4.9.2.12.1 Not Required

These windows are sometimes built into the door, although not always. (*There are fire-rated doors with windows.*) Such windows may serve several purposes.

4.9.2.12.2 Requirements

Such windows are usually installed for free lighting, although there can be drawbacks. Some chemicals may react on exposure to sunlight.

4.10 Hygiene Facilities

4.10.1 General

Language similar to this section is found in most state CODES.

4.10.1.2 Minimum to Provide

During 2011–2012, 36 (81.8%) of 44 treated recreational water–associated outbreaks of diarrheal illness were caused by *Cryptosporidium*³⁵⁶. These cryptosporidiosis outbreaks tend to disproportionately affect children under 5 years of age and can cause community-wide outbreaks³⁵⁷. Infectious *Cryptosporidium* OOCYSTS’ extreme CHLORINE tolerance allows them to survive for 2.4–10.6 days when FREE CHLORINE levels are maintained at 1–3 mg/L^{358,359}. The OOCYSTS small size (4.5 μm x 5.5 μm) also allows them to bypass typical sand and cartridge filters³⁶⁰. While SECONDARY DISINFECTION SYSTEMS or SUPPLEMENTAL TREATMENT SYSTEMS can inactivate the OOCYSTS, these UV and ozone treatment systems are circulation dependent so can require extended times for inactivation of pathogens in the POOL.^{361,362,363,364,365} Thus, changing BATHER behavior in the following ways are needed to help prevent cryptosporidiosis outbreaks:

- Enforcement of policies that exclude swimmers with diarrhea,
- Swimmer education about hygienic swimming behaviors (*e.g., taking a CLEANSING SHOWER before entering the water, not swallowing the water*).

Chloramines

During January–March 2007, over 660 BATHERS and aquatic staff at a waterpark experienced respiratory symptoms and eye irritation caused by chloramines.³⁶⁶ Chloramines form when FREE CHLORINE OXIDIZES nitrogenous compounds (*e.g., sweat, urine, and personal care products*) that wash off BATHERS’ bodies. Chloramines can volatilize into the air where it can accumulate in air of indoor AQUATIC VENUES. One in five (17%) American adults reports having ever urinated in a POOL³⁶⁷, and elite athletes can sweat over 700 mL/h³⁶⁸. Rinsing off in the SHOWER for 60 seconds and wearing bathing caps significantly decreases the amount of total organic carbon and total nitrogen³⁶⁹. Studies also suggest that UV treatment can reduce chloramine levels in the water^{370,371}. Accumulation of chloramines in the air at indoor treated recreational WATER VENUES can be reduced with the following practices:

- Policies that require SHOWERING before entering the water,
- Swimmer education about hygienic swimming behaviors (*e.g., taking a RINSE SHOWER and using the toilet before entering the water, not urinating in the POOL, and wearing bathing caps*), and
- Using UV water treatment
- Improving ventilation.

4.10.1.5 Theoretical Peak Occupancy

The minimum number of RINSE SHOWERS and CLEANSING SHOWERS should have PLUMBING FIXTURE counts correlated directly to the THEORETICAL PEAK OCCUPANCY IN MAHC 4.1.2.3.5. Any PLUMBING FIXTURE counts above this should be accordance with the AHJ’s requirements.

4.10.2 Location

4.10.2.1 Distance

The intent of this CODE item is to discourage PATRONS from drinking POOL water and encourage them to keep themselves hydrated. The intent is also to encourage PATRONS to use the HYGIENE FACILITIES rather than urinating in the POOL or changing diapers at the side of the AQUATIC VENUE or on AQUATIC VENUE furniture. Restrooms need to be easily accessible and available to PATRONS of AQUATIC VENUES so that they will use restrooms rather than urinating or defecating in the VENUE water, which is common. Compared with other public locations, people feel that it is more acceptable to “pee in the POOL” and not use sanitary facilities for this bodily function. This may not be possible in large waterparks, however, they can possibly be located within 300 feet (91 m) from the AQUATIC VENUE. The distance needed for parents to walk or carry children less than 5 years of age should be shorter (200 ft or 61 m) to ensure use. These distances are found in multiple state or local CODES including Wisconsin, Oregon, Florida, and New York. When possible, it is preferable to have a bathroom on the same floor as the AQUATIC VENUE; however, it is not required at this time in the MAHC. Drinking water should be available so that PATRONS, especially young children, are less likely to drink POOL water and to ensure that PATRONS are kept well-hydrated.

4.10.2.2 Children Less than Five Years of Age

There are specific types of AQUATIC VENUES that pose an INCREASED RISK of fecal contamination of the water and transmission to BATHERS such as WADING POOLS, WATER ACTIVITY POOLS, INTERACTIVE WATER PLAY

VENUES, or other AQUATIC VENUES designed primarily for children less than 5 years of age. For these AQUATIC VENUES, diaper changing areas should be located directly adjacent to the kiddie areas to promote use. It is especially important that HYGIENE FACILITIES be available to these INCREASED RISK groups. Children less than 5 years of age have the highest incidence of diarrheal illness and are more likely to be a source for spreading RWIs.

4.10.3 Design and Construction

Language similar to this section is found in most state CODES.

4.10.3.2 Floor Base

The purpose of coving is to prevent water splashing on the wall when mopping. Six inches (*15.2 cm*), a common height, was taken from building CODE.

- For further information, also see the FDA Food Code for Kitchens.

4.10.3.3 Floor Drains

4.10.3.3.1 Opening Grill Covers

Holes in floor drain cover openings need to be sized to prevent small children's toes from becoming entrapped when walking over them.

4.10.3.3.2 Sloped to Drain

Floors not sloped to drain have been shown to allow bacterial growth on indoor and outdoor AQUATIC VENUE POOL DECKS.

4.10.3.5 Hose Bibb

The purpose of these hose bibs is to permit adequate cleaning of SHOWER and toilet facilities and to permit cleaning of any spills occurring in the HYGIENE FACILITY. See also MAHC 6.5 for further rationale.

4.10.4 Plumbing Fixture Requirements

Language similar to this section is found in most state CODES.

4.10.4.1 General

4.10.4.1.1 Protected

It is fundamental that there be no CROSS-CONNECTIONS between safe (*potable*) and unsafe (*non-potable*) water supplies. All hose bibbs should be equipped with a vacuum breaker to prevent back siphonage. This CROSS-CONNECTION protection can also be achieved at lavatories and laundry tub washing facilities through an air gap. As a general rule, the INLET pipe is terminated at a distance about four times the diameter of the pipe and not less than 4 inches (*10.2 cm*) above the maximum overflow level of the PLUMBING FIXTURE rim.

4.10.4.1.3 Toilet Counts

Facilities in jurisdictions with requirements governing the number of sanitary facilities should follow those requirements. AQUATIC FACILITIES with an average PATRON load of over 100 persons should follow the IPC. Facilities with average PATRON loads of less than 100 persons should follow either the IPC or UPC. The IPC may require significantly more toilet facilities for women than for men.

Gender Potty Parity

(Abstracted from ICBO adoption materials) Previous issues of the nation's model consensus CODE mandated an equal amount of toilet FIXTURES for both men and women. Newer versions of the CODE will likely provide recommendations that increase the minimum required facilities for women. The IPC requires far less HYGIENE FIXTURES for various types of occupancies than the UPC. This is contrary to the "potty parity" movement which demands more FIXTURES for women's toilet rooms to avoid the long waiting lines. The UPC also provides more WCs and urinals in most men's toilet rooms than the IPC and assures adequate WCs by limiting the number that can be deleted by installing additional urinals. The authors of the ICBO have suggested that the provisions of the UPC reflect what the "potty parity movement" called for. The provisions of the IPC do address the issue of "potty parity". The issue of "potty parity" is mostly an issue in assembly buildings with large occupant loads, especially where there is a period of high demand such as at intermission at a theater or at halftime at a football stadium. "Potty parity" is not an issue for occupancies where there is no instantaneous demand on the FIXTURE usage. IPC Table 403.1 reflects requirements for twice as many PLUMBING FIXTURES in the ladies' room compared with the

men's room, when the type of occupancy demands such a count. In occupancies where the factors do not demand such an increase, the CODE does not require it. It should also be pointed out that part of this issue arises because of some CODES requiring both WCs and urinals within the men's restroom. Therefore, the numbers for men were somewhat higher. The IPC does not have a mandatory requirement for urinals. It will generally require the same number of PLUMBING FIXTURE in the men's and women's restrooms. However, when two or more WCs are required, the IPC will permit up to 67 percent of the FIXTURES to be replaced by urinals.

Some differences between the IPC and UPC CODES on this issue are as follows:

International Plumbing Code:

- Utilizes a fixed PLUMBING FIXTURE to OCCUPANT LOAD ratio.
- Does not mandate urinals for men.
- Allows up to 67% of the requirement for WCs to be substituted for urinals.
- Establishes a separate FIXTURE calculation factor for men and women. In some cases twice as many FIXTURES are required for women compared with men.
- No arbitrary parity requirement.

Universal Plumbing Code:

- Utilizes a variable PLUMBING FIXTURE to OCCUPANT LOAD ratio.
- Requires urinals to be installed based on a FIXTURE to OCCUPANT LOAD ratio. Does not allow for one to one substitutions. For each urinal added over what is required, you may have one to one substitutions up to 2/3 of what is required.
- Requires the total number of WCs for women to be equal to the total number of WCs and urinals for men.

4.10.4.2 Cleansing Showers

The purpose of CLEANSING SHOWERS described in this section is to remove dead skin, sweat, nitrogenous waste, and perianal fecal material before BATHERS enter the POOL. This is best done through nude SHOWERING using warm water and soap. An average of 0.14 grams of fecal material can be found on a person's peri-anal surface (*the amount of feces for children ranges from 0.01-10 grams and for adults 0.0001 to 0.1 g³⁷²*). Therefore, fecal contamination of the perianal area is common. This contamination may include the CHLORINE-tolerant parasite *Cryptosporidium*^{373,374} which is not inactivated by routine DISINFECTANT levels required in AQUATIC VENUES. Since the effectiveness of most halogen-based DISINFECTANTS is reduced by the presence of organic material, the purpose of CLEANSING SHOWERS is to reduce the inorganic, organic, and fecal load introduced into POOLS.

4.10.4.2.1 Count

The THEORETICAL PEAK OCCUPANCY (*MAHC 4.1.2.3.5*) has been accounted for in the one SHOWER per sex per 4000 square feet (372 m²). This assumes using one BATHER per 20 square feet (1.9 m²), so at 4000 square feet, there will be one SHOWER per 200 BATHERS. Further research on this topic is recommended and can be addressed in future versions of the MAHC.

4.10.4.2.3 Location

The placement of the SHOWERS is intended to encourage BATHERS to see and use the SHOWERS before they enter the water.

4.10.4.2.4 Enclosed

Entryways to CLEANSING SHOWER compartments shall be enclosed to provide privacy. Individual SHOWER stall curtains and doors are not required. Providing privacy for CLEANSING SHOWERS promotes BATHER cleansing prior to entering AQUATIC VENUES.

4.10.4.2.6 Exemption

“Residential settings” includes condos, apartments, and homeowners associations but does not apply to individual residential POOL settings. The intent is for BATHERS to use their rooms/homes for a CLEANSING SHOWER; however, one RINSE SHOWER on the DECK is required at these AQUATIC FACILITIES encouraging BATHERS to SHOWER prior to entering water if a BATHER had not already done so.

4.10.4.3 Rinse Showers

The purpose of the RINSE SHOWERS is to remove inorganic material such as sand or dirt that can bind with CHLORINE and reduce the amount for other pathogen inactivation. Rinsing with water also removes BATHER'S CONTAMINANTS such as sweat, hygiene products, deodorant, hair spray, etc. Rinsing off in the SHOWER for 60 seconds and wearing bathing caps significantly decreases the amount of total organic carbon and total nitrogen³⁷⁵. A RINSE SHOWER can be taken on the DECK in open SHOWERS by the AQUATIC VENUE using ambient temperature water so dirt and other CONTAMINANTS are rinsed off before entering the water.

4.10.4.3.3 Floor Sloped

Floors of RINSE SHOWERS shall be sloped to drain waste water away from the AQUATIC VENUE and any landscaping areas if present. The intent is to prevent landscaping materials from being tracked back or washed into the AQUATIC VENUE area.

4.10.4.3.4 Large Aquatic Facilities

The intent is to encourage BATHERS to see and use the RINSE SHOWERS before they enter the water.

4.10.4.3.5 Beach Entry

The intent of having at least four showerheads every 50 feet (15.2 m) at a beach entry allows multiple people to rinse off at the same time. Showerheads could be provided as wall units, pedestals (*one pedestal could have four showerheads or two pedestals could have two showerheads each*), allowing AQUATIC FACILITY owners to have versatility in design.

4.10.4.3.6 Lazy River

BATHERS enter LAZY RIVERS only in designated areas; therefore locating RINSE SHOWERS near these entrances facilitates rinsing before entering the LAZY RIVER.

4.10.4.3.7 Waterslide

BATHERS congregate into queue lines for access to WATERSLIDES. Providing a RINSE SHOWER on the DECK of a queue line encourages use prior to entering the water.

4.10.4.4 All Showers

The intent is to encourage use of SHOWERING prior to entering an AQUATIC VENUE. Large AQUATIC FACILITIES, based on their THEORETICAL PEAK OCCUPANCY, would require a large number of CLEANSING SHOWERS which would put an economic burden on these facility types. The MAHC acknowledges CLEANSING SHOWERS are more expensive to install than RINSE SHOWERS, therefore as long as the required number of SHOWERS is met, AQUATIC FACILITIES can decide which type of SHOWER is conducive for their PATRONS. In addition, the ISPSC Section 609.3.1 allows flexibility on the ratio of CLEANSING to RINSE SHOWERS above 7,500 square feet of water surface area.

4.10.4.5 Diaper-Changing Stations

The material in this section addresses diapering of infants and young children. These are the age groups most commonly involved in contamination of recreational water that can lead to outbreaks of illness associated with recreational water. Although some older persons must wear diapers the incontinence is less likely to be associated with a diarrheal illness so the risk of infection from adults is much less than that from children. Therefore, we do not believe that special regulations are needed for elderly BATHERS. Current DIAPER-CHANGING UNIT designs do not supply all the features needed for sanitary and efficient diaper changing and clean-up to minimize spreading pathogens further in the AQUATIC FACILITY.

The MAHC defines a DIAPER-CHANGING STATION to include the following:

- A DIAPER-CHANGING UNIT,
- An adjacent hand washing sink,
- Soap with dispenser,
- Trash receptacle, and
- Necessary cleaning materials for the DIAPER-CHANGING UNIT.

4.10.4.5.1 Each Facility

4.10.4.5.1.1 Hand Wash Sink

HAND WASH STATIONS are required adjacent to DIAPER-CHANGING STATIONS to promote use after using the toilet/urinal or changing diapers. Facilities will have 1 year after adoption on this MAHC section to install a plumbed sink with soap and dispenser, hand drying device/or paper towels and dispenser, and trash receptacle.

4.10.4.5.1.2 Portable

If a permanently plumbed hand wash sink is not economically feasible to install, a portable HAND WASH STATION can be used as a substitute for 1 year. Portable HAND WASH STATIONS are used at temporary events and include a water and waste tank that requires frequent refilling and draining for continual use.

4.10.4.5.2 Conform

There appear to be two different configurations of DIAPER-CHANGING UNITS currently available and suitable for this setting. The first type, a fold-down commercial unit commonly mounted on the wall, is addressed by ASTM F2285-04. The second type, a free-standing unit, is addressed by *Caring for Our Children (CFOC)*. A major difference between these two designs is that ASTM F2285 calls for restraining straps while CFOC prohibits the use of straps and relies on a 3 inch (7.6 cm) lip to keep children from falling off. Both designs have inherent problems. The problems with straps are associated with cleaning and possible hanging hazard. The problem with a 3 inch (7.6 cm) lip is that they are not available on fold-up units. The MAHC language does not discriminate between these two designs, but the unit used should conform to one of these two STANDARDS.

4.10.4.5.3 Unisex

Increasingly, many AQUATIC VENUES are providing family dressing areas and caregiver rooms to attend to family needs. This provision permits parents to attend to the needs of small children of the opposite sex.

4.10.4.5.4 Trash Can

Trash receptacles are needed to help maintain cleanliness around the DIAPER-CHANGING STATION for any disposable changing unit covers, diapers, SANITIZING wipes, or disposable paper towels.

4.10.4.6 Non-Plumbing Fixture Requirements

4.10.4.6.4 Lockers

While some lockers are designed to sit directly on the floor, other lockers may need to be elevated. This prohibits water accumulation beneath the lockers. Such accumulation can lead to the growth of mold, mildew, and slime build up. The MAHC has gone with the current industry STANDARD of 3.5 inches (8.9 cm) high but recommends moving to a new STANDARD of 6 inches (15.2 cm) to allow better access, cleaning, and drying under the lockers.

4.10.4.6.6 Dryers / Paper Towels

Hand drying devices or paper towel dispensers should be located adjacent to the hand washing sinks to facilitate use. To prevent overcrowding, they may be positioned to move users away from the sink and toward the exit. In childcare settings, the dispensers and devices are usually within arm's reach of the sink.

4.10.5 Provision of Suits, Towels, and Shared Equipment

Although providing reusable bathing suits is no longer common, many AQUATIC FACILITIES provide PATRONS with towels and other shared equipment. The purpose of this wording STANDARD is to ensure that these AQUATIC FACILITIES provide adequate equipment and space in their design and construction for laundering, SANITIZING, and drying these items.

4.10.6 Foot Baths

FOOT BATHS with standing water allow the buildup of organic material and bacterial and fungal growth and can lead to the spread of pathogens.

4.10.7 Sharps

This section was included to address AQUATIC VENUES that provide PATRONS with sharps, especially razors, so that safe disposal is assured. Approved sharps containers are rigid, leak-proof, puncture resistant boxes of various sizes made of hard red plastic. They have a lid that can be securely sealed to keep contents from falling out, and they are clearly marked with the bio-hazard symbol. OSHA regulations describe the design and use of sharps containers for a variety of settings.

Businesses are required by OSHA to deposit sharps into a sharps container that complies with OSHA regulations in order to protect employees. Once that container is full, it must be disposed of according to state and federal regulations.

4.11 Water Supply / Wastewater Disposal

4.11.1 Water Supply

4.11.1.1 Public Water System

PUBLIC WATER SYSTEMS include community water systems, non-transient non-community water systems, or transient non-community water systems with some noted exceptions.

4.11.1.1.1 Other Sources

There are several lake, spring, private well, or other approved private water sources around the country that have been used for decades to supply water to AQUATIC FACILITIES. Hauled water obtained from a public water supply or approved private water supply may also be used to fill POOLS. As long as the source water quality does not significantly change and can be treated by the AQUATIC FACILITY equipment to protect the health and SAFETY of PATRONS, it can be allowed.

4.11.1.1.2 Condensate / Reclaimed Water

The steps necessary to make reclaimed water meet source water STANDARDS are beyond the scope of the MAHC. These steps are set by the state and federal agencies that set requirements for drinking water. This would be up to the AHJ and local conditions. The MAHC felt that, especially considering recent affinities towards sustainability, reclaiming condensate would be acceptable as long as this water met the same STANDARDS as incoming domestic water (*even if this required UV or other DISINFECTANTS, filters, etc.*); this could be challenging since some CONTAMINANTS introduced by swimmers may not be removed by filtration, UV or other treatment. A provision for deferring to the AHJ ruling based on locale was important to include in the MAHC. For instance, this may be more of a politically important issue in Arizona or Nevada than in other areas of the country. Non-potable use for this water is in keeping with water as a limited resource.

4.11.1.2 Sufficient Capacity

This requirement is for when AQUATIC FACILITIES choose to be open when backwashing (*e.g., they can backflush one filter while still maintaining filtration through another system; operating without the RECIRCULATION SYSTEM running is prohibited*). A facility may choose to regulate when their backwash cycles occur (*such as at closing*). Many fully automated backwash systems for HRS filters are programmed to backwash at night when the facility is closed and there are no other demands on the source water coming into the facility. Alternatively, QUALIFIED OPERATORS may choose for an all deep 50 meter POOL to just backwash one filter at a time and allow make-up water to reestablish rim flow before doing the next one, as opposed to doing all six or eight tanks sequentially.

4.11.2 Fill Spouts

For example, a fill spout located under a diving board or next to a ladder or handrail is less likely to be a trip hazard or be a hazard to swimmers coming up from below.

4.11.3 Cross-Connection Control

An air gap can be provided through a fill spout at the side of an AQUATIC VENUE, through water supply piping over the edge of an open balance tank or surge tank, or over a fill stand pipe that is connected to the side of an AQUATIC VENUE. Splash guards are simply a means to keep fill water from splashing onto adjacent floors and walls. Water cannot be siphoned into the potable water supply through a properly designed splash guard. A proper design often consists of a concentric pipe that is a larger diameter than the fill pipe and that is open to the atmosphere at the top and bottom. Because of the potential for back pressure or back siphonage, any potable water piping connected directly to any AQUATIC VENUE piping must have an RPZ. Some permitting agencies or CODES may allow pressure vacuum breakers or atmospheric vacuum breakers on water supplies not connected to the POOL piping but supplying potable water to the AQUATIC VENUE through a submerged INLET in the AQUATIC VENUE. The pressure vacuum breaker would be located upstream of the shut-off valve. The atmospheric vacuum breaker would be located downstream of the shut-off valve.

4.11.4 Deck Drains and Rinse Showers

4.11.5 Sanitary Wastes

4.11.6 Pool Wastewater

AQUATIC VENUE waste streams (*including filter backwash water and AQUATIC VENUE drainage water*) should be discharged through an air gap to sanitary sewers, storm sewers, drain fields, or by other means, in accordance with local municipal and building official recommendations including obtaining all necessary permits. The discharge should occur in a manner that does not result in a nuisance condition. Each waste line should have a unique air gap. Waste lines from different sources (*e.g. AQUATIC VENUE, SPA, overflow, sump pump, etc.*) should not be tied together, but multiple waste lines may discharge into a common sump or receptacle after an air gap. The AHJ may allow an elimination of an air gap to control splashing or flow of AQUATIC VENUE wastewater outside the receiving sump onto the EQUIPMENT ROOM floor. This can be accomplished by extending the AQUATIC VENUE wastewater pipe below the rim of the sump. This can be approved if the wastewater disposal pipe from the AQUATIC VENUE does not have a sealed connection to the sewer piping. This constitutes an air break. An air break can be justified for the worst case scenario of a sewer backup at the AQUATIC VENUE wastewater sump. During a sewer backup, sewage cannot back pressure into AQUATIC VENUE piping through an air break. Further, if the sewage is above the AQUATIC VENUE waste pipe outlet when the AQUATIC VENUE is operating, the normal pressure of the POOL piping leaks AQUATIC VENUE water towards the sewer, preventing the AQUATIC VENUE piping from siphoning wastewater. If the AQUATIC VENUE is not operating, then there is no pressure or suction in the piping that could create a condition for siphoning sewage. If the permitting agency does not allow an air break, they may allow an air gap with a splash guard.

4.11.6.2 Ground Surface

Filters work to reduce the level of pathogens in the AQUATIC VENUE water by retaining the pathogen in the filter. As a result, AQUATIC VENUE backwash water has been demonstrated to contain detectable pathogen levels (*e.g., Cryptosporidium and Giardia*).^{376,377,378} Therefore, filter backwash water should be considered waste water requiring appropriate disposal. A ground surface discharge may be the only option for disposing waste water from an AQUATIC VENUE. A suitable location is one where the discharged waste water does not pond excessively, flow directly to surface water, or create other nuisance conditions. The discharge should not cross property boundaries.

4.11.6.4 Separation Tank for Precoat Media Filters

If local or state CODES prohibit disposal of backwash filter media (*perlite, cellulose or diatomaceous earth*) directly to sanitary sewer, a separation tank may be recommended. The separation tank is to be designed for the conditions of the specific facility filtration system. The separation tank should be designed to accommodate the volume of water and spent media recommended for at least a single backwash (*media change*), without overflowing. The separation tank may include separation screens or a settling pit to allow for the spent media to be removed and properly disposed of according to AHJ requirements.

4.12 Specific Aquatic Venues

4.12.1 Spas

4.12.1.2 Maximum Water Depth

SPAS are designed for sitting and the expectation is that it will not be over the average 11-year-old child's head. That depth is about 48 inches (*1.2 m*). The MAHC felt that 24 inches (*61.0 cm*) is reasonable since it is half of the maximum depth previously stated (*48 in or 1.2 m*) and would allow for the vast majority of the population to sit comfortably with their head above water. The MAHC also consulted the ISPSC and their maximum depth of 28 inches (*71,1 cm*) is pulled from APSP which has been utilized by the industry for some time. The Committee recommends additional studies to determine if decreasing the SPA seating depth is necessary.

4.12.1.3 Handholds

Even though a person is seated in a SPA, a sufficient number of positive handholds are needed to assist with standing up. Handholds at the edge of the SPA above the water line are visible and easily reachable.

4.12.1.5 Perimeter Deck

This is to provide adequate area for life saving and rescue purposes. The AHJ may allow a smaller rescue area based on the assessment of a local emergency rescue agency. SPAS elevated for transfer wall or other purposes

need to be provided with an effective BARRIER so that the elevated wall is not used as a platform to access an adjacent AQUATIC VENUE. An effective BARRIER shall be one that does not allow BATHERS to walk on the elevated wall. Small and/or narrow SPAS are examples where the AHJ may allow a relief from the 50% minimum DECK requirements. The rationale is that if a SPA is of a limited size or width then it can be entirely be guarded effectively from one side or one location.

4.12.1.5.4 Elevated Spas

For example, if an elevated SPA is next to or within 4 feet (1.2 m) of another AQUATIC VENUE, a guard rail or post-and-rope system would be a couple of options as effective BARRIERS which would discourage PATRONS to use this elevated wall to jump into the other AQUATIC VENUE.

4.12.1.7 Temperature

Temperatures above 104°F are essentially inducing a fever in the BATHER'S body as internal temperature rises. It also causes birth defects in fetuses so that pregnant women, particularly in their first trimester, should consult their physician before using. Further research is needed to understand the potential role of SPA use early in pregnancy and associated birth defects. See MAHC Annex 5.7.4.7.2 for further discussion.

4.12.1.10 Timers

The "Fifteen Minute Rule" – complies with most state CODES. The timer for the hydrotherapy pump is for the SAFETY of the BATHERS. Longer times can be hazardous to BATHERS and the therapy pump shutting off at least reminds the BATHER to get out and reset the timer.

4.12.1.11 Emergency Shutoff

Emergency shutoffs should be located between 5 feet (1.5 m) and 50 feet (15.2 m) and within sight of the SPA structure.

4.12.2 Waterslides and Landing Pools

4.12.2.1 Design and Construction

The designs of WATERSLIDES are governed by amusement ride regulations such as ASTM F2376 that have appropriate experience. However, the design of the LANDING POOL along with associated water quality and circulation is regulated by this CODE.

4.12.2.4 Exit into Landing Pools

Present practices for safe entry into LANDING POOLS include:

- A water backup, and
- A deceleration distance.

4.12.2.9 Drop Slides

DROP SLIDES are being highlighted because of one incident that resulted in a fatality in Massachusetts. WATERSLIDES, particularly those that drop BATHERS into the water (*versus being delivered to a water entry point*), from a height above the water require diligent MONITORING by staff at the top of the SLIDE and the water entry point to ensure there is adequate SPACING between SLIDE users so that people do not land on top of each other. Each SLIDE user must have time to move out of the collision zone before another SLIDE user is allowed down the SLIDE. The incident cited above resulted in the drowning of a SLIDE user and a multi-day period to discover the victim because of the high turbidity of the water.

4.12.3 Wave Pools

The WAVE POOL will still have side wall ladders for egress purposes (*and therefore partial trafficking*) and the MAHC still felt that "NO DIVING" signage should still be required for all areas around the WAVE POOL regardless of water depth due to the freeboard.

4.12.4 Therapy Pools

4.12.5 Lazy Rivers

4.12.5.2 Access and Egress

4.12.5.2.1 Means

Since there is moving water in a LAZY RIVER, less frequent means of ingress/egress are acceptable. The moving water propels people around a LAZY RIVER quickly and with less effort to the next means of egress. LAZY RIVERS can be several hundred feet long. They are often constructed with side walls that make it difficult to exit the water. This distance will make it so that a BATHER will never be more than 75 feet (22.9 m) from an exit. The distance to the nearest exit for a large regular POOL can be as much as 50 feet (15.2 m). This distance can be farther for a LAZY RIVER because of the current. If water is flowing at 1 to 4 feet/second around the river, then a person floating around a river will never be more than 2.5 minutes from a means of egress.

4.12.5.2.2 Handhold

When BATHERS are required to be in or on a tube while in a LAZY RIVER, the SAFETY need for handholds is minimal (shallow depth and slow current) while the SAFETY deficits for such a requirement are increased. BATHERS on tubes holding onto a handhold can cause jams in the river, block the free flow of other guests, may cause bathers to be flipped out of tubes by jamming tubes together and could lead to aggressive action by those being blocked. An increased number of tubes in a small area will put additional and unnecessary pressure on lifeguards to control traffic and arbitrate disputes. Tube and raft congestion at entry/exit locations could impact lifeguarding, sight lines and/or rescue operations. It could impede entry points to a LAZY RIVER that would create crowd management and egress issues. It could create obstructions cited in MAHC 4.12.5.2.3.2. This could also make it much more difficult to spot and assist BATHERS who have fallen off a tube and require immediate help to get out from underneath the glut of tubes. In addition, handholds in a LAZY RIVER could also create the potential for injuries for BATHERS holding on from the opposing force of the water flow.

4.12.5.2.3 Deck

LAZY RIVERS are of necessity closed (*or mostly closed*) loops. The wall for the inside of a LAZY RIVER loop is an ISLAND which may be designed for people but is most often not. Therefore, a PERIMETER DECK is only needed for the outside of the river loop, or only on one side of the river.

4.12.5.2.4 Bridges

Seven feet (2.1 m) minimum clearance overhead is required since it is consistent with requirements of building CODE minimum ceiling clearances. Most LAZY RIVERS are closer to 3.5 feet (1.1 m) deep making the clearance 7.5 feet (2.3 m) if you adhere to the 4 foot (1.2 m) clear requirement above the water surface. The MAHC chose 7 feet (2.1 m) because it is the typical building CODE minimum height requirement for ceilings whereas the 6 foot 8 inches (2 m) minimum clearance is usually only applicable to doorways.

4.12.6 Moveable Floors

4.12.6.3 Safety

4.12.6.3.1 Not Continuous

Examples of adequate SAFETY precautions for entering the other area of the AQUATIC VENUE include but are not limited to the following:

- A moveable BULKHEAD, located at least at the water surface, to enclose the area of the MOVEABLE FLOOR;
- A highly visible floating line installed over the MOVEABLE FLOOR surface, 2 feet (61.0 cm) in front of the end of the MOVEABLE FLOOR. A 4 inch (10.2 cm) wide contrasting marking shall be provided at this leading edge; and
- A railing system that shall be anchored into the MOVEABLE FLOOR.

4.12.6.3.2 Underside

When the MOVEABLE FLOOR is not continuous over the entire surface area of the POOL, access to the underside of the MOVEABLE FLOOR shall be denied when it is not flush with the POOL floor. Examples of adequate measures to prevent access under the MOVEABLE FLOOR include but are not limited to the following:

- Position a BULKHEAD at the end of the MOVEABLE FLOOR;
- Have a trailing ramp that hinges to the MOVEABLE FLOOR and extends to the POOL floor.

4.12.6.4 Movement

There are no United States regulations on MOVEABLE FLOORS. This velocity was obtained from European design STANDARDS.

- European Standard EN 13451-11.

4.12.7 Bulkheads

4.12.7.2 Entrapment

All BULKHEAD parking positions should be designed such that QUALIFIED LIFEGUARDS can see under 100% of the BULKHEAD from their station on the POOL DECK.

4.12.7.5 Gap

BULKHEADS designed with greater gaps may result in BULKHEADS veering off its intended path.

4.12.7.6 Handhold

During FINA sanctioned events, full height touchpads will be on most BULKHEADS. But the majority of BULKHEADS in the United States allow for wide holes at the waterline for handholds and USA Swimming / NFHS / NCAA touchpads which are hung from these holes and are below the waterline. Touchpads aren't normally installed during normal operating hours. End wall concrete parapets that cantilever over the gutter that require full height FINA touchpads for those level of competitions do not negate the requirement for handholds (*though behind*) in these locations.

4.12.7.9 Width

Any BULKHEAD that is intended for foot traffic for use by officials shall be at least 1 meter (*3 feet and 3 inches*) wide which is the current minimum width provided by commercial manufacturers.

4.12.7.9.1 Starting Platforms

Any BULKHEAD that dictates starting platforms shall be installed shall be at least 3 feet and 9 inches (1.1 m) wide in order to allow for sufficient trafficking space for officials and athletes behind the starting platforms.

4.12.8 Interactive Water Play Venues

4.12.8.3 Sloped

An example for an acceptable design solution would be a diverter valve installation.

4.12.8.10 Hazard

While consistent with many state CODES, the MAHC has determined that this topic needs more research regarding water velocity and eye SAFETY³⁷⁹.

4.12.8.12 Signage

Since there is no standing water on INTERACTIVE WATER PLAY VENUES, depth markers and “NO DIVING” warning signs are not required. This was included because it deviates from the regular marking and warning signage requirements for typical AQUATIC VENUES as stated in this CODE. Other signage requirements such as diaper changing reminders and “Do Not Drink” would likely be appropriate.

4.12.9 Wading Pools

4.12.9.2 Barrier

A more stringent requirement is stipulated for separating WADING POOLS from other BODIES OF WATER (*compared with the spacing between other AQUATIC VENUES*) is due to the fact that the predominant users of WADING POOLS are small toddlers, most of whom cannot swim, and the inherent dangers posed by larger and deeper POOLS in close proximity.

4.12.9.2.2 Shallow Water

Rationale of 24 inches (*61.0 cm*) deep rule is that if adjacent water is not substantively deeper than the WADING POOL, there is no need to segregate them.

4.12.10 Floatation Tanks

“Floating” is a health and wellness practice in which users float in a saturated Epsom salt solution (MgSO₄). The practice is intended to reduce sensory input through several means. The dense, highly buoyant solution allows users to float without effort, and is maintained at or near the external temperature of the skin (93.2-95°F/34–35°C). The “float tanks” in which floating occurs may vary greatly in design (ranging from open basins

to chambers to pods), but are generally designed to reduce light and sound penetration. However, some tank designs may provide sensory inputs in the form of colored lights, sounds, or aromatherapy. Although FLOATATION TANKS are typically found in commercial float centers containing multiple units, they could be installed in a range of settings. The academic literature on FLOATATION TANKS is limited. There is a growing body of research examining potential health benefits.³⁸⁰ Recently, the National Collaborating Centre for Environmental Health (NCCEH) produced two documents related to potential environmental health risks of floating^{381,382} and an overview of guidance and lack of regulation pertaining to these devices. A second literature review of microbial risks was also produced by Public Health Ontario.³⁸³

4.12.10.1 Design and Construction

Due to the unique nature of the FLOATATION TANK SOLUTION and the nature of use of FLOATATION TANKS, the typical system design criteria detailed in MAHC Section 4 are not appropriate. The MAHC provisions that are applicable are individually listed. NSF International developed criteria to test and certify FLOATATION TANK systems, components and related equipment; those criteria can be found in NSF CCS-12804.³⁸⁴ While developing and refining the proposed requirements for the MAHC, the CMAHC Floatation Tank Ad Hoc Committee identified areas of the CCS-12804 that are inconsistent with the MAHC proposals, which can cause confusion, and other areas to be considered for revision. Due to these inconsistencies and potential for further changes to CCS-12804, the Committee chose to specify only certain CCS-12804 provisions instead of requiring compliance and certification to the complete STANDARD at this time. Upon additional discussion and review of submitted comments, it was decided to remove the reference to CCS-12804 at this time while incorporating some of the specific provisions into the proposed requirements for the MAHC.

4.12.10.4 Floatation Tank Electrical Systems and Components

Electrical considerations and SAFETY pertaining to the equipment used in and around the salt solution was deemed extremely important. Therefore, the National Electrical Code was referred to and the FLOATATION TANK and room containing a FLOATATION TANK was deemed to be a wet and CORROSIVE environment with respect to electrical systems and components.

4.12.10.8 Disinfection

The CMAHC Ad Hoc Committee considered several factors that distinguish FLOATATION TANKS from other forms of recreational water when determining the minimum requirements for DISINFECTION. One key factor in disease transmission risk is that the potential routes of exposure are different than typical swimming POOLS. The following information is excerpted.^{385,386} “There are several aspects of FLOATATION TANKS and their typical user profile that may modify the risk of communicable disease compared to POOLS and hot tubs. Due to the high salinity and bitter taste of the solution, clients avoid ingestion or eye contact. Water is less likely to get in the ears as many facilities provide ear plugs, although some users prefer a plug-free experience. Clients are typically advised to protect small cuts with a BARRIER of petroleum jelly to prevent stinging, and are unlikely to float with open sores or wounds. Clients are also generally adults, thus reducing hygiene and fouling issues sometimes seen in other types of recreational water facilities caused by children with decreased bowel and bladder control. It should be noted that some Canadian float facilities do not exclude (and in some cases market toward) children. Furthermore, total daily BATHER load in a FLOATATION TANK is low (8–12 individuals) and constant (1–2 people at a time), such that operators do not need to adjust DISINFECTANT in response to changes in use. Clients are generally naked while floating, but there is no evidence as to whether swimwear significantly affects bacterial load or has any impact on urinary tract infections. Clients are asked or required to SHOWER before using the tank, which reduces pathogen inputs, as well as organic CONTAMINANTS that contribute to DISINFECTION BY-PRODUCT formation and decreased DISINFECTION efficiency. Finally, users SHOWER after their sessions to remove the salt, which should help to reduce infection risk. “These aspects of FLOATATION TANK use decrease the likelihood of ingestion and eye contact as routes of transmission compared to recreational water facilities. FLOATATION TANK users do remain potentially vulnerable to skin, genitourinary, and outer ear infections. Inhalation may represent another route of transmission, as some FLOATATION TANK models agitate the water vigorously between clients; it is unclear if this may lead to the formation of bioaerosols if pathogens are present in the water. Finally, the hydrodynamics of a FLOATATION TANK, specifically the stillness of both solution and client, may also positively or negatively affect the ability of pathogens to contact, adhere to, and invade the skin. Thus, despite mitigating circumstances, a number of questions remain regarding disease transmission between clients in float facilities.” Potential pathogens of concern, their ability to survive and/or thrive and corresponding acceptable DISINFECTION methods were also considered. Previous work conducted by NSF found that common indicator organisms were able to survive the highly saline conditions without reduction over the interval between two clients (15-30 min),

and with a less than 3-log reduction up to 24 hours later.^{387,388} Because pathogens can survive FLOATATION TANK SOLUTION over the short term, and because repeated use of the solution over many floats could further compromise water quality in a way that might promote pathogen presence, an effective sanitation system is necessary. FLOATATION TANK sanitation systems may include the use of:

- 1) a halogen (CHLORINE or bromine), typically with ultraviolet (UV) light and/or ozone (O₃),
- 2) O₃ with UV or H₂O₂, or 3) H₂O₂ with UV.

There is very limited data regarding the efficacy of these sanitation systems in FLOATATION TANKS specifically. Although two studies have examined the use of bromine and UV, the studies available provided limited detail regarding tank design and operation and did not provide sufficient experimental detail to assess efficacy.^{389,390} The most thorough evaluation of a FLOATATION TANK was carried out by NSF as part of the certification of an O₃ / UV system according to CCS-12804, which met the DISINFECTANT efficacy criteria.^{391,392} The CMAHC Ad Hoc Committee proposed that only ozone or ozone/UV combination systems be provided for DISINFECTANT, CHLORINE or bromine are not required, and use of hydrogen peroxide as a DISINFECTANT is prohibited in the MAHC. The following considerations provide rationale for this:

- CHLORINE or bromine are reportedly not EPA REGISTERED for use in FLOATATION TANKS;
- Hydrogen peroxide is not an EPA-registered DISINFECTANT or SANITIZER in recreational water. Based on data summarized^{393,394}, its use as a DISINFECTANT at the levels typically recommended for FLOATATION TANKS (50-100 pm) is unlikely to be effective. However, some operators use hydrogen peroxide as a water conditioner, with no claims of DISINFECTANT efficacy. This use is acceptable as long as its use is consistent with EPA label requirements.
- Ability to accurately test CHLORINE/bromine residuals in the salt solution is in question, particularly at concentrations lower than 2.5 ppm;³⁹⁵
- The use of FLOATATION TANKS is typically restricted to one person at a time, such that potential exposure to shed pathogens from other BATHERS, as is the case in POOLS or SPAS, does not occur during the individual float session;
- Routes of exposure (ingestion, inhalation, contact) are limited:
 - Ingestion (G.I. illness) is less likely due to manner of floating and palatability of tank water;
 - Inhalation (respiratory-*Legionella*) is likely minimal/reduced based on little or no agitation/aerosolization of tank water during use in most tank designs.
 - Contact with the skin and ear canal occurs, but eye contact unlikely or very short-lived due to extreme irritation of eyes by salt.
- Pathogens of concern may be able to persist/survive over short periods, but are unlikely to readily grow in the tank water;
- Ability to adequately DISINFECT between users using ozone/UV combination or ozone;
- Control of biofilm and/or slime through routine physical scrubbing and/or wiping surfaces and treatment by ozone/UV or ozone;
- Requiring ozone or ozone/UV DISINFECTANT systems only.
 - UV alone is not acceptable due to the demonstrated resistance of some viral pathogens to UV DISINFECTANT, even at relatively high doses.³⁹⁶ Furthermore, UV does not provide contact DISINFECTANT of surfaces at any other point in the system other than the UV cell itself. This is in contrast to O₃ treatment, which due to its relatively long half-life at 95°F/35°C (8 min³⁹⁷) could be expected to permeate all parts of the tank and plumbing.

Upon additional discussion, review of submitted comments and technical data, the proposal was amended to require either ozone or UV DISINFECTANT systems, not both. It appears that the limited number of viral pathogens that demonstrated resistance to UV alone, their routes of exposure (typically fecal/oral), and absence of any identified illness outbreaks from viruses associated with use of FLOATATION TANKS or SPA POOLS, which are similar in that ingestion of water is not typical, use of UV DISINFECTANT systems alone is allowable at this time.

4.12.10.9 Ventilation

There was discussion within the CMAHC Ad Hoc Committee about potential air quality concerns within the closed FLOATATION TANK during use, such as build-up of carbon dioxide or DISINFECTANT BY-PRODUCTS. However, there is insufficient information at this time to determine if, or to what extent, there may be a problem.

4.12.11 Other Aquatic Features

The industry continues to evolve with new AQUATIC FEATURES coming into the market place that are not yet specifically addressed in the MAHC or other CODES. Features such as climbing walls, inflatables, and play structures are now available for installation at AQUATIC FACILITIES. The intent of this section is to provide a basis for acceptance for installation and use of different AQUATIC FEATURES versus prohibition of installation and use of AQUATIC FEATURES not specifically identified/specified in the MAHC due to an absence of specific criteria. This allows an avenue to compliance until such a time that the MAHC is updated as appropriate with AQUATIC FEATURE specific criteria.

2018 Annex to the Model Aquatic Health Code

Scientific Rationale

OPERATION AND MAINTENANCE



5.0 Aquatic Facility Operation and Maintenance

5.1 Operating Permits

5.1.1 Owner Responsibilities

5.1.2 Operating Permits

5.2 Inspections

5.2.1 Preoperational Inspections

5.2.2 Exemptions

5.2.3 Variances

The permit issuing official may waive, in writing, any of the requirements of this CODE, and include the variance as a condition of the permit to operate, when it reasonably appears that the public health and SAFETY will not be endangered by granting of such a variance and adequate alternative provisions have been made to protect the health and SAFETY of the BATHERS and the public. The burden of providing the data and proof that any alternative provision is at least as protective as the CODE requirement is entirely on the permit holder.

5.3 Equipment Standards [N/A]

5.4 Aquatic Venue Operations and Facility Maintenance

5.4.1 Closure and Reopening

5.4.1.1 Closure

Short Closures

It is important for the QUALIFIED OPERATOR to be aware that when closed for even short periods of time, the AQUATIC VENUE water distribution system, including drinking fountains and other potable water sources, may become stagnated. It is important to adequately ensure that all AQUATIC FEATURES should be adequately flushed and DISINFECTED prior to reopening. Standing water, including closed AQUATIC VENUES, can be a source of mosquitoes if DISINFECTION is halted. Although mosquitoes can carry infectious pathogens such as those that cause dengue, malaria, and encephalitis, one of the most common mosquito-borne infections in the US is due to West Nile virus which can cause fever and encephalitis. One study demonstrated a link between abandoned residential swimming POOLS, increases in mosquitos, and West Nile virus infections³⁹⁸. Swimming POOLS should be DISINFECTED to prevent them from becoming public nuisance issues as mosquito breeding areas or SAFETY concerns. Additionally, closed POOLS can be a SAFETY concern, especially for small children. When the POOL is not drained or covered tightly to prevent entry, children may knowingly or accidentally enter the POOL and drown. Because of the slime that often builds on the wall of these abandoned POOLS, it may be impossible for those that enter the POOL to climb out. Abandoned POOLS may also have limited visibility so people falling in cannot be seen by other persons in the area. While fence BARRIERS or SAFETY covers can create a “safe condition” for the POOL, these methods will not prevent the potential mosquito problems mentioned above.

Long Closures

The closing of an AQUATIC FACILITY for less than 7 days is considered a temporary closure. A closure of more than 7 days is considered a long term closure. Both types of closure require certain maintenance activities when closing or reopening to ensure a safe environment for PATRONS.

Drain / Cover

POOLS that use a cover should refer to ASTM F1346-91. For POOLS where covers are not used or are not practical, access should be restricted and routine check of fence integrity is advised.

ASTM F1346-91 establishes requirements for SAFETY covers for swimming POOLS, SPAS, hot tubs, and WADING POOLS. When correctly installed and used in accordance with the manufacturer's instructions, this specification is intended to reduce the risk of drowning by inhibiting the access of children under 5 years of age to the water. For long term and seasonal closures, where no residual DISINFECTANT is maintained in the pipes, further research is

needed to understand the growth of biofilms during closure. More research is needed to develop protocols for removing biofilms in AQUATIC VENUES. If the AQUATIC VENUE system becomes non-operational, such as during a power outage, the AQUATIC VENUE should be cleared of BATHERS. Prior to reopening, the QUALIFIED OPERATOR should confirm that all systems are operational as required by the MAHC. For example, recoating DE filters will be necessary and it should be confirmed that feed pumps did not continue feeding chemicals during a RECIRCULATION SYSTEM shutdown that may lead to outgassing into the POOL when the system is re-started.

5.4.1.2 Reopening

The QUALIFIED OPERATOR should refer to previous inspection reports for more details on repairs or replacements needed, and any replacements or new items should be discussed with the regulatory authority to verify they comply with current CODE requirements. It is recommended that a model reopening checklist be developed in the future.

5.4.2 Preventive Maintenance Plan

A preventive maintenance plan is a necessary and important part of any AQUATIC FACILITY operation based on data showing 22.8% of POOL chemical-related events were due to equipment failure indicating they could have been prevented³⁹⁹. The best maintenance plan is one that follows the manufacturer's and POOL designer/engineer's recommendations for all equipment. A POOL maintenance plan is similar in many ways to the purchase of a new vehicle. With the purchase of a new vehicle, a manufacturer's maintenance schedule is included. The schedule lists the maintenance items that should be followed such as rotating tires and performing major tune-ups. Likewise, the QUALIFIED OPERATOR should perform an inventory of all equipment used in the AQUATIC FACILITY operation. For each piece of equipment, the QUALIFIED OPERATOR should develop a list and schedule of maintenance items. By following this maintenance schedule, the operator can help prevent costly repairs and breakdowns in the future. Replacing items before they breakdown may prevent system breakdowns that could lead to outbreaks or injuries. For example, a common breakdown leading to loss of DISINFECTION is a break in the tubing leading from feed pumps to the RECIRCULATION SYSTEM. Although inexpensive, lack of replacement has been implicated in outbreaks. AQUATIC FACILITIES need increased sophistication in plan maintenance and MONITORING.

5.4.2.2 Facility Documentation

This equipment inventory should contain information such as:

- Equipment name,
- Manufacturer and contact information,
- Local vendor/supplier & technical representative,
- Model number,
- Horsepower, GPM, & filter size,
- Year of manufacture,
- Original cost,
- Warranty, and
- Operating Manual.

Equipment may be cataloged by area, such as:

- DECK,
- Lifesaving,
- HYGIENE FACILITY,
- Filter System,
- Concession Stand, and
- AQUATIC FEATURES.

5.4.3 General Operations

5.5 Aquatic Venue Structure

5.5.1 Shape [N/A]

5.5.2 Access Ladders [N/A]

5.5.3 Color and Finish [N/A]

5.5.4 Walls [N/A]

5.5.5 Depth Markings

Existing AQUATIC FACILITIES should still adhere to the requirements of MAHC 4.5.19 for depth and NO DIVING MARKERS. Existing AQUATIC FACILITIES may have to resort to using non-permanent (i.e., painted) alternatives if not already installed, which will need to be maintained to ensure they are readable and legible

5.5.6 Pool Shell Maintenance

These sections of the CODE require repairs related to health and SAFETY such as if the CRACKS could cause trips, falls, lacerations, trap dirt and debris, or harbor algae or bacteria. It is still good operational practice to identify and MONITOR CRACKS that could lead to water loss and structural failure and consult a structural engineer for assessment as needed.

CRACKS exhibiting any of the following characteristics shall be evaluated by a structural engineer:

- 1) CRACKS with vertical displacement;
- 2) CRACKS of varying width;
- 3) CRACKS concentrated to a specific area;
- 4) CRACKS exposing any reinforcement;
- 5) CRACKS obviously recurring from previous patches;
- 6) CRACKS in corners;
- 7) CRACKS drawing a defined line; and
- 8) Surface CRACKING over $\frac{1}{8}$ inch (3.2 mm) in width.

5.6 Indoor / Outdoor Environment

5.6.1 Lighting

5.6.1.1 Lighting Maintained

5.6.1.1.1 Light Levels

System components will deteriorate and eventually need to be replaced, but lamp performance will continue to change prior to complete lamp failure. Indoor overhead lights, outdoor pole mounted lights, and underwater lighting are the key POOL light sources. Building lighting must also be maintained to provide safe AQUATIC FACILITY use, building and area security, and meet the aesthetic goals. Planned lighting maintenance includes group relamping, cleaning lamps, cleaning luminaires, and replacing defective components on a regular basis. Lamp lumen depreciation is a characteristic of all lamps. Each lamp type has a different lamp life, thus impacting your maintenance schedule. As lamps fail or burn out, the local light levels are decreased and the lighting uniformity is also affected. Luminaire surface deterioration and dirt accumulation may also occur and can reduce the light reaching the needed areas. During relamping and cleaning, inspect each luminaire for deterioration or damage. Repair or replace components and inspect and clean light FIXTURES and luminaires as needed to maintain required light levels. Consider regular group relamping combined with cleaning as part of an efficient and effective maintenance plan.

Basic steps for cleaning and relamping operations include the following:

- 1) Turn off electrical circuits and carefully remove lenses, diffusers, shields and/or lamps.
- 2) Dispose of replaced lamps and ballasts per state and federal guidelines.

- 3) Contact the EPA for more information.
- 4) Follow the light FIXTURE and lamp manufacturer's recommendations for cleaning, relamping, and maintaining each light in good condition.
- 5) Routinely MONITOR underwater lights for proper operation.

Windows and natural lighting need to be evaluated seasonally and throughout the operating day.

Light levels may also be altered by dirty windows. Ensure that windows are cleaned regularly to eliminate any buildup of material that would affect light transmission.

5.6.1.1.2 Main Drain Visible

The requirement for being able to see the main drain from POOLSIDE is a SAFETY issue. If QUALIFIED LIFEGUARDS or QUALIFIED OPERATORS cannot see the main drain, then they are unable to see a person on the bottom of the AQUATIC VENUE and unable to initiate rescue procedures. This is cause for immediate closure and rectification before re-opening. Please refer to the MAHC 6.6.3 for more information. The section also clarifies that mixed use AQUATIC FACILITIES (for example, AQUATIC FACILITIES with mechanical rides, catering facilities) may host evening events where lighting does not allow main drains to be visible but these AQUATIC VENUES must have ENCLOSURES and be closed to PATRON use.

5.6.1.1.3 Underwater Lighting

Recent high-profile electrocution incidents have highlighted the need to clarify underwater lighting requirements to prevent these incidents. A defect occurring in an electrical circuit operating at greater than the Low Voltage Contact Limit that is not GFCI protected can result in serious injury or an electrocution death of BATHERS.

5.6.1.2 Glare

In addition to discomfort, annoyance, interference, and eye fatigue, glare reduces the visibility of an object. Without clear vision, there are increased chances for accidents that can cause injuries or potential drowning. Glare can be from reflections as well as direct lighting problems.

5.6.1.2.1 Assessments

The AQUATIC FACILITY owner or LIFEGUARD SUPERVISOR may consider adjusting lifeguard positions to improve visibility.

5.6.1.2.1.1 Lifeguard Positions

The wording ensures that each lifeguard position as identified in the Zone of Patron Surveillance is evaluated appropriately and includes roving positions since it is not limited to just those position which have a fixed stand or 'station'.

5.6.2 Indoor Aquatic Facility Ventilation

Drains on AIR-HANDLING SYSTEM equipment should be tested before the system is started. It is important that the drain system be checked regularly to ensure that the condensate drain pan, drain connection, and piping are free from buildup or blockages. In cases where air handling equipment is intended for use with P-trap type drains, the P-trap must be kept filled manually if normal operation does not keep the P-trap filled. If not kept filled, sewer gases, and odors can enter the system.

5.6.2.8 Combined Chlorine Reduction

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 AQUATIC VENUES 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 DISINFECTION⁴⁰⁰.

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

5.6.3 Indoor/Outdoor Aquatic Facility Electrical Systems and Components

5.6.3.1 Electrical Repairs

NEC Article 225 provides installation requirements for outside branch circuits and feeders that run on (*or between*) structures or poles. NEC Article 680 applies to the construction and installation of electrical wiring for and equipment in or adjacent to all swimming, wading, therapeutic, and decorative POOLS; fountains; hot tubs; SPAS; and hydro-massage bathtubs, whether permanently installed or storable, and to metallic auxiliary equipment, such as pumps, filters, and similar equipment.

5.6.3.2 Electrical Receptacles

NEC Article 680.22, "General Circuitry Pool Pump Motors," states that "all 15- and 20-amp, single-phase, 125-volt or 240-volt outlets supplying pool pump motors shall have GFCI protection." 29 CFR 1910.304, "Wiring Design and Protection," applies to temporary wiring installations that are used during construction-like activities, including certain maintenance, remodeling, or repair activities, involving buildings, structures or equipment.

5.6.3.3 Ground-Fault Circuit Interrupter

GFCI testing should follow the manufacturer's recommendations. However, the minimum test procedure should include:

- 1) Testing personnel must wear shoes during the entire test. Where exposed terminals may be present, or where conditions warrant, other PPE may be required.
- 2) A suitable indicating test load should be connected to the circuit under test, and remain so for the duration of the test.
- 3) Test personnel should press the "TEST" button on the GFCI device.
- 4) The test load should then be observed to have ceased operation due to loss of electrical power.
- 5) Test personnel should next press the "RESET" button on the GFCI device.
- 6) The test load should then be observed to have resumed operation.
- 7) Where any of the conditions specified in steps (b) through (f) fail, the GFCI circuit must then be inspected and tested. Replace the GFCI device as necessary.

Chemical-Free Storage

POOL chemicals, fertilizers, salt, oxidizing cleaning materials, and other CORROSIVE MATERIALS should not be stored in any INTERIOR SPACE containing electric light FIXTURES, panel boards, fuses, circuit breakers, disconnects, motors, motor overloads, bonding conductors, or similar devices.

- **Exception (1):** Otherwise approved CHEMICAL STORAGE AREAS having light FIXTURES which are approved for use in CORROSIVE atmospheres, and which serve the CHEMICAL STORAGE AREA only, should be acceptable.
- **Exception (2):** Otherwise approved CHEMICAL STORAGE AREAS having a light switch or switches approved for use in CORROSIVE atmospheres, and which serve the CHEMICAL STORAGE AREA only, should be acceptable.
- **Exception (3):** Otherwise approved CHEMICAL STORAGE AREA containing small motors and the associated controllers, such as those for exhaust-blowers and peristaltic pumps should be acceptable where such motor circuits are protected by GFCI.
- **Exception (4):** Otherwise approved CHEMICAL STORAGE AREA containing devices CERTIFIED, LISTED, AND LABELED for use in interior POOL-CHEMICAL STORAGE AREAS should be acceptable.

- **Exception (5):** Otherwise approved CHEMICAL STORAGE AREAS containing devices CERTIFIED, LISTED, AND LABELED for use in CORROSIVE atmospheres should be acceptable where approved by the AHJ.

Flammable liquids and flammable gases should not be stored in any INTERIOR SPACE containing electric light FIXTURES, panel boards, fuses, circuit breakers, disconnects, motors, motor overloads, bonding conductors, or similar devices, unless such devices comply with Article 500 of the NEC, or with the relevant local CODES.

POOL chemicals, acids, fertilizers, salt, oxidizing cleaning materials, and other CORROSIVE or oxidizing chemicals should not be stored in INTERIOR SPACES where electrical conduits enter or pass through the space.

- **Exception (1):** Otherwise approved CHEMICAL STORAGE AREAS into which conduits enter or pass through should be acceptable, where such conduits
 - Are sealed where they enter and exit the STORAGE space, and
 - Are listed as corrosion resistant, and
 - Serve only approved loads in the STORAGE space itself.
- **Exception (2):** Otherwise approved CHEMICAL STORAGE AREAS containing conduits approved for use in CORROSIVE atmospheres should be acceptable if approved by the AHJ.

Where an interior CHEMICAL STORAGE SPACE was previously approved for STORAGE of POOL chemicals, acids, fertilizers, salt, oxidizing cleaning materials, other CORROSIVE or oxidizing chemicals, or flammable liquids or gases and will continue to be used for such STORAGE, any replacement electrical parts or devices should be of the same type as the original equipment, or should be CERTIFIED, LISTED, AND LABELED for such use. No new electrical devices or equipment should be installed in an interior CHEMICAL STORAGE SPACE used for STORAGE of POOL chemicals, acids, fertilizers, salt, oxidizing cleaning materials, or flammable liquids or gases without re-inspection by the AHJ.

Isolation Of Chemical Storage Areas

An interior STORAGE space used for storing POOL chemicals, fertilizers, salt, oxidizing cleaning materials, other CORROSIVE or oxidizing chemicals, or pesticides must be kept in ISOLATION from other INTERIOR SPACES, except for entry, egress, material transport, or alarm testing. The period of each instance of entry, access, or alarm testing should not exceed 15 minutes. The sum of the periods of all instances of breach of ISOLATION should not exceed 1 hour in each 24-hour period. Where the ISOLATION of an interior STORAGE space containing such chemicals from other INTERIOR SPACES containing COMBUSTION DEVICES depends on an interior door, such door should be gasketed to prevent the passage of air, fumes, or vapors, and should be equipped with an automatic door closer and an alarm that will give notice if the door remains open for more than 5 minutes. Function of this alarm should be confirmed monthly as part of scheduled maintenance. Failures of door gasketing, or of the door closer, or of the alarm should be repaired immediately.

Unsealed Openings

Where any unsealed openings exist between an interior STORAGE space used for POOL chemicals, acids, fertilizers, salt, or CORROSIVE or oxidizing chemicals and any other INTERIOR SPACE containing electrical equipment, the air pressure in the CHEMICAL STORAGE SPACE should be maintained at a level low enough to insure that all air flow should be toward the CHEMICAL STORAGE SPACE. This pressure difference should be maintained by a continuously operating exhaust system used for no other purpose than to remove air from the CHEMICAL STORAGE SPACE. Function of this exhaust system should be MONITORED continuously by a pressure switch and alarm. Function of the pressure switch and alarm should be confirmed monthly as part of scheduled maintenance. In the event of failure of the exhaust system or of the alarm, repairs should be done immediately. In any space containing electrical equipment, ambient conditions such as temperature, humidity, and maximum concentrations of chemical fumes or vapors, or of flammable fumes or vapors should be continuously maintained to meet the operational requirements of installed electrically powered equipment. Labels or other marks indicating the circuits served by fuses, circuit breakers, and disconnect switches should be maintained in a condition readable by a person unfamiliar with the function of the circuits. For spaces containing fuses, circuit breakers, electric motors, or motor-operated loads, the recommended minimum illumination capability should be maintained as part of the scheduled monthly maintenance. STORAGE should not interfere with the largest of the minimum working clearances specified by the NEC, the equipment manufacturer, 29 CFR 1910, or by local CODES or regulations.

Re-lamping

Re-lamping operations within 20 feet (6.1 m) horizontally of the nearest inside edge of a POOL, SPA, FLUME, WATERSLIDE, or other open AQUATIC FEATURE should be carried out in such a way as to minimize the likelihood of lamp breakage. New lamps should be kept in their packing until just before installation. Old lamps should be packed immediately upon removal into a suitable container to prevent breakage. New lamps should not be stored in an interior STORAGE space used for POOL chemicals, fertilizers, salt, or other CORROSIVE or oxidizing chemicals. Neither new lamps nor old lamps should be stored in the INDOOR AQUATIC FACILITY, SHOWER room, locker room, or hallways. Where visible or accessible, any required bonding jumpers should be visually inspected for damage, breaks, looseness, or corrosion quarterly as part of scheduled maintenance. Where any doubt exists concerning the condition of bonding jumpers, they should be inspected and, if necessary, the effectiveness of such jumpers should be tested.

5.6.3.4 Grounding

The purpose and objective of NEC Article 250 - Grounding is to insure that the electrical system is safe against electric shock and fires by limiting the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and a GROUND-FAULT (*line-to-case fault*). The rules contained in NEC Article 250 identify the installation methods that must be followed to insure a safe electrical installation. NEC Article 680 applies to the construction and installation of electrical wiring for and equipment in or adjacent to all swimming, wading, therapeutic, and decorative POOLS, fountains, hot tubs, SPAS, and hydromassage bathtubs (*whether permanently installed or storable*) and to metallic auxiliary equipment, such as pumps, filters, and similar equipment.

5.6.3.6 Extension Cords

5.6.3.6.3 Exception

The intent is to prevent the extension cord from reaching the water.

5.6.3.6.6 Compliance

- See 29 CFR 1910.304 (b)(2) at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9881

5.6.3.8 Communication Devices and Dispatch Systems

NEC Article 800 covers multi-purpose and communication cable. Multi-purpose cable is the highest listing for a cable and can be used for communication, Class 2, Class 3, and power-limited fire protective cable. Communication cable can be used for Class 2 and Class 3 cable and also as a power-limited fire protective cable with restrictions.

5.6.4 Facility Heating

5.6.4.1 Facility Heating

5.6.4.1.1 Maintenance and Repair

There are a number of CODES which can be consulted. These include but are not limited to the NFPA 54, NEC, and certain building CODES.

5.6.4.1.2 Defects

If inspection shows excessive fouling of air filters before the cleaning or replacement period has ended, that period should be reduced to prevent overloading of filters. Filters that become clogged with dirt, mold, or other CONTAMINANTS can become a source of increased operating costs and poor air circulation. In addition to the reduction of system effectiveness, which can result in costly repairs, air-borne CONTAMINANTS can be spread as a result of improper air handling.

5.6.4.1.3 Temperature

The air temperature of an indoor AQUATIC VENUE should be controlled to the original specifications where possible. Where this is not possible, the air temperature of an INDOOR AQUATIC FACILITY should be controlled so as to prevent unexpectedly high levels of evaporation and to prevent condensation of water onto surfaces not designed for condensation. Particular care should be taken to prevent the condensation of water inside INDOOR AQUATIC VENUE building surfaces such as walls and ceilings. Please note that this CODE only looks at the part of

the facility where the water “vessel” is located and not at other areas of buildings (*the building CODE would cover*). Particular attention needs to be given to the prevention of algae and mold growth on surfaces.

5.6.5 First Aid Room [N/A]

5.6.6 Emergency Exit

5.6.7 Plumbing

5.6.7.1 Water Supply

The potable water pressure should be maintained to enable the AQUATIC VENUE and all other water using PLUMBING FIXTURES to operate to design specifications.

5.6.7.3 Waste Water

In some AQUATIC FACILITIES, backwash water may be recycled for other purposes instead of wasted in order to conserve water. This water must be treated in accordance with local CODE requirements prior to being re-used. Backwash water is likely to be routinely contaminated with pathogens so its use should be carefully considered and health issues planned for prior to re-use. It should not be re-used in AQUATIC VENUES, but may be used in landscaping or other non-potable water uses with AHJ approval.

5.6.7.4 Water Replenishment

See MAHC Annex Section 4.7.4 for more information. A minimum of 4 gallons (15 L) of water per BATHER per day must be discharged from the POOL, but a volume of 8 gallons (30 L) per BATHER per day is recommended. Backwash water will count toward the total recommended volume of water to be discharged, but evaporated water will not count since inorganic CONTAMINANTS (*e.g., salts and metals*) and many organic CONTAMINANTS (*e.g., sweat and urine*) can simply be concentrated as water evaporates. Backwash water or other discharged water may not be returned to the POOL without treatment to reduce the total organic carbon concentration, DBP levels, turbidity, and microbial concentrations less than the limits set for tap water by the EPA.

5.6.8 Solid Waste

5.6.9 Decks

5.6.9.1 Food Preparation and Consumption

5.6.9.1.2 Eating and Drinking

Eating and drinking in AQUATIC VENUE areas may expose BATHERS to CONTAMINANTS. Food particles that fall into the POOL not only contribute to contamination burden, but may also affect POOL DISINFECTION. Additionally, contamination can occur through ingestion. Alcohol increases urine output and therefore creates more chloramines and other DBPs if BATHERS do not regularly get out of the POOL to urinate. Regular bathroom breaks should be considered to reduce urination in the AQUATIC VENUE that allows designated areas like “swim-up bars” that may increase POOL urination and create compliance issues with MAHC combined CHLORINE levels. However, at this time, the MAHC does not have data suggesting that AQUATIC VENUES containing “swim-up bars” have any more issues with water quality compliance issues than those AQUATIC VENUES that do not. AQUATIC VENUES considering “swim-up” bars need to be aware that these areas may also increase the risk of drowning caused by excessive alcohol consumption and should include this thinking in lifeguard training and in-service training. Currently the majority of states do not allow swim-up bars; however, Ohio, Hawaii, Texas, and a few local jurisdictions do, mostly in resort areas. The MAHC defers to local jurisdictions to assess and determine potential risks. Another topic to consider is nursing mothers and SAFETY and health risk to infants. While many mothers consider nursing in the POOL a pleasant experience for the baby there is a definite SAFETY risk for the infant from hypothermia and a health risk from potentially ingesting contaminated POOL water that may contain organisms such as *Cryptosporidium*.

- For more information about this topic, see CDC Healthy Swimming discussion at: <http://www.cdc.gov/healthywater/swimming/protection/breastfeeding-in-pools.html>

5.6.9.2 Glass

Glass is prohibited in the POOL DECK area to prevent injuries to PATRONS. Most BATHERS and PATRONS are bare foot, so stepping on glass can cause serious injuries. If a glass container breaks in the AQUATIC VENUE vicinity it

could potentially fall into the water. Clear glass is virtually invisible in water and is difficult to remove. The only way to ensure all broken glass is removed from POOL water is to thoroughly drain and clean the POOL structure. Depending on the size, draining and cleaning an AQUATIC VENUE can cost thousands of dollars.

5.6.9.3 Deck Maintenance

5.6.9.3.1 Free From Obstructions

DECKS should always be kept clear of obstructions to preserve space that may be needed for rescue efforts. Obstructions also cause tripping hazards and can lead to falls and serious injuries. Attention must also be given to potential fall hazards from slippery DECK areas.

5.6.9.3.3 Vermin

It is important to maintain these areas free from debris, vermin, and vermin harborage. Animals can carry diseases which could be transmitted through bites or contact with bodily fluids or feces.

5.6.9.3.4 Original Design

Proper maintenance of surfaces will help prevent abrasions to BATHERS and biofilm growth.⁴⁰¹

5.6.9.3.4.1 Crack Repair

CRACKS in the DECK shall be part of the daily inspection process and be repaired when they might increase the potential for injury. See MAHC 5.5.6.1.1, 5.5.6.1.2, and 5.5.6.1.3 and MAHC Annex 5.5.6, "Pool Shell Maintenance."

5.6.10 Aquatic Facility Maintenance

5.6.10.1 Diving Boards and Platforms

Slip resistance can be accomplished by ensuring that the coefficient of friction is greater than or equal to that specified in MAHC 4.8.1.4.

5.6.10.3 Starting Platforms

Starting blocks are designed for use by trained persons or those under the supervision of a qualified individual. Use by untrained, unsupervised individuals can lead to serious injury. Since they can be an attraction for unqualified BATHERS to use, starting block use needs to be clearly prohibited by signage, covers, or other BARRIERS/deterrents. Since BATHERS are known to ignore signs or BARRIERS prohibiting use, the safest approach for removable blocks is to remove them and store elsewhere when not in use.

5.6.10.5 Fencing and Barriers

This wording refers to alarms associated with open gates or BARRIERS. It is not meant to include burglar or fire alarms.

5.6.10.6 Aquatic Facility Cleaning

In-POOL cleaning systems must be periodically inspected to make sure they retract and stay flush with the floor.

5.7 Recirculation and Water Treatment

5.7.1 Recirculation Systems and Equipment

5.7.1.1 General

The MAHC does not allow shut down of the RECIRCULATION SYSTEM during closure times since uncirculated water would soon become stagnant and loose residual DISINFECTANT likely leading to biofilm proliferation in pipes and filters. This would likely compromise water quality and increase the risk to BATHERS. MAHC 4.7.1.10.5 describes turndown system design. The flow turndown system is intended to reduce energy consumption when AQUATIC VENUES are unoccupied without compromising water quality. A turbidity goal of less than 0.5 NTU has been chosen by a number of United States state CODES (*e.g., Florida*) as well as the PWTAG and WHO. The maximum turndown of 25% was selected to save energy while not necessarily compromising the ability of the RECIRCULATION SYSTEM to remove, treat, and return water to the center and other extremities of the POOL. Additional research in this area could identify innovative ways to optimize and improve this type of system and that more aggressive turndown rates are acceptable.

5.7.1.1.3 Gutter / Skimmer Pools

The recommendation for gutter or SKIMMER POOLS with main drains to have the majority of the water (*at least 80% of the recommended recirculation flow*) be drawn through the POS and no greater than 20% through the main drain during normal operation is based on subsurface distribution of bacteria data that showed most POOLS had higher surface concentrations of bacteria.⁴⁰² For the 65 POOLS examined, surface concentrations of bacteria were an average of 3.4 times greater at the surface. However, about 30% of the POOLS showed the opposite trend with higher subsurface concentrations, which is why some operational flexibility is provided with these values. For reverse flow (*upflow*) POOLS, 100% of the recommended circulation flow should be through the POS, which is consistent with the German DIN Standards.⁴⁰³ Efficient removal of surface water is critical for maintaining water quality because surface water contains the highest concentration of pollutants from body oils, sunscreens, as well as other chemicals or particles that are less dense than water. Bacteria appear to follow the same trend in most cases⁴⁰⁴. The distribution of CHLORINE-tolerant pathogens like *Cryptosporidium* is not known at present. The majority of the organic pollution and contamination is concentrated at or near the surface irrespective of the mixing effects of the circulation.

5.7.1.3 Inlets

During regular seasonal operation following initial adjustments, INLETS should be checked at least weekly so that the rate and direction of flow through each INLET has not been changed substantially from the original conditions that established a uniform distribution pattern and facilitated the maintenance of a uniform DISINFECTANT residual throughout the entire facility without the existence of dead spots. A tracer test (*e.g., with a sodium chloride tracer injected on the suction side of the pump*) should be conducted annually at startup and documented to quantitatively assess distribution pattern in the POOL. An amount of salt sufficient to increase the baseline conductivity by at least 20% should be added over a 1 minute period, and the conductivity or TDS should be measured at 1 minute intervals until the conductivity increases by 20% and/or stops changing for ten consecutive readings after an initial increase. Samples may also be taken at the corners, center, and bottom of the POOL (*via a sample pump with the POOL unoccupied*) in small labeled containers for later measurement to increase the amount of information available to assist in interpreting the results. Increases greater than predicted by the amount of salt added to the POOL volume indicate poor mixing. Areas with conductivities lower than in the return stream at the time the sample was collected are likely to be areas with poor recirculation flows.

Note: It is possible to do a tracer test, which is quantifiable in terms of salt concentration ratios and/or time required to reach equilibrium concentration near the filter.

5.7.1.6 Piping

Winterization may involve dropping the water level below the level of the INLETS, blowing or draining all of the water out of the pipes, adding antifreeze, and closing off both ends. Pipes should be drained or winterized in regions where freezing temperatures are expected to be reached inside of the pipes. This should not be done with car antifreeze, and the antifreeze should not be toxic to humans.

5.7.1.8 Flow Meters

Flow meters are important for the maintenance of proper filtration, backwashing, and recirculation flow rates. It is also feasible to save money on electrical costs by using the flow meter to MONITOR and adjust the speed of the pump.

5.7.2 Filtration

5.7.2.2 Granular Media Filters

5.7.2.2.4 Backwashing Frequency

Backwashing frequency is important for multiple reasons. First, solids attach more strongly to the filter media over time and can be more difficult to remove following infrequent backwashing. Secondly, the organic particles (*e.g., skin cells*) held in the filter in contact with FREE CHLORINE can break down over time and produce DBPS and/or combined CHLORINE. The potential to form “mudballs” also increases with solids loading inside of a filter and can cause filter failures. The preceding items are the rationale for requiring backwashes at manufacturer-prescribed pressure losses through the filter. Some data suggests tainted backwash water remains inside of the filter at the conclusion of the backwash procedure and therefore should be wasted to drain for at least the first 2 minutes after restarting.

5.7.2.2.4.1 Backwash Scheduling

Backwashing while PATRONS are in the water is not recommended. First, the MAHC requires that RECIRCULATION SYSTEMS are running at all times that an AQUATIC VENUE is open for BATHER use. Second, with no interlock in place, stopping recirculation while inadvertently continuing chemical feed pumps can cause a build-up of acid and CHLORINE product in the lines that leads to CHLORINE gas production. When the RECIRCULATION SYSTEM is turned back on, the risk increases dramatically for a CHLORINE gas plume being delivered into the AQUATIC VENUE causing injury to BATHERS and initiating an emergency response^{405,406}. As a result, there have been frequent occurrences of CHLORINE gas exposure following the restart of the recirculation pump while BATHERS are in the POOL. This underscores the need for BATHER evacuation of the AQUATIC VENUE prior to restart of recirculation, and waiting 5 minutes to check for potential gas release before allowing BATHERS in to the water, to prevent potential exposure to CHLORINE gas. Exceptions to this would be if an AQUATIC VENUE has multiple filters and an individual filter can be taken off line without shutting down the RECIRCULATION SYSTEM and there is no chance of overfeeding chemicals that may lead to outgassing events or other chemical mixing emergencies.

5.7.2.2.7 Filtration Enhancing Products

Coagulants should be used with caution due to potential for filter bed fouling. Maintaining records of clean bed headloss is recommended to help detect problems of filters not being adequately cleaned via backwashing. If a facility decides to use coagulants, they should be used continuously. Not using coagulants when the water is clear to save money will significantly impair the capabilities of the filters to remove pathogens like *Cryptosporidium* and *Giardia*.

5.7.2.3 Precoat Filters

5.7.2.3.2 Return to the Pool

In closed-loop mode, it will be necessary to charge the media slurry to the suction side of the pump or precoat tank, prior to closing down the loop and putting the system into recirculation. Precoating of a filter typically takes 5 to 10 minutes. At the end of the precoat cycle, the discharge out of the filter should be clear and free of filter media. If the discharge is not clear, the filter should be opened, inspected, and repaired as necessary.

5.7.2.3.3 Operation

When flow or pressure is lost in the filter, the precoat layer may become unstable and fall off of the filter septum. To reduce the likelihood of debris and CONTAMINANTS being returned to the POOL, it is recommended that prior to restarting the filter, it should be backwashed and/or cleaned and the precoat re-established with new filter media in a closed loop recirculation mode or with water wasting until the discharge of the filter is clear to minimize the potential of media or debris returning to the POOL. It is important that flow not be interrupted after the precoating process is completed and the flow out of the filter is redirected from the recirculation or waste piping back to the POOL. It is acceptable to open and close valves on the filter effluent stream as long as the closed valves are opened first so that the filter effluent water can flow continuously. Allowing the media to fall off of the filter septum decreases the capability of the filter to remove particles. The critical importance of always cleaning the filter and replacing the media when the flow is interrupted for any reason is related to uneven recoating permitting pathogen passage as well as fouling of the media support layers.⁴⁰⁷

5.7.2.3.4 Cleaning

Septum covers should be properly cleaned and inspected to maintain proper performance of precoat filters. Filters should be backwashed following a significant drop in the flow rate or when the pressure differential across the filter is greater than 10 pounds per square inch (69.90 KPa). Vacuum-type precoat filters should be cleaned when the vacuum gauge reading increases to greater than 8 inches (20.3 cm) of mercury or as recommended by the manufacturer. If after precoating with fresh media, the filter pressure does not return to the normal initial starting pressure noted on filter start-up, it would be advisable to disassemble the filter and clean the elements (*septum covers*) per the filter manual. Septum covers should be cleaned or replaced when they no longer provide effective filtration or create a friction loss preventing maintenance of the recommended recirculation rate. Water and spent media should be discharged in a manner approved by the appropriate regulatory agency.

5.7.2.3.6 Bumping

Bumping is the act of intentionally stopping the filter and forcing the precoat media and collected CONTAMINANTS to be removed from the filter septum. Bumping may impair pathogen removal and could facilitate the release of pathogens previously trapped in the filter. Therefore, bumping should be performed in accordance with the manufacturer's recommendations. Prior to restarting a bumped filter, it is recommended that the precoat be re-established in a closed loop recirculation mode or with water wasting until the discharge of the filter is clear to minimize the potential of media or CONTAMINANTS returning to the POOL. Pending future research, bumping is strongly discouraged in any precoat filter application where pathogen removal is a concern. Bumping may impair pathogen removal as pathogens once trapped at the surface of the cake could be re-positioned close to the septum and penetrate the filter during operation.⁴⁰⁸ Cyst-contaminated water used for precoating filters led to much higher cyst concentrations in the filter effluent.⁴⁰⁹ Precoat filters have been demonstrated to remove greater than 99% of the OOCYSTS. Using clean precoat media to precoat filters as well as maintaining continuous flow is recommended.^{410,411,412}

5.7.2.3.7 Filter Media

Continuous filter media feed (*or body-feed*) can be used to increase the permeability of the cake, maintain flow, and extend cycle length as it becomes coated with debris. Body-feed is filter media added during the normal filtration mode on a continuous basis. The amount of body-feed used is dependent upon the solids loading in the POOL. Turbidity is the best available method to quantify and estimate solids loading. For filter influent turbidities greater than 1.5 NTU, body-feed may be beneficial with addition rates ranging from 1.0 to 4.0 ounces of DE per square foot of filter area per day dependent on the solids loading in the POOL. The lowest effective concentration of suspension should be used in a body-feed system. The concentration of the suspension may not exceed 5% by weight. The body-feed system head and lines should be flushed once every 15 minutes for at least 1 minute to assure proper and continuous operation. Water from the discharge side of the recirculation pump may be used. If connection is to a potable water supply line, the supply line should be equipped with an approved BACKFLOW prevention device.

Precoat media should normally be fed into the filter at a concentration not to exceed 5% by weight. Since perlite is approximately half the density of DE, half of the weight of perlite will achieve a similar depth of media inside of the filter as shown in MAHC Annex Table 5.7.2.3.7.1.

Table 5.7.2.3.7.1: Required Use Rates for Precoat Media

Media Type	Amount	Approximate Precoat Depth
DE	1.0-2.0 lb/10 ft ² (453.59 – 907.18 g/0.93 m ²)	¹ / ₁₆ – ¹ / ₈ inch (1.59 mm – 3.18 mm)
Perlite	0.5 – 1.0 lb/10 ft ² (226.80 – 453.59 g/0.93 m ²)	¹ / ₁₆ – ¹ / ₈ inch (1.59 mm – 3.18 mm)

5.7.2.3.7.1 Diatomaceous Earth

Drinking water applications typically recommend using DE at application rates of 0.2 pounds per square foot (*1 kg/m²*).⁴¹³ This practice seems to be based on research showing that the removal of 9-micron (*Giardia-sized*) microspheres increased from greater than 99% to greater than 99.9% as the precoat amount increased from 0.5 to 1 Kg/m².⁴¹⁴ Under the range of conditions tested, Logsdon and coworkers⁴¹⁵ found that the amount of DE had a greater impact on microsphere removal than did the grade of DE.

Alum-coated DE has been shown to significantly improve the removal of turbidity and bacteria not normally removed by DE filters.⁴¹⁶ Logsdon⁴¹⁷ reported that alum could be added at 0.05 gram of alum as Al₂(SO₄)₃· 14 H₂O per 1 gram of DE in a slurry to form a precipitate on the surface to enhance performance.

5.7.2.4 Cartridge Filters

5.7.2.4.1 NSF Standards

Cartridge filter elements should be cleaned (*or replaced*) when the differential pressure across the filter exceeds 10 psi (68.9 KPa). Every cartridge filter should have two sets of cartridges. This will allow for one set to be in use while the other is being cleaned (*soaking and drying are recommended*).

5.7.2.4.2 Filtration Rates

The 0.375 GPM per square foot (0.26 L/s/m^2) maximum design flow rate is acceptable, but an allowance is necessary to accommodate irreversible fouling of cartridges (*i.e., cartridges that do not recover 100% of the original capacity when cleaned after fouling*). Systems designed for a given TURNOVER TIME with a filter flow rate of 0.375 GPM per square foot (0.26 L/s/m^2) would not be in compliance if partially fouled cartridges dropped the flow rate to 0.30 GPM per square foot (0.20 L/s/m^2). Therefore, an acceptable operating range is provided beyond which cartridge replacement would be necessary.

5.7.2.4.3 Filter Elements

Cartridges should be cleaned when the gauge pressure differential is 10 psi (68.9 KPa) and in accordance with manufacturer's instructions. Cleaning equipment should include a soaking container properly sized to immerse the filter elements, a rinsing area with proper drainage, and a drying area protected from contamination (*e.g., birds and insects*). New filters do not regain 100% of their capacity. Perhaps only about 80% of the capacity is recoverable, regardless of the treatment. If the recommended design flow rate exceeds 80% of the maximum flow allowed on the filter, the filter may be undersized.

5.7.2.4.3.1 Cleaning Procedure

Facilities with cartridge filters are recommended to have the equipment on-site to clean the cartridges. This includes a basin or tub large enough to immerse the entire cartridge. Water from the cleaning and soaking process must be discharged to the sanitary sewer. Proper cleaning is critical. Failure to clean the cartridge properly can lead to disease outbreaks.

How to Clean Cartridge Filters:

- 1) **RINSE THOROUGHLY:** Rinse the cartridge of as much dirt and debris as possible by washing inside and out with a garden hose and spray nozzle.
 - **DO NOT** use a pressure washer. High flow/pressure can drive the dirt into the interior and permanently damage the cartridge. It can also aerosolize pathogens in filter.⁴¹⁸
- 2) **DEGREASE:** Cartridge filters need to be degreased each time they are cleaned. Body oil, suntan oil, cosmetics, hair products, and/or algae and biofilms can form a greasy coating on the filter pleats, which will clog the pores and reduce the filter capacity.
 - Soak the cartridge overnight in:
 - Filter cleaner/degreaser, or
 - A solution of water with 1 cup (236.6 g) of TSP (*tri-sodium phosphate*), or
 - One cup (236.6 g) of automatic dishwashing detergent per 5 gallons (3.8 L) of water.
 - **Never use muriatic acid or products with acid in them prior to degreasing. Acid may permanently set the grease and ruin the cartridge.**
- 3) **RINSE THOROUGHLY**
- 4) **SANITIZE:** To remove or prevent biofilms, algae, and bacteria growing on the cartridge, add 1 quart (0.95 L) of household bleach per 5 gallons (19 L) of clean water and soak 1 hour before rinsing.
- 5) **RINSE:** Remove the clean cartridge from the SANITIZATION soak water and rinse thoroughly with a hose.
- 6) **DRY:** After the filter is cleaned and degreased, it should be allowed to dry completely. Some bacteria (*e.g., Legionella spp.*) that survive the cleaning process can be killed by drying. Do not allow the filter to become contaminated with dirt or soil after it is cleaned. Put the cartridges in a clean plastic trash bag if they are to be transported and the original boxes are not available.
- 7) **ACID WASH – ONLY IF NECESSARY:** Excessive calcium or mineral deposits on the filter media can be cleaned with a 1:20 solution of clean water and muriatic acid. Put a few drops of muriatic acid on the filter. If it foams, it might need to be acid washed. Very few filters need to be acid washed.

5.7.2.4.3.3.2 Pressure Washer

A pressure washer should not be used because high flow/pressure can drive the dirt into the interior and permanently damage the cartridge or can aerosolize pathogens in the filter biofilm, which expose and infect workers when cleaning the cartridge filters in an enclosed space.⁴¹⁹

5.7.3 Water Treatment Chemicals and Systems

Certification, listing, and labeling is required to ensure chemicals used in recreational water treatment have been evaluated including analysis for potential CONTAMINANTS of the product.

5.7.3.1 Primary Disinfectants

5.7.3.1.1 Chlorine (Hypochlorites)

Although CHLORINE and bromine are the only primary DISINFECTANTS allowed at this time, future research may produce other acceptable primary DISINFECTANTS.

5.7.3.1.1.2 Minimum FAC Concentrations

It is necessary to ensure that FAC is maintained at or above the 1.0 ppm (mg/L) minimum level at all times and in all areas of the POOL. Because CHLORINE efficacy is reduced in the presence of CYA, higher FAC levels may be necessary for POOLS using CYA or stabilized CHLORINE.

The minimum FAC level of 1.0 ppm (mg/L) for swimming POOLS is well-supported by available data. The CDC data indicate that a 1.0 ppm (mg/L) FAC residual can provide effective DISINFECTION of most pathogens other than *Cryptosporidium*.⁴²⁰

Table 5.7.3.1.1.2: Germ Inactivation of Chlorinated Water

Germ	Time
<i>E. coli</i> O157:H7 Bacterium ⁴²¹	Less than 1 minute
Hepatitis A Virus ⁴²²	5-20 minutes
<i>Giardia</i> Protozoan* ⁴²³	About 45 minutes
<i>Cryptosporidium</i> Protozoan* ^{424,425}	About 15,300 minutes (10.6 days)

*Laboratory testing results using chlorine demand free water with 1 ppm (mg/L) chlorine at pH 7.5, 77°F (25 °C) and in the absence of cyanuric acid.

Substantial laboratory data shows that kill times for microbial CONTAMINANTS are increased in the presence of CYA. However, the precise impacts on CT INACTIVATION VALUES in a swimming POOL environment are not well-established (see MAHC Annex Section 6.5.3.2.1 for discussion of CYA impact on *Cryptosporidium* inactivation when conducting a diarrheal fecal incident response). The impact on CT INACTIVATION VALUES is mostly related to the HOCl concentration that can be calculated using equilibrium constants for CYA. In general, studies show that the presence of CYA up to 50 mg/L increases CT INACTIVATION VALUES under demand free conditions, and the amount of this increase depends upon the pH and the ratio of CYA to AVAILABLE CHLORINE. Studies suggest that this effect is mitigated with the addition of ammonia nitrogen as low as 0.05 mg/L by producing monochloramine which, although a weaker DISINFECTANT than HOCl, remains unbound to CYA. Swimming POOL survey data demonstrates that 1.0 ppm (mg/L) FAC provides acceptable bacteriological quality⁴²⁶. However, another paper suggests that FREE CHLORINE levels significantly higher than 1.0 ppm (mg/L) may be required. Based on data collected from seven chlorinated POOLS, Ibarluzea et al. predicted that 2.6 ppm (mg/L) is needed “in order to guarantee, with a probability of 90%, the acceptability of bathing water at indoor chlorinated swimming pools.”⁴²⁷ A minimum FAC level (3.0 ppm (mg/L)) for SPAS addresses the relatively higher THEORETICAL PEAK OCCUPANCY, higher temperatures, and/or at-risk populations served by these venues. The THEORETICAL PEAK OCCUPANCY and temperatures of these venues favor microbial growth and can lead to rapid depletion of CHLORINE. This minimum requirement is consistent with CDC recommendations to minimize transmission of *Legionella* via whirlpool SPAS on cruise ships, published in 1997, which recommends maintaining free residual CHLORINE levels in SPA water at 3 to 10 ppm (mg/L). It is further supported by a study reviewing both bromine and CHLORINE, which states, *Pseudomonas aeruginosa* was rapidly reestablished in SPAS (greater than 103 cells per mL) when DISINFECTANT concentrations decreased below recommended levels [CHLORINE, 3.0

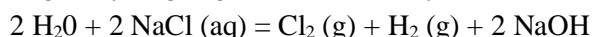
ppm (mg/L), bromine 6.0 ppm (mg/L)].⁴²⁸ In general, a range of 2-4 ppm (mg/L) FAC for POOLS (3-5 ppm (mg/L) for SPAS) is recommended to help ensure the minimum FAC is maintained and to provide a margin of SAFETY for BATHERS.

For individual POOLS, considerations for ideal FAC levels include:

- **Chlorine demand:** FAC levels should be sufficient to accommodate peak BATHER loads and other sources of contamination.
- **Temperature and sunlight:** FAC levels should be sufficient to accommodate loss of FAC from higher water temperatures and sunlight.
- **Cyanuric acid:** Because CHLORINE efficacy is reduced in the presence of CYA, higher FAC levels may be necessary for POOLS using CYA or stabilized CHLORINE.^{429,430,431, 432}
- **Algae control:** Algae is more difficult to control than most pathogens and may require FAC residuals greater than 3.0 ppm (mg/L) although peer-reviewed data is lacking.
- **Accuracy of FAC tests:** POOL test kits have been reported to give FAC results which diverge significantly from true values although peer-reviewed data is lacking.
- **Feeder equipment:** Automated feeders help reduce variability in dosing and the potential for FAC levels to fall below minimum levels.
- **SECONDARY DISINFECTION:** While the minimum FAC level must be maintained in all POOLS, approved SECONDARY DISINFECTION SYSTEMS such as UV and ozone reduce risks from CHLORINE-resistant pathogens and may reduce CHLORINE demand. However, the effects of UV/CHLORINE on water chemistry are still largely undefined. Recent research suggests that UV can increase some forms of CHLORINE demand.

5.7.3.1.1.5 Maximum FAC Concentrations

FAC levels should be consistent with label instructions of the DISINFECTANT. All POOL and SPA DISINFECTANTS must be registered by the EPA under FIFRA. The MAHC welcomes input and supporting data for establishing upper limits. At this time, the MAHC requires FAC maximum levels to be consistent with label instructions. An upper limit of 10 ppm (mg/L) has been chosen to ensure operators can still reasonably measure FAC. Issues have arisen with extremely high levels being added when poorly trained operators cannot measure FAC and continue adding DISINFECTANT without realizing the test is bleaching out rapidly (See MAHC Annex Section 4.7.3.5 for more information). EPA has not approved any POOL product use above 4 ppm (mg/L) FAC or SPA product use above 5 ppm (mg/L) FAC when BATHERS are present. The maximum FAC level approved for POOLS is consistent with EPA's Maximum Residual Disinfectant Level (MRDL) of 4 ppm (mg/L) for drinking water. No data were identified suggesting health risks from FAC levels at, or even significantly above, these levels. The EPA MRDL and the World Health Organization's drinking water guideline value for CHLORINE (5 ppm (mg/L)) are based on drinking water studies that found no adverse effects related to CHLORINE⁴³³. Use of high levels of CHLORINE as a "shock dose" when BATHERS are not present may be part of an overall water quality management strategy. Periodic shock dosing can be an effective tool to maintain microbial quality of water and to minimize build-up of biofilms and inorganic chloramines. For BATHER re-entry, FAC levels shall be consistent with label instructions of the DISINFECTANT. Salt water (*saline*) chlorination systems generate and deliver a CHLORINE DISINFECTANT on-site directly into POOL water. While cell size and configuration of these systems may differ depending on the manufacturer, the principles of their operation remain the same. Sodium chloride is added to balanced POOL water to establish a saline solution, which flows through the electrolytic cell. A low voltage electrical charge is passed through the saline solution and the current breaks the sodium and chloride bonds resulting in the formation of CHLORINE gas, hydrogen gas, and sodium hydroxide:



The hydrogen gas is dissolved in the water and eventually vents to the atmosphere. The CHLORINE gas then dissociates into HOCl, which provides a residual of FAC:



Salt water chlorination units should be sized appropriately to maintain minimum FAC levels during maximum load periods. The units should ideally be controlled by an ORP controller. Operators must still test the FAC residual of the water to ensure that the cell is producing adequate CHLORINE for the POOL. However, a separate chlorinating product may be needed to provide a sufficiently high FAC level for shock treatment or remediation

following a fecal accident. MONITORING and maintaining the pH, total alkalinity, and TDS of the water in the POOL is important. Salt water POOLS intentionally have high concentrations of sodium chloride. The sodium chloride will contribute to TDS, but will not cause decreased DISINFECTANT efficacy or cloudy water. Electrolytic cells do wear out and need to be replaced. The life of the cell depends upon how many hours the cell operates each day, the pH of the water, and the calcium content of the water. The cells have to be cleaned to remove scale build-up. The systems usually utilize reversal of the polarity on the cells to minimize the scale formation, but eventually the cell will have deposits that require the cell to be removed from the plumbing and soaked in an acid solution. The cells are also vulnerable to damage if they are operated in conditions of lower than recommended salt residuals or in water that is too cold. The systems have sensors and cut-offs to prevent this damage, but operators must be sure to MONITOR the unit to recognize when there is a problem.

5.7.3.1.2 Bromine

5.7.3.1.2.1 EPA Registered

The EPA Office of Pesticides registers products and approves labels for bromine. Currently bromine products on the market for use in recreational water are registered with use levels ranging from 1-8 ppm (*mg/L*), depending on the product. The efficacy of these products have been studied by the manufacturers and submitted to the EPA under FIFRA. The efficacy data analyzed by the EPA is company confidential and has not been reviewed as part of the development of the MAHC.

5.7.3.1.2.2 Minimum Bromine Concentrations

Bromine concentrations established by state and local jurisdictions have not been found to correlate with data supporting the concentrations being used. However, every state or local jurisdiction that allows bromine as a DISINFECTANT requires bromine at higher concentrations than CHLORINE and almost twice as much in SPAS and warmer POOLS. Commercially available test kits are not capable of distinguishing free bromine (*Br₂*, *HOBr*, *OBr-*) from combined bromine (*bromamines*). The bromine value specified in test results is the concentration of total bromine, not the free available halogen that is tested with CHLORINE. To determine total bromine, test kit manufacturers use a CHLORINE value and multiply it by 2.25. The 2.25 conversion factor accounts for the molecular weight difference between elemental bromine and elemental CHLORINE (*Br* = 79.90 grams per mole and *Cl* = 35.45 grams per mole). Further, presently used field test kits assay only for total bromine. Bromine is commonly used in indoor commercial SPAS, probably due to these two factors. First, bromamines (*bromine and ammonia combined*) do not produce irritating odors as do chloramines. Second, bromine efficacy is less impacted than CHLORINE'S at a higher pH, which typically occurs in a SPA environment. At pH of 7.5, 94% of bromine is HOBr, whereas at the same pH, HOCl is 55% in chlorinated water. At pH of 8.0 bromine still has 83% HOBr, while in a chlorinated water, HOCl is 28%.⁴³⁴ Bromine is also not very common in outdoor POOLS because like CHLORINE, bromine is destroyed rapidly in sunlight. CYA was developed to combat the problem in chlorinated POOLS, but does not provide a stabilizing effect for bromine. While reviewing the literature and surveillance data from CDC, evidence that outbreaks have occurred when required minimum bromine concentrations have been maintained is lacking (i.e., likely due to lack of information on DISINFECTANT type). Therefore, in absence of any clear research, the decision to use common state requirements as the recommended levels is prudent. SPAS have been implicated in many skin disease outbreaks throughout the years. One paper suggests that a common culprit, *Pseudomonas aeruginosa*, were rapidly reestablished in SPAS (*less than 103 cells per mL*) when DISINFECTANT concentrations decreased below recommended levels (*CHLORINE: 3.0 ppm (mg/L); bromine: 6.0 ppm (mg/L)*). The authors studied the reoccurrence of bacteria following cleaning and halogen shock treatment⁴³⁵. This study emphasized the need for maintaining a consistent CHLORINE level in the SPA. CDC recommends 4-6 ppm (*mg/L*) for bromine. The MAHC recommends a follow up study to evaluate the efficacy of bromine on *P. aeruginosa*, since it is so commonly found in SPAS. Because bromine is a very common DISINFECTANT used in SPAS, prevention and treatment is essential. There are few peer-reviewed studies on bromine efficacy in real world POOLS and SPAS in the literature. Brown et al. reported reasonable bacterial control with 2.0 ppm total bromine in an 118,000 gallon (*447 m³*) INDOOR POOL using BCDMH⁴³⁶. Normal day time BATHER COUNTS were around 0.21 persons per 500 gallons (*1893 L*) per hour but often increased to as high as 0.85 in the evening. The POOL did not use supplemental OXIDATION but did replace 5% of the water daily which likely contributed to the low reported ammonia nitrogen and organic nitrogen. Shaw reports a retrospective analysis of brominated and chlorinated semi-public SPAS in Alberta.⁴³⁷ The data used was from the microbiological results of the weekly samples required under provincial regulations. The treatment systems compared include BCDMH (*OXIDATION method not specified*), bromide salt regenerated by HOCl/potassium monopersulfate continuous feed, CHLORINE gas,

hypochlorite (*type not specified*), dichlor, and trichlor. The concentrations were generally in line with provincial regulations of 2 ppm (*mg/L*) total bromine and 1 ppm (*mg/L*) FREE CHLORINE. The brominated SPAS had a higher failure rate in all three bacterial parameters. There were several complaints of both contact dermatitis and *Pseudomonas* folliculitis from the brominated SPAS during the period studied, but due to the nature of the retrospective studies, it was not possible to link the reported RWIs to the concentration of the DISINFECTANT at the time of the complaint. It appears from composite data that when semi-public SPAS are operated using the EPA minimum halogen concentration of 1.0 ppm (*mg/L*) FREE CHLORINE or 2 ppm (*mg/L*) total bromine that *Pseudomonas aeruginosa* can be isolated from the brominated SPAS at greater than twice the frequency than from chlorinated SPAS.

Bromates

Ozone and bromide ions in water form HOBr and bromate ions. Bromates have been classified by the IARC as having sufficient evidence of carcinogenicity in laboratory animals. As a result, WHO has set a provisional drinking water guideline value of 10 ug/L. The EPA has established a maximum CONTAMINANT level of 10 ug/L for bromate in drinking water. BCDMH (*1-bromo-3-chloro-5, 5-dimethylhydantoin*) is the most common form of bromine used in commercial POOLS and SPAS today. The function of DMH is to inhibit the formation of bromates. At present there is little information on the functionality of using DMH in this manner. Since there is not a convenient field test kit available, an operator has no way of knowing what the DMH level is in the water or when it may go below 10 ppm (*mg/L*) to allow bromates to form. We also do not know what the maximum safe level of DMH should be. To rely on DMH for bromate prevention, suitable test methods and further research are necessary. Operators should consider that ozone should likely not be used with bromine systems when there is a substantial likelihood of ingestion of the water. When ozone is used in conjunction with organic bromine sources (*BCDMH or DBDMH—another common source of bromine*), the ozone readily converts residual bromide ion back to HOBr. This process reduces ozone. With the continued addition of BCDMH, DBDMH, or sodium bromide, the bromide levels will continue to climb in the POOL or SPA. Continuous build-up of bromide will constantly reduce ozone; diminishing ozone's effective OXIDATION (*and destruction*) of organics and microorganisms in the water. Because of the wide variation in the concentration of bromide and the potential for bromate ingestion at least one ozone manufacturer does not recommend the installation of ozone units in bromine-treated facilities.

Disinfection

DISINFECTION using bromine is more complex but less well documented than DISINFECTION using CHLORINE. HOBr is the putative biocidal chemical species at recreational water pH. HOBr reacts with inorganic ammonia and forms monobromamine, dibromamine, and nitrogen tribromide, depending on the pH and concentration of ammonia.⁴³⁸ These inorganic bromamines are all considered more biocidal than their corresponding CHLORINE analogs. HOBr is converted to inert bromide ion upon biocidal action in a manner similar to that seen with HOCl. One key difference between bromine and CHLORINE DISINFECTION is that bromide is readily OXIDIZED back to HOBr and chloride is not. Further, HOBr is a much weaker OXIDIZER than HOCl. As a consequence of these two differences, exogenous OXIDATION of brominated waters (*e.g. shocking with CHLORINE*) is more important for safe operation than it is in chlorinated waters. In reviewing the published epidemiological studies on RWIs, it is often difficult to determine the exact treatment system used because the SUPPLEMENTAL TREATMENT SYSTEM is not described. Further, presently used field test kits assay only for total bromine and are not capable of distinguishing free bromine from biocidal inorganic bromamines or from non-biocidal organic bromamines.

Bromamines

Current POOL and SPA operating manuals state that combined bromine (*bromamines*) is as efficacious as free bromine. This may be an over generalization of the complex nature of bromine chemistry. Bromine reacts with inorganic ammonia and forms analogous compounds (*Br₂, HOBr, monobromamine, dibromamine, and nitrogen tribromamide*) depending on the pH and concentration of ammonia.⁴³⁹ All three bromine-ammonia derivatives are biocidal, but all three are also less stable than their corresponding CHLORINE compounds. As with their CHLORINE analogs, the ratios of the bromamines are highly dependent on the ratio of ammonia to bromine. Further, at low ammonia to bromine ratios the biocidal action appears to be substantially reduced⁴⁴⁰. The levels of ammonia that result in loss of bromine efficacy have been detected in SPA water⁴⁴¹. At these documented concentrations of bromine and ammonia, the predominant bromamine is most likely dibromamine, which has an estimated half-life of 10 minutes⁴⁴². The MAHC was not able to locate data on the efficacy of organic bromamines.

Future Research Needs

Cryptosporidium Inactivation

Methods to hyper-brominate recreational water in response to diarrheal fecal accidents have not been established. Research in this area is lacking.

Bromine Associated Rashes

Note to readers: These comments have been inserted to point future researchers toward an under-investigated area of public health and are not meant to imply a negative bias toward bromine. Literature reviews demonstrate a large number of reports describing rashes associated with brominated water. These rashes fall into two general categories:

- Contact dermatitis due to brominated species in the water, and
- Dermal infections due to *Pseudomonas aeruginosa*.

These are most easily differentiated by incubation time. The vast majority of contact dermatitis reactions occur within 24 hours of immersion, sometimes within minutes. These are often referred to as “bromine itch” and are widely reported in the medical literature^{443,444,445}. In most cases the putative etiological agent is thought to be bromamines. This type of dermatitis appears to be a result of cumulative exposure to bromine treated water and is particularly prevalent among medical personnel who provide aquatic physical therapy⁴⁴⁶. The exact compounds inducing contact dermatitis have not been identified. One study strongly suggests that the use of bromine with supplemental OXIDATION minimizes contact dermatitis⁴⁴⁷. In numerous epidemiological studies, poor water quality is commonly, but not always, reported (*Woolf and Shannon report an extreme example of a foamy POOL leading to multiple cases of contact-related RWI*⁴⁴⁸). The typical incubation period for *Pseudomonas aeruginosa* folliculitis is several days but can be as short as 24 hours. Outbreaks of *Pseudomonas aeruginosa* folliculitis are routinely associated with inadequate sanitation in both chlorinated and brominated waters. The minimum concentration to prevent such outbreaks has not been established but appears to be at least 1 ppm (mg/L) FREE CHLORINE and 2 ppm (mg/L) total bromine. A survey of the literature since the mid-1980s shows more dermal RWI outbreaks reported in brominated waters than in chlorinated waters. It is not known whether the reports reflect the true incidence, a bias in reporting of bromine systems, or a bias in reporting RWIs in SPAS, which tend to use bromine DISINFECTANTS. There are many unanswered questions surrounding bromine-treatment systems commonly used in AQUATIC VENUE DISINFECTION. After reviewing the literature, the MAHC has concluded the following research is essential to understanding bromine DISINFECTION.

Further research needs to address, in priority order:

- The efficacy of bromine to establish a minimum concentration for AQUATIC VENUES and warm water SPAS and THERAPY POOLS,
- The maximum bromine concentration that should be allowed,
- The contribution of bromamines to DISINFECTION and BATHER rashes,
- Methods to better control bromamines,
- Creation of a test kit to differentiate free bromine from combined (*as is currently practiced with CHLORINE*) in the water,
- Use of DMH in respect to bromate formation,
- Establish a safe maximum level,
- Creation of a test kit to establish levels in the water, and
- Fecal accident recommendations to control *Cryptosporidium* when using a bromine POOL.

5.7.3.1.2.3 Maximum Bromine Concentrations

Maximum bromine levels have been set to prevent exposure of BATHERS to high levels of bromine. Without an upper limit, very high levels may be present with no requirement to prohibit BATHERS from entering the water. Currently, the EPA Office of Pesticides registers products and approves labels for bromine. Currently bromine products on the market for use in recreational water are registered with use levels ranging from 1-8 ppm (mg/L), depending on the product. At present time, no manufacturer specifies a level above 8.0 ppm.

5.7.3.1.3 Stabilizers

5.7.3.1.3.1 Cyanuric Acid

CYA is effective in protecting AVAILABLE CHLORINE from UV degradation. The chemical associates with CHLORINE to form chlorinated isocyanurates: trichlor (*trichloroisocyanuric acid*) and dichlor (*sodium dichloroisocyanuric acid*). It can also be added as a separate chemical in the form of isocyanuric acid, commonly referred to as CYA. Trichlor is commonly found as tablets or sticks. Dichlor is a granular material, as is the isocyanuric acid. Products containing or forming CYA must be clearly labeled and directions provided to the user for proper use, limitations, toxicity, cautions, and effects. The most important factor in POOL DISINFECTION is the presence of sufficient levels of FREE CHLORINE. CYA is used to help maintain measurement of FREE CHLORINE levels in outdoor POOLS. CYA is not a DISINFECTANT, so it is not registered by the EPA. Stabilized CHLORINES are registered with the EPA as DISINFECTANTS; however, EPA has not reviewed efficacy data on CHLORINE in the presence of increasing stabilizer to date. The EPA reviewed efficacy data on dichlor and trichlor when it approved registrations for drinking water DISINFECTION. However, these data are not directly applicable to swimming POOLS where repeated doses lead to higher CYA levels.

Minimum Disinfection

Minimum CHLORINE levels should be increased by a factor of at least two when using CYA: One study found “50 mg/L of CYA produced pronounced retardation of the bactericidal efficiencies of solutions of calcium hypochlorite, trichloroiso-cyanuric acid, and potassium dichloroisocyanurate such that a four- to eightfold increase in the amount of "free" available residual CHLORINE may be necessary to attain the same degree of inactivation of the same organisms in the same interval of time”⁴⁴⁹. Another study showed that addition of 50 mg/L CYA to 0.5 - 1.0 mg/L AVAILABLE CHLORINE resulted in a significant increase in the CT of *Staphylococcus aureus*, in parallel with the increase in AVAILABLE CHLORINE stability in sunlight. However, higher concentrations of CYA resulted in little to modest further increases in CT over that for 50 mg/L CYA. For example, the data suggest that for 50, 100 and 200 mg/L of CYA, the level of CHLORINE required for 99% kill of *Staphylococcus aureus* in one minute would be 1.9, 2.15, and 2.5 mg/L, respectively⁴⁵⁰. The MAHC has adopted a SAFETY factor of 2 so that 2 ppm is the minimum concentration of using stabilized products. More data are needed to understand the impact of increasing cyanurate levels on pathogen inactivation to assess what this level should be. Until that time, the MAHC first adopted a concentration of less than or equal to 100 ppm, as has the World Health Organization⁴⁵¹. The maximum allowable CYA value was reduced from 100 ppm to 90 ppm to avoid the need for operators to make dilutions since 100 ppm is the maximum level measured in the test. The level of cyanurate allowed in outdoor AQUATIC VENUES is double that for non-stabilized CHLORINE, which is a SAFETY factor for the decrease in oxidative capacity. The MAHC has decided that from a public health standpoint it cannot support a prohibition of the use of cyanurate in most INCREASED RISK AQUATIC VENUES. The SAFETY margin of two times the level of non-stabilized product would also apply for increased indoor settings in addition to the requirement for a SECONDARY DISINFECTION SYSTEM and therefore prohibition in an INCREASED RISK VENUE cannot, at this time, be supported with a public health argument. The exception to this is operation of SPAS and THERAPY POOLS, which have large issues with efficacy of agents against pathogens in biofilms and difficulties with maintaining needed pH levels (*SPAS*) and the use by INCREASED RISK groups of patients (*THERAPY POOLS*). *SPAS* and *THERAPY POOLS* will, therefore, not be allowed to use CYA or stabilized CHLORINE products. Users should be aware that if AQUATIC VENUES using CYA or stabilized CHLORINE products have a fecal incident, they will need to close for more prolonged periods for a diarrheal fecal incident and HYPERCHLORINATION, circulate water through a SECONDARY DISINFECTION SYSTEM, or replace the water in the AQUATIC VENUE per MAHC 6.5.3.2.1^{452,453} (see MAHC 6.5.3 for further discussion).

Indoor Pools

There appears to be no operational or public health reason for INDOOR AQUATIC VENUES to use CYA. It is a stabilizer for degradation from direct sunlight and so likely has limited benefits for indoor POOLS despite some operators claiming a benefit for indoor POOLS with large glassed areas. However, the level of FAC required in all AQUATIC VENUES using cyanurate or stabilized CHLORINE products is double that for non-stabilized CHLORINE, which was included to add a SAFETY factor for the decrease in oxidative capacity. The MAHC has decided that it cannot support, from a public health standpoint, a prohibition of the use of cyanurate in indoor settings. The SAFETY margin applies to all AQUATIC VENUES, including indoor settings. Prohibition in an indoor setting would require specific data on the direct impact in indoor settings since the MAHC allows it in outdoor settings.

CDC still does not recommend CYA use for indoor POOLS or hot tubs. The recommendation was underscored in a 2000 MMWR after investigating a *Pseudomonas dermatitis/folliculitis* outbreak associated with indoor POOLS and

hot tubs in Maine, noting that CYA was added to an indoor POOL, which reduces the antimicrobial capacity of FREE CHLORINE^{454,455}. Users should be aware that if AQUATIC VENUES using CYA or stabilized CHLORINE products have a fecal incident, they will need to close for more prolonged periods for a diarrheal fecal incident and HYPERCHLORINATION, circulate water through a SECONDARY DISINFECTION SYSTEM, or replace the water in the AQUATIC VENUE per MAHC 6.5.3.2.1⁴⁵⁶. *Cryptosporidium* inactivation data collected in the presence of increasing quantities of CYA demonstrate that at 50 ppm or 100 ppm cyanurate do not reach 3-log inactivation in reasonable amounts of time.⁴⁵⁷ See MAHC Annex 6.5.3.2.1 for more detailed discussion.

Effects of Cyanuric Acid on Microbial Inactivation

There are a large number of references on the effect of CYA on microbial kill times (CT INACTIVATION VALUES). In general, they show that the presence of CYA increases CT INACTIVATION VALUES, and the amount of this increase depends on the pH and the ratio of CYA to AVAILABLE CHLORINE. However, there are few reports that relate specifically to the issue of what levels of AVAILABLE CHLORINE and CYA are required to maintain a swimming POOL in a biologically satisfactory state. Studies examining the effect of CYA on the DISINFECTION capacity of CHLORINE show that using CYA or stabilized CHLORINE slows down the inactivation times on bacteria, algae, protozoa (*Naegleria gruberi* and *Cryptosporidium parvum*), and viruses. Yamashita et al. concluded the addition of CYA increased the time needed for DISINFECTION of 12 virus types by a factor of 4.8-28.8 compared with FREE CHLORINE alone^{458,459}.

Table 5.7.3.1.3.1: 99.9% Inactivation time in buffer studies, 0.5 ppm (mg/L) FAC, 25 C

Organism	No CYA, min	30 ppm (mg/L) CYA, min
Poliovirus 1	0.8	5.6
Coxsackievirus A24	0.5	14.4
Enterovirus 70	0.12	2.5
Adenovirus type 3	0.14	2.1

Table 5.7.3.1.3.2: 99.9% Inactivation time in pool water studies, 1.0 ppm (mg/L) FAC, 25 C

Organism	No CYA, min	30 ppm (mg/L) CYA, min
Poliovirus 1	0.4	4.4

In a later study, Yamashita et al.⁴⁶⁰ found “Total plate counts ranged from 0 to 1 per mL in the swimming POOLS treated with sodium hypochlorite and 0 to 51 in those with trichloroisocyanurates. In 11 of 12 water samples of three swimming POOLS using trichloroisocyanurates, poliovirus type 1 survived after 2 minute contact while in five samples poliovirus type 1 survived after 5 minute contact.” The researchers concluded this showed that the risk of viral infection is greater in swimming POOL water treated with chlorinated isocyanurates than that with sodium hypochlorite. The addition of CYA similarly impaired the inactivation of poliovirus⁴⁶¹. CYA, used as CHLORINE stabilizer in swimming POOL waters, had a relatively minor effect on the algicidal efficiency of FREE CHLORINE⁴⁶². There are few data regarding protozoa and the effect of CYA on inactivation though the DISINFECTION rate for *Naegleria gruberi* was reduced by CYA in laboratory-controlled CHLORINE demand free conditions⁴⁶³. Shields et al.⁴⁶⁴ extended the previous findings by demonstrating that CYA significantly decreases the rate of inactivation for *Cryptosporidium parvum* OOCYSTS. In this study a three-log reduction of OOCYSTS was found to take place in the presence of 20 ppm (mg/L) FAC. When 50 ppm (mg/L) CYA was introduced, the 10-hour kill rate was less than ½ log. Recent data show that 3-log inactivation of *Cryptosporidium* is possible with CYA concentrations of 15-16 ppm or less.⁴⁶⁵ A 3-log inactivation could not be achieved with 50 ppm or 100 ppm CYA. A 1-log inactivation of OOCYSTS was achieved with 50 ppm cyanurate concentrations after an average contact time of 61.9 hours with 20 ppm FREE CHLORINE RESIDUAL, for an average estimated CT INACTIVATION VALUE for 1-log inactivation of 76,500 mg min/L. With 40 ppm FREE CHLORINE RESIDUAL and 50 ppm CYA, a 1-log inactivation of OOCYSTS was achieved after an average contact time of 17.2 hours, giving an average estimated CT INACTIVATION VALUE for 1-log inactivation of 40,000 mg min/L. Increasing the concentration to 100 ppm CYA showed even more limited OOCYST inactivation, which did not differ much from natural decay/inactivation curves for *Cryptosporidium* in water. *Pseudomonas* inactivation in the presence of CYA was

also studied in POOL water and it was found that increased CYA concentrations lengthened the kill times. The effect of CYA was greater as the concentration of CHLORINE in the water decreased⁴⁶⁶. Favero et al. found that at FREE CHLORINE concentrations of more than 0.5 ppm (mg/L), *P. aeruginosa* was rarely found except in those POOLS which used sodium dichloroisocyanurate as a POOL DISINFECTANT. Three private swimming POOLS using sodium dichloroisocyanurate as a POOL DISINFECTANT were found to contain large numbers of the potential pathogen, *P. aeruginosa*⁴⁶⁷. Fitzgerald found concentrations of 25, 50, and 100 mg of CYA per liter had large effects on the *Pseudomonas* kill rate of 0.1 mg/L FREE CHLORINE but this effect diminished with increasing FREE CHLORINE content (0.25, 0.5 mg/L). Fitzgerald found concentrations of 25, 50, and 100 mg of CYA per liter had little effect on the kill rate of 0.5 mg of CHLORINE plus 0.1 mg of NH₄-N per liter; however, CYA did reduce the time required for 99.9% kills when tested in the presence of higher concentrations of ammonia⁴⁶⁸. The basis for this finding should be explored further.

Fecal Accident Response

The use of stabilized CHLORINE is not recommended for HYPERCHLORINATION in RWI outbreaks caused by *Cryptosporidium*, or in response to diarrheal fecal accidents. Present MAHC requirements for HYPERCHLORINATION and POOL remediation are ineffective for *Cryptosporidium* in AQUATIC VENUES using cyanurate-stabilized CHLORINE. CHLORINE stabilizers such as CYA slow DISINFECTION (see MAHC Annex 5.7.3.1.3.1 for more discussion); therefore, higher CHLORINE levels are necessary to reach the CT INACTIVATION VALUE for *Cryptosporidium* inactivation in POOLS that use CHLORINE stabilizers.⁴⁶⁹ As the stabilizer concentration rises, parasite inactivation is inhibited to the point where inactivation is similar to natural decay of the parasite.⁴⁷⁰ As a result, higher levels of stabilizer must be reduced in order to reach 3-log inactivation levels using HYPERCHLORINATION. Recent data show that 3-log inactivation of *Cryptosporidium* is possible with CYA concentrations of 15-16 ppm or less.⁴⁷¹ A 3-log inactivation could not be achieved with 50 ppm or 100 ppm CYA. A 1-log inactivation of OOCYSTS was achieved with 50 ppm cyanurate concentrations after an average contact time of 61.9 hours with 20 ppm FREE CHLORINE RESIDUAL, for an average estimated CT INACTIVATION VALUE for 1-log inactivation of 76,500 mg min/L. With 40 ppm FREE CHLORINE RESIDUAL and 50 ppm CYA, a 1-log inactivation of OOCYSTS was achieved after an average contact time of 17.2 hours, giving an average estimated CT INACTIVATION VALUE for 1-log inactivation of 40,000 mg min/L. Increasing the concentration to 100 ppm CYA showed even more limited OOCYST inactivation, which did not differ much from natural decay curves for *Cryptosporidium* in water. Because 3-log OOCYST inactivation was achieved with 16 ppm CYA and was not achieved with 50 ppm CYA, the remediation protocol must be conducted in water with ≤15 ppm CYA. If the CYA concentration is above 15 ppm, the POOL will need to be partially drained to reduce the concentration. Alternate methods of reducing the CYA concentration are acceptable, as long as test data shows that the CYA concentration is at or below 15 ppm.

Toxicity

The maximum CYA concentration of 90 ppm (mg/L) should be considered protective from a toxicological perspective. Using an assumption that 100 mL of POOL water is swallowed per swim session; the World Health Organization (WHO) concluded that CYA levels in POOLS should be below 117 ppm (mg/L). This is based on a tolerable daily intake (TDI) for anhydrous sodium dichloroisocyanurate (NaDCC) of 2 mg/kg of body weight, which translates into an intake of 20 mg of NaDCC (or 11.7 mg of CYA per day) for a 10 kg child. The EPA SWIMODEL, relying on somewhat lower exposure assumptions, would yield a higher acceptable level for CYA.

Research

Though the data shows CYA use increases the inactivation time of many pathogens, the MAHC recommends a study is conducted on specific pathogens and inactivation rates at differing CYA levels, up to at least 200 ppm (mg/L). New *Cryptosporidium* inactivation data demonstrate that, at higher levels of cyanurate, inactivation is similar to natural die off rates.⁴⁷² Further research on the inhibitory effect of CYA on DISINFECTION should evaluate the level at which CYA can still protect CHLORINE from UV and also balance the inactivation rate of the most common AQUATIC VENUE pathogens. The effect of pH in the presence of CYA should also be investigated. Additionally, a test kit should be created to test lower and higher levels of CYA. The current products on the market are not very accurate and need to operate over a wider range of CYA levels. During RWI outbreaks, it is strongly recommended that the investigation team measure CYA levels.

5.7.3.1.4 Compressed Chlorine Gas

Installation/use of compressed CHLORINE gas is prohibited for new AQUATIC FACILITIES; however there are existing facilities that continue to use these gas systems. Because of the potential hazard, it is important that existing facilities meet STORAGE, ventilation, handling, and operator training requirements if use is to continue. If these requirements are not met, use must be discontinued and a properly designed/sized and approved DISINFECTANT system installed. The following design criteria from an existing health CODE provide additional details for consideration when evaluating acceptability of an existing compressed gas installation.

- **Location.** The chlorinator room shall be located on the opposite side of the POOL from the direction of the prevailing winds. CHLORINE STORAGE and chlorinating equipment shall be in a separate room. This room shall be at or above grade.
- **Venting.** The CHLORINE room shall have a ventilating fan with an airtight duct beginning near the floor and terminating at a safe point of discharge to the out-of-doors. A louvered air intake shall be provided near the ceiling. The ventilating fan shall provide one air change per minute and operate from a switch located outside the door.
- **Door.** The door of the chlorinator room shall not open to the swimming POOL, and shall open outward directly to the exterior of the building. The door shall be provided with a shatterproof inspection window and should be provided with “panic hardware.”
- **Chlorine cylinders.** CHLORINE cylinders shall be anchored. The cylinders in use shall stand on a scale capable of indicating gross weight with one-half pound accuracy. STORAGE space shall be provided so that CHLORINE cylinders are not subjected to direct sunlight. STORAGE space shall be in an area inaccessible to the general public.
- **Injection location.** Mixing of CHLORINE gas and water shall occur in the CHLORINE room, except where vacuum-type chlorinators are used.
- **Backflow.** The chlorinators shall be designed to prevent the BACKFLOW of water or moisture into the CHLORINE gas cylinder

5.7.3.1.5 Salt Electrolytic Chlorine Generators, Brine Electrolytic Chlorine or Bromine Generators

In-line generators shall use only POOL-grade salt dosed into the POOL to introduce CHLORINE into the POOL vessel through an electrolytic chamber to avoid potential health risks associated with DISINFECTION byproducts forming from salt impurities, including bromide and iodide. For example, Kristensen et al. directly correlated bursts of bromodichloro-methane formation to the addition of salt to POOL water over a MONITORING period of more than 1 year.⁴⁷³ In a comparison study of common DISINFECTANT methods, Lee et al. found salt brine electrolysis formed the highest levels of bromodichloro-methane, dibromochloro-methane and bromoform.⁴⁷⁴ Zwiener et al. noted that iodized table salt should not be used in salt POOLS because iodized DISINFECTION byproducts, which are generally more toxic than chlorinated DISINFECTION byproducts, could form.⁴⁷⁵ Additionally, there is a perception by some that salt water POOLS can be operated with table salt (*which is commonly iodized*).

5.7.3.2 Secondary or Supplemental Treatment Systems

Due to the risk of outbreaks of RWIs associated with halogen-tolerant pathogens such as *Cryptosporidium*, it is strongly recommended that all AQUATIC FACILITIES include SECONDARY DISINFECTION SYSTEMS to minimize the risk to the public associated with these outbreaks. All existing regulations covering fecal events or detection of pathogens must still be adhered to when SECONDARY DISINFECTION SYSTEMS are utilized. SECONDARY DISINFECTION SYSTEMS can only minimize the risk and are not a guarantee of treatment due to the possibility of cross contamination of the POOL or water feature and the time required to pass the entire volume of water through the treatment process. As the general effectiveness of a SECONDARY DISINFECTION SYSTEM is affected by the AQUATIC VENUE TURNOVER RATE and mixing/circulation within the AQUATIC VENUE, the MAHC requirements for filter recirculation and TURNOVER RATES must be followed. The performance of SECONDARY DISINFECTION SYSTEMS will be enhanced when the shortest TURNOVER TIMES are achieved for any particular type of AQUATIC FACILITY. The use of certain types of AQUATIC VENUES presents an increased risk of RWI transmission to users. These AQUATIC VENUES include THERAPY POOLS, WADING POOLS, SPRAY PADS, swim schools, INTERACTIVE WATER PLAY AQUATIC VENUES, and AQUATIC FEATURES. Given that users of these types of facilities frequently have naive immune systems (*e.g., children less than 5 years of age*), higher prevalence of disease (*e.g., children less than 5 years of age and older adults*), compromised immune systems, or open wounds, additional precautions

against RWIs are warranted. CDC data on public AQUATIC VENUES indicate DISINFECTANT violations were identified during 9.2% of POOL, 19.2% of SPA, 19.2% of WADING POOL, and 10.1% of INTERACTIVE WATER PLAY VENUE routine inspections⁴⁷⁶. The use of INTERACTIVE WATER PLAY AQUATIC VENUES has previously been associated with outbreaks of gastroenteritis. In 1999, an estimated 2,100 people became ill with *Shigella sonnei* and/or *Cryptosporidium parvum* infections after playing at an "interactive" water fountain at a beachside park in Florida⁴⁷⁷. In one of the largest outbreaks reported, approximately 2,300 persons developed cryptosporidiosis following exposure to a New York spray park. The environmental investigation revealed that filtration and DISINFECTION of the recycled water were not sufficient to protect the PATRONS from this disease. In response, emergency legislation was passed, which required the installation of SECONDARY DISINFECTION (*e.g.*, UV radiation or ozonation) on water returning through the spray features⁴⁷⁸.

5.7.3.2.1 Ultraviolet Light

5.7.3.2.1.2 Log Inactivation

Records of the correct calibration, maintenance, and operation of SECONDARY DISINFECTION SYSTEMS should be maintained by the facility's management.

5.7.3.2.1.4 Calibrated Sensors

Owners/operators need to consult the unit manual and the manufacturer's manual for guidance on how to accomplish this and who is qualified to do the job.

5.7.3.2.3 Copper / Silver Ions

EPA has set current drinking water STANDARDS at 1.3 ppm for copper and 0.10 ppm for silver, which are generally accepted in the states that have requirements for this treatment. These ion generation systems are not meant to replace DISINFECTING halogen and the minimum levels must continue to be provided. The manufacturer's recommended procedures should be followed to avoid the potential of staining, and operating the POOL with copper levels outside the recommended range may cause staining. Copper-based algacides should not be used in these systems since use of these products increase the level of copper in the POOL and increases the potential to cause health effects or stain surfaces. In addition, studies have shown that the presence of copper in POOL water has a catalytic effect on the formation of THMS⁴⁷⁹.

5.7.3.3 Other Sanitizers, Disinfectants, or Chemicals

The MAHC has opted to not include lists of DISINFECTANTS that should not be used in AQUATIC VENUES versus discussing that these chemicals must not pose a hazardous issue with the CHLORINE or bromine DISINFECTANTS in use and that all water quality criteria must be met.

PHMB

Polyhexamethylene biguanide hydrochloride (*PHMB*) is a polymeric antimicrobial that has been used as an alternative to CHLORINE and bromine. PHMB is often referred to as biguanide in the industry. The formal name for PHMB on EPA accepted labels is "Poly (*iminoimidocarbonyliminoimido-carbonyl iminohexamethylene*) hydrochloride". The EPA has registered PHMB for use in POOLS and SPAS as a "SANITIZER" with label directions requiring that the concentration be maintained between 30 and 50 ppm (*mg/L*) as product (*6 to 10 ppm (mg/L) of active ingredient*). PHMB is not an OXIDIZER and must be used in conjunction with a separately added product. Hydrogen peroxide is the strongly preferred OXIDIZER. The vast majority of the PHMB used in POOLS and SPAS is used in private residences but a limited number of public facilities have used PHMB. Because of its limited use in public AQUATIC FACILITIES, there are few independent studies on the efficacy of PHMB in recreational water. Studies report that the rate of kill of bacteria is slower than that of CHLORINE under laboratory conditions. However, the EPA found that manufacturer's generated data demonstrated adequate efficacy under the EPA guideline DIS/TSS-12 to grant registration under FIFRA and without regard to whether the facility is public, semi-public, or private. As part of their registration process, the EPA does not distinguish between public and private facilities. The efficacy data analyzed by the EPA is company confidential and has not been reviewed as part of the development of the MAHC. There are no known published studies of the efficacy of PHMB against non-bacterial POOL and SPA infectious agents (*e.g. norovirus, hepatitis A, Giardia sp., Cryptosporidium spp.*) under actual use conditions. PHMB is generally compatible with both UV and ozone, but both UV and ozone will increase the rate of loss of PHMB. Since SECONDARY DISINFECTION SYSTEMS require the use of a halogen as the primary DISINFECTANT, the use of PHMB, even with a secondary system is problematic. PHMB **IS NOT** compatible with CHLORINE or bromine. POOLS using PHMB have a serious treatment dilemma for control of

Cryptosporidium after a suspected outbreak or even a diarrheal fecal accident. The addition of 3 ppm (*mg/L*) of CHLORINE to a properly maintained PHMB-treated POOL results in the precipitation of the PHMB as a sticky mass on the POOL surfaces and in the filter. Removal of the precipitated material can be labor intensive. Testing for PHMB requires special test kits. Conventional kits for halogens are not suitable. PHMB test kits are readily available at most specialty retail POOL stores and on-line.

Hydrogen Peroxide

Hydrogen peroxide is not registered by the EPA as a DISINFECTANT for recreational water. Since it is not registered, the use of hydrogen peroxide as a recreational water DISINFECTANT, or any market claims that implies hydrogen peroxide provides any biological control in recreational water is a violation of FIFRA. Hydrogen peroxide has been granted registration by the EPA as a hard surface DISINFECTANT and several other applications. The EPA Registration Eligibility Document (*RED*) on hydrogen peroxide is available from the EPA website at <https://archive.epa.gov/pesticides/reregistration/web/pdf/4072fact.pdf>. The EPA posts PDF copies of accepted product labels on the National Pesticide Information Retrieval System website (<http://ppis.ceris.purdue.edu/#>.) Product claims for uses and concentration may be verified by reading the PDF of the EPA stamped and accepted copy of the product use directions at this website. When used as a hard surface DISINFECTANT, hydrogen peroxide is normally used at around 3%. When used in recreational water, hydrogen peroxide is used at 27 to 100 ppm (*mg/L*), which is 1111 and 300 times, respectively, more dilute than that used on hard surfaces. Borgmann-Strahsen evaluated the antimicrobial properties of hydrogen peroxide at 80 and 150 ppm (*mg/L*) in simulated POOL conditions.⁴⁸⁰ Whether 150 ppm (*mg/L*) hydrogen peroxide was used by itself or in combination with 24 ppb of silver nitrate it had negligible killing power against *Pseudomonas aeruginosa*, *E. coli*, *Staphylococcus aureus*, *Legionella pneumophila* or *Candida albicans*, even with a 30 minute contact period. In the same tests, the sodium hypochlorite controls displayed typical kill patterns widely reported in the literature. Borgmann-Strahsen concluded that hydrogen peroxide, with or without the addition of silver ions, was, “no real alternative to CHLORINE-based DISINFECTION of swimming POOL water from the microbiological point of view.”

5.7.3.3.1 Chlorine Dioxide

Chlorine dioxide is not presently registered by the EPA for any use in recreational water. Since it is not registered, the use of chlorine dioxide as an antimicrobial treatment (*e.g. DISINFECTANT, SANITIZER, algaecide, slimicide, biofilm control agent*) in recreational water, or any market claims that implies chlorine dioxide provides any biological control in recreational water is a violation of FIFRA. Chlorine dioxide has been granted registration by the EPA as an antimicrobial for other applications, including drinking water. One product was previously registered as a slimicide for use in PHMB-treated recreational water but that registration has since been dropped. The EPA Registration Eligibility Document (*RED*) on chlorine dioxide is available from the EPA website at https://archive.epa.gov/pesticides/reregistration/web/pdf/chlorine_dioxide_red.pdf. The EPA posts PDF copies of accepted product labels on the National Pesticide Information Retrieval System website (<http://ppis.ceris.purdue.edu/#>). Product claims for uses and concentration may be verified by reading the PDF of the EPA stamped and accepted copy of the product use directions at this website. Chlorine dioxide has the potential to be an alternative remediation tool, but it has not yet been approved by EPA for this use and can be hazardous unless appropriate SAFETY protocols are included. CDC has determined that chlorine dioxide can be used instead of HYPERCHLORINATION for rapid inactivation of *Cryptosporidium* (3-log inactivation in 105 to 128 minutes) and that this effect was synergistically enhanced with a FREE CHLORINE RESIDUAL in place.⁴⁸¹ This suggests chlorine dioxide might be very useful in rapidly remediating contaminated AQUATIC VENUES in the absence of BATHERS.

Potential for Using Chlorine Dioxide in the Future

During the drafting of this section of the MAHC, several members of the MAHC had interest in using chlorine dioxide as a remedial treatment for *Cryptosporidium* and *Legionella*. Published studies, including the *EPA Alternate Disinfection Manual* for drinking water shows that chlorine dioxide may be a very rapid remedial treatment for these life-threatening pathogens. If the EPA registration status of chlorine dioxide changes, the MAHC suggests that chlorine dioxide use should be reconsidered under adequate SAFETY precautions.

Provisions for Emergency Use of Chlorine Dioxide

Even though chlorine dioxide is not presently registered for use in recreational water, it is possible to use it under Section 18 of FIFRA. An example of this would be the remediation of a *Legionella*-contaminated health club SPA where other treatments were proven to be ineffective. More information on emergency exemptions can be found

on the EPA website at <http://www.epa.gov/opprd001/section18/>. Because of the lack of existing use directions and potential for occupational exposure, it is strongly suggested that a certified industrial hygienist be included in developing emergency treatment plans.

5.7.3.3.2 Clarifiers, Flocculants, and Defoamers

POOLS and SPAS may benefit from the use of one or more of these types of products. There are numerous brands available that are formulated for commercial POOLS and SPAS. Each product is marketed for a specific procedure. Each may contain one or more natural or synthetic polymers, chemical or metallic ingredients. Neither the efficacy nor the SAFETY of product chemistry of these products has been reviewed by the EPA or any other federal agency. The state of California does require submission of a detailed data package prior to registration. Products sold in the state of California must have the state registration number on the label as required by the California Code of Regulations, Title 3, Division 6, Pesticides and Pest Control Operations. Products registered in California but sold outside of the state usually, but are not required to, have the California registration number on the label. Any local agency concerned about a particular product could request the producer supply the California registration number and then verify the status of the product with the California Department of Pesticide Regulation.

5.7.3.4 pH

There are three reasons to maintain pH:

- Efficacy of the CHLORINE,
- BATHER comfort, and
- Maintenance of balanced water.

Each of these reasons are discussed briefly below:

Efficacy of Chlorine

The efficacy of CHLORINE/HOCl is dramatically impacted by pH and therefore pathogen inactivation can be severely affected by higher pH levels where only a small percentage of FREE CHLORINE is active. Lower pH levels below this range allow a greater percentage of FREE CHLORINE to be “active”. Further data are needed to ensure that lower levels (*e.g.*, 6.8 to 7.2) do not adversely impact membranes, particularly eyes. The present practice of maintaining the pH between 7.2 and 7.8 has been developed by coupling physical chemistry with empirical observations. There is no definitive peer-reviewed study that extensively covers the subject of pH in POOL and SPA water except those showing the titration of HOCl and the importance of pH for assuring maximal efficiency. The best general authority is the 1972 edition of the Handbook of Chlorination by Geo. Clifford White. The 1972 edition of this widely recognized authority on CHLORINE chemistry is the only edition that has a chapter especially on POOLS. Much, but not all, of the POOL chemistry chapter can be found in subsequent editions. Copies of the 1972 edition are difficult to locate in libraries but are available for sale on the internet as of July 2009. The discussion on efficacy and BATHER comfort is a summary of the 1972 edition discussion on pH. CHLORINE used in POOLS refers to HOCl, a weak acid that readily dissociates to form hypochlorite (OCl^-) and hydrogen ion (H^+). The mid-point of the dissociation (*the pKa*) is at pH 7.5. Functionally, this means that at pH of 7.5, 50% of the FREE CHLORINE present will be in the form of HOCl and 50% will be in the form of hypochlorite. As the pH decreases below 7.5, the proportion of HOCl increases and proportion of hypochlorite ion decreases. The opposite occurs as the pH increases above 7.5. Numerous investigators have reported that HOCl is approximately 100 times more effective at killing microorganisms than the hypochlorite ion. Thus from a public health perspective, it is desirable to maintain the pH so as to maximize the portion of HOCl portion of the FREE CHLORINE present in the water.

Bather Comfort

As BATHERS enter the water, their skin and eyes come into direct contact with the water and its constituent components. In general, the eyes of BATHERS are more sensitive to irritation than the skin. Studies on the sensitivity of BATHERS’ eyes to pH changes in the water show wide variations in tolerance limits. The tolerance of the eye to shifts in pH is also impacted by the concentration of FREE CHLORINE, combined CHLORINE, and alkalinity. Under normal POOL conditions, the optimum limits for BATHER comfort appears to be from pH 7.5 to 8.0.

Potential for Lowering pH in the Future

During the review of the data, the MAHC had a broad interest in lowering the minimum pH. This would increase the efficacy of the CHLORINE by increasing the proportion of HOCl (*at the expense of hypochlorite*) and thus increase DISINFECTION efficacy. This was not recommended because of the lack of data on the impact on BATHERS, particularly the eyes. If additional information on the impact of lower pH on BATHERS' skin and eyes is developed, the MAHC suggests that the acceptable range for pH be reexamined. As part of the reexamination, consideration should also be made concerning how this change will impact the water balance and any possible negative impact on the facility. In addition, many manufacturers include a pH range on equipment use so that lowering the pH may void the warranty.

5.7.3.5 Feed Equipment

The Chlorine Institute has checklists and guidance for working with compressed CHLORINE gas at: <http://chlorineinstitute.org/stewardship/ci-checklists.cfm>.

5.7.3.5.1.2 Installed and Interlocked

Periodic visual inspections of the electrical interlock system should be performed to determine if the system appears to be installed per manufacturer's instructions and has not been altered.

5.7.3.5.1.2.2 Bather Re-entry

The 5-minute wait period after turning the RECIRCULATION SYSTEM back on before allowing BATHERS to reenter the AQUATIC VENUE is to ensure the system did not overfeed chemicals into the recirculation lines that could potentially expose BATHERS. If such an event did occur, the wait period will allow staff to determine if a gas release does occur, which will prevent BATHER exposure to dangerous CHLORINE gas that potentially formed during the pause in recirculation pump flow if chemical feed pumps continued to pump chemicals into the system. This short delay and check could prevent many of the exposures that occur during these events in addition to interlocks on the recirculation and chemical feed systems.⁴⁸²

5.7.3.7 Automated Controllers and Equipment Monitoring

5.7.3.7.7 Ozone System

As a SECONDARY DISINFECTION SYSTEM, it is critical to MONITOR the system on a regular basis to ensure it is performing as required and, if not, repaired.

5.7.3.7.8 UV System

As a SECONDARY DISINFECTION SYSTEM, it is critical to MONITOR the system on a regular basis to ensure it is performing as required and, if not, repaired.

5.7.4 Water Sample Collection and Testing

5.7.4.3 Bulk Water Sample

When collecting samples from AQUATIC VENUE, an 18-inch (*45.7 cm*) water depth for sample collection is recommended. Both NSPF's *Pool and Spa Operator Handbook*TM and NRPA's Aquatic Facility Operator Manual instruct the operator to reach at least 18 inches (*45.7 cm*) below the water's surface to collect the water sample. In an outdoor POOL, there is chemical interaction with UV light at the surface which will affect the reading. Most of the chemical CONTAMINANTS in a POOL are located within the top 18 inches (*45.7 cm*), which is why most studies of POOL CONTAMINANTS are performed by collecting samples at a depth of less than or equal to 30 centimeters (*11.8 inches*) below the POOL water surface^{483,484}. These CONTAMINANTS will give false pH and DISINFECTANT readings in indoor and outdoor AQUATIC VENUES. To sample, plunge the assembly (*mouth first*) quickly to the marked depth, invert, and let the bottle fill. Remove when full of water and begin testing. A consistent sampling point is important and this sampling point is the feed into the ORP controller which is required by MAHC 5.7.3.7.1. However, the purpose of the samples in MAHC 5.7.4.3 is to ensure that the DISINFECTANT feed settings based off of the ORP are sufficient to ensure that there is a DISINFECTANT residual throughout the POOL at all times BATHERS are present. Since there is usually a higher concentration of BATHERS (and hence BATHER load) in the shallow end, it is especially important to get samples from that area. In other words, the fixed sampling point of the ORP controller provides the variation over time (temporal variation), while the rotating sample points provide the spatial variation. It is important to cover both kinds (temporal and spatial) of variation.

5.7.4.4 Aquatic Venue Water Chemical Balance

Water balance is a term used to describe the tendency of water to dissolve (*corrode*) or deposit minerals (*form scale*) on surfaces contacted by the water. Balanced water will neither corrode surfaces nor form scale. Factors that impact water balance are pH, hardness, alkalinity, dissolved solids, and temperature. The presently used water balance parameters are used to protect AQUATIC VENUE equipment and surfaces from deleterious effects of corrosion and scale formation. Improperly balanced water is not in itself a threat to public health. Water balance is expressed in several ways but the most common one is by the SATURATION INDEX. Each factor in the SATURATION INDEX equation can vary within a limited range and the water is still considered balanced. Shifts in pH have a significant impact on water balance. Water balance chemistry is discussed extensively in all POOL operator classes and is well beyond the scope of this Annex.

5.7.4.4.1 Total Alkalinity Level

Total alkalinity is closely associated with pH, but rather than a measure of hydrogen ion concentration, it is a measure of the ability of a solution to neutralize (*buffer*) hydrogen ions. Expressed in parts per million (*ppm*), total alkalinity is the result of alkaline materials including carbonates, bicarbonates and hydroxides - mostly bicarbonates. As noted in the MAHC, the ideal range is 60 ppm to 180 ppm. This acid neutralizing (*buffering*) capacity of water is desirable because it helps prevent wide variations in pH (*pH bounce*) whenever small amounts of acid or alkali are added to the POOL. Total alkalinity is a measure of water's resistance to change in pH and is a source of rising pH itself from the outgassing of carbon dioxide.

Too Low

If total alkalinity is too low: pH changes rapidly when chemicals or impurities enter the water. pH may drop rapidly when using net acidic sources of CHLORINE or other acidic chemicals (*e.g. Trichlor (trichloro-s-triazinetrione), Dichlor (sodium dichloro-s-triazinetrione), potassium monopersulfate*), causing etching and corrosion.

Raising Total Alkalinity

Total alkalinity can be raised by the addition of bicarbonate of soda (*sodium bicarbonate, baking soda*). Each 1.4 lbs. bicarbonate of soda per 10,000 gallons (*635.0 g per 37,854.1 L*) will raise total alkalinity approximately 10 ppm.

Too High

If total alkalinity is too high: pH becomes difficult to adjust. High pH often occurs causing other problems, such as cloudy water, decreased DISINFECTANT effectiveness, scale formation, and filter problems. The higher the total alkalinity, the more resistant the water is to large changes in pH in response to changes in the dosage of DISINFECTANT and pH correction chemicals.

Lowering Total Alkalinity

Add acid - The acid reacts with bicarbonates in the water and reduces the total alkalinity. Add 1.6 pounds of dry acid (*Sodium Bisulfate*) per 10,000 gallons of water, or 1.3 quarts of muriatic acid, to decrease the total alkalinity by 10 ppm. Retest and adjust the pH. High levels of CYA will cause interference in the total alkalinity test. This interference is magnified at low levels of total alkalinity. To correct for CYA interference, measure the concentration of CYA, divide that number by 3, and then subtract that value from the measured total alkalinity value. Minor deviations from the alkalinity levels stated in the CODE do not in themselves present imminent health threats to the BATHERS. As such, minor deviations in alkalinity levels do not require the immediate closure of the facility. Rather, deviations from permissible alkalinity levels indicate poor management of the water balance and should indicate a need for a thorough inspection of the entire facility.

5.7.4.4.2 Combined Chlorine (Chloramines)

Combined CHLORINE compounds (*chloramines*) are formed when FAC combines with amine-containing compounds such as urea, amino acids, and ammonia from perspiration and urine. Chloramines include inorganic compounds (*monochloramine (NH₂Cl), DICHLORAMINE (NHCl₂) and TRICHLORAMINE (NCl₃)*) as well as a variety of organic compounds. Inorganic chloramines are biocides, but are much less effective DISINFECTANTS than FAC. If the local water treatment plant uses chloramination for drinking water DISINFECTION, inorganic chloramines (*predominantly monochloramine*) may be present in the fill water.

High Chloramines

A high level of chloramines is undesirable in AQUATIC VENUES. The action level for combined CHLORINE is 0.4 ppm (*mg/L*). Higher levels indicate that BATHER loads or pollution from BATHERS may be too high, or that treatment is inadequate. Higher levels may also pose a health concern to BATHERS, employees, and other PATRONS. The World Health Organization recommends that combined CHLORINE levels be “as low as possible, ideally below 0.2 mg/L”⁴⁸⁵. However, this “ideal” level would be challenging to implement as a CODE requirement. Since the combined CHLORINE values reflect the combination of inorganic (*well demonstrated health effects*) and organic (*poorly understood relationship to health effects*) chloramines, the MAHC has decided to work with an “action” level until they can be differentiated. Development of tests that can measure the inorganic chloramines separately from the organic chloramines is needed so actionable levels can be set. With such tests, aquatics staff will be able to respond to actionable levels of volatile chloramines so appropriate air quality can be maintained. The separate measurement of organic chloramines, which accumulate in the POOL, may be a useful marker for the need to replace water or supplement with a system known to remove these compounds. Published data are limited, but suggest that combined CHLORINE levels are commonly above 0.2 ppm (*mg/L*) in swimming POOL water^{486, 487, 488}.

Inorganic Chloramines

Volatilization of chloramine compounds can lead to strong objectionable odors in AQUATIC VENUE environments, as well as eye, mucous membrane, and skin irritation for BATHERS and PATRONS. Among the inorganic chloramines, TRICHLORAMINE has the greatest impact on air quality, owing to its relatively low affinity for water and its irritant properties. TRICHLORAMINE has been reported to be an irritant at concentrations in water as low as 0.02 ppm (*mg/L*).

Odors are unlikely to be present from inorganic chloramines below the following concentrations:

- Monochloramine (NH_2Cl): 5.0 ppm (*mg/L*)
- DICHLORAMINE ($NHCl_2$): 0.8 ppm (*mg/L*)
- TRICHLORAMINE (NCl_3): 0.02 ppm (*mg/L*)

Research to understand the relationship between inorganic chloramine concentrations in water and their impact on air quality is limited, although some research indicates that the gas phase TRICHLORAMINE concentration is dynamic and impacted by BATHER COUNT, swimmer activity, liquid phase TRICHLORAMINE concentration. Reliable sampling and analytical methods affect the accuracy of the characterization of the AQUATIC VENUE water and air.

Health Incidents

Studies of swimming POOL users and non-swimming attendants have shown a number of changes and symptoms that appear to be associated with exposure to the atmosphere in indoor AQUATIC VENUES. CDC has investigated various health incidents reporting skin and eye irritation and acute respiratory outbreaks that could be associated with exposures to chloramines and other by-products at recreational water facilities, including swimming POOLS^{489,490}.

Lifeguard Exposure

For lifeguards at swimming POOLS, a dose–response relationship has been identified between TRICHLORAMINE, measured as total chloramines, and irritant eye, nasal, and throat symptoms, although not chronic respiratory symptoms or bronchial hyper responsiveness⁴⁹¹.

Respiratory Conditions

In addition to potential occupational exposures, there have been a number of studies investigating respiratory conditions, including asthma, related to swimming POOLS (Also see MAHC 4.0.1.4.7). There appears to be no consistent association between swimming POOL attendance during childhood and the prevalence of asthma or atopic disease^{492, 493, 494,495,496}. Studies indicate that asthma is more commonly found among elite swimmers than among other high-level athletes, although it is premature to draw conclusions about the causal link between swimming and asthma because most studies available to date used cross-sectional design, because the association is not confirmed among non-competitive swimmers, and because asthmatics may be more likely to select swimming as the activity of choice because of their condition⁴⁹⁷.

Contact Dermatitis

Chloramines have also been implicated in contact dermatitis (*rashes*). The number of rashes that occurs among BATHERS in treated recreational water is not known. One cross-sectional study of Australian school POOLS retrospectively examined the incidence rate of rashes in three POOLS. The three POOLS treatment types were 1) CHLORINE alone (*hand dosing*), 2) CHLORINE plus ozone (*automatic dosing and control*), and 3) bromine (*sodium bromide plus ozone using automatic dosing and control*). This study reported 14.4% of the BATHERS in the hand-dosed CHLORINE POOLS experienced rashes⁴⁹⁸. This and anecdotal reports strongly suggests that rashes are the most common RWI. The greatest number of rashes appears to be among hydro-therapists (*aquatic physical therapists*). A survey of 190 professional hydro-therapists in Israel reported that 45% developed skin disease after beginning work. Symptoms reported included itchiness, redness, dry skin. The areas affected were the extremities, the face and trunk, and folds in the skin. The authors concluded: 1) exposure to water influences development of irritant contact dermatitis; 2) cumulative exposure of low-potency irritants may be cause of contact dermatitis; 3) contact dermatitis is an occupational disease of hydro-therapists⁴⁹⁹. In these and similar reports, the exact chemical species inducing the contact dermatitis has not been identified but the collective opinions of the investigators is that halogenated organic compounds is the cause. One conservative estimate places the number of halogenated DISINFECTION byproducts (*DBPs*), including organic chloramines, in swimming POOLS at greater than 200. The clinical significance of these is likely to vary with the concentration of specific chloramine and BATHER specific factors (*length of exposure, underlying health conditions, and cumulative previous exposure*).

Maximum Concentration

After considerable discussion the MAHC decided to recommend an action level concentration of 0.4 ppm (*mg/L*) for combined CHLORINE in all recreational waters. As stated in MAHC 5.7.4.4.2, 0.4 ppm is an action level, not an absolute limit that would result in a violation. That is because the combined chlorine measurement made in STANDARD test kits is actually a measure of all organic and inorganic combined chlorine compounds in the water, not just the inorganic chloramines, DICHLORAMINE and TRICHLORAMINE, that are well documented to cause many of the health effects discussed above. Most of the organic CHLORINE compounds measured have little to no information about short or long-term health effects. This means that the combined CHLORINE measured is a variable mixture of irritant compounds and other CHLORINE compounds not known to have these effects or without adequate health effects data. As a result, similar combined CHLORINE levels could vary significantly in the amount of irritating inorganic chloramines in the mix. This makes it difficult to set a regulatory level for combined CHLORINE or other related chemical measures until a test is available to differentiate the irritating inorganic chloramines from the remainder of the combined CHLORINE mixture currently measured. The MAHC's interim solution decision was to move to an action level until such tests are available. The action level is then used to minimize the potential for both respiratory and dermal disease that is known to be associated with exposure to chloramines. The action level is intended to drive POOL operators to conduct regular combined CHLORINE testing and use exceedances of the action level to implement a chloramine reduction plan. That means that failure to conduct regular combined CHLORINE testing or exceeding the action level and having no plan for reducing the value would be the violation cited by inspectors rather than the actual exceedance of the combined CHLORINE action level. The MAHC recognizes that the 0.4 ppm combined CHLORINE concentration chosen is arbitrary and that it has not been substantiated by adequate human clinical studies. In the absence of an adequate human study, the MAHC has opted for a conservative value rather than a more lenient value of 0.5 ppm (*mg/L*) preferred by some operators. The key is that regulators start enforcing regular testing for combined CHLORINE so that POOL operators work towards keeping levels low by responding to this action threshold. Levels of chloramines and other volatile compounds in water can be minimized by reducing introduction of CONTAMINANTS that lead to their formation (*e.g., urea, creatinine, amino acids and personal care products*), as well as by use of a shock OXIDIZER (*e.g., potassium monopersulfate*) or supplemental water treatment. Effective filtration, water replacement, and improved BATHER hygiene (*e.g., SHOWERING, not urinating in the POOL*) can reduce CONTAMINANTS and chloramine formation. Shock dosing with CHLORINE can destroy inorganic chloramines that are formed. Some research shows that non-CHLORINE shock OXIDIZERS reduce the propensity to develop chloramines. However, this research has not been peer-reviewed to date. The EPA has determined that manufacturers of "shock OXIDIZERS" may advertise that their "shock OXIDIZER" products "remove," "reduce," or "eliminate" organic CONTAMINANTS.

- For more information, see the EPA website: <https://www.epa.gov/pesticide-labels/use-term-shock-swimming-pool-hot-tubs-and-spa-products> and https://www.epa.gov/sites/production/files/2015-06/documents/shock_addendum_final.pdf.

Secondary Disinfection

SECONDARY DISINFECTION SYSTEMS such as ozone and UV light may effectively destroy inorganic chloramines. As this also has a public benefit and can assist in meeting the MAHC requirements for combined CHLORINE, it is strongly recommended that any installation utilizing UV or ozone as a SECONDARY DISINFECTION SYSTEM consider the positive impact the equipment may have on reducing combined CHLORINE levels in addition to achieving DISINFECTION goals. To improve chloramine control strategies, future research should be aimed at:

- Defining the fundamental chemistry of DISINFECTION byproducts including, organic and non-organic chloramine formation from precursor compounds that are common to swimming POOLS;
- Defining relationships between levels of combined CHLORINE in water and air of AQUATIC VENUES and the adverse effects on POOL attendees, to include inhalation, ingestion, and contact;
- Documenting efficacy of water treatment technologies to reduce chloramine levels;
- Improve testing for combined CHLORINE in air and water; and
- Testing for the components of combined CHLORINE.

5.7.4.4.3 Calcium Hardness

Calcium hardness is the amount of dissolved calcium (*plus some other minerals like magnesium*) in the water. Calcium hardness of 200 - 400 ppm (*mg/L*) is preferred for proper calcium carbonate saturation and for avoiding soft-water scale found in SPAS and hot tubs when other water parameters are near their nominal levels. For venues with water temperatures greater than 90° F (32°C), the range should be 100 to 200 ppm. Too much calcium causes cloudiness and scale formation. Too little calcium, especially when combined with low pH or low Total Alkalinity can also lead to “aggressive water,” which can dissolve calcium carbonate from plaster, as well as metallic parts of the POOL (*walls, floor, handrails, ladders, light FIXTURES, and equipment*), and also cause discolored water or stains on the POOL walls and floor. The maximum permissible concentration of 2500 ppm (*mg/L*) may not be appropriate for regions with particularly hard source water. In such regions local CODES should reflect the specialized practices needed for source waters containing more than 2500 ppm (*mg/L*) total hardness. Deviations up to 300,000 ppm do not in themselves present imminent health threats to the BATHERS. As such, deviations in hardness levels do not require the immediate closure of the facility. Rather, deviations from permissible hardness levels indicate poor management of the water balance and should indicate a need for a thorough inspection of the entire facility.

5.7.4.4.4 Algaecides

In practice, most algaecides are reasonably effective when applied according to their EPA accepted label directions and the application is coupled with frequent and thorough brushing. CHLORINE and bromine can be registered and used as algaecides, but must be used in accordance with EPA label directions. Bromine and bromamine have been demonstrated to be algaecidal⁵⁰⁰.

Common Types

The two basic types of non-halogen algaecides are copper-based algaecides and quaternary ammonia compounds (*QACs*), often referred to as “quats”. Some algaecides contain a mixture of a quat and a copper compound. Copper-based algaecides can be used to treat against all types of algae, but are especially effective against mustard and green types of algae. These will not cause foam to appear in a swimming POOL as is common with simple quaternary ammonia types of algaecides. There is however a problem with stains on the surface of the swimming POOL if the product is not used properly. Proper pH control is very important to minimize staining potential when using copper-containing algaecides. The other most common types are quaternary ammonium compounds. These algaecides will not stain a swimming POOL. There are two types of quats: simple and polymeric (*more commonly called “polyquats”*). Simple quats are mixtures of various alkyl dimethyl benzyl ammonium compounds (*ADBACs*) or didecyl dimethyl ammonium compounds (*DDACs*). There are numerous variations of these. The technical name for the active ingredient in polyquats is “Poly[oxyethylene (dimethylimino) ethylene (dimethylimino) ethylene dichloride]”. Neither type of quat will cause staining. When overdosed, simple quats tend to cause foam, especially in POOLS with water features (*e.g. fountains, waterfalls*). Polyquats do not cause foaming, even when used repeatedly at the maximum label dose in POOLS with water features.

EPA-Registered Algaecides

In selecting a quat, it is vital that the product has been registered by the EPA for use in swimming POOLS. The vast majority, but not all, of the products on the market have current EPA REGISTRATIONS. All products registered by the EPA will have a registration number on the label (usually it will state “EPA Reg. No.” followed by a series of numbers). This registration number can be verified by using the EPA National Pesticide Information Retrieval System which is managed for the EPA by Purdue University. As part of their registration process the EPA does not distinguish between public and private facilities.

- To access the EPA National Pesticide Information Retrieval System: (<http://ppis.ceris.purdue.edu/#>)

Registered Process

The EPA registration process for algaecides is substantially different than the registration process used for DISINFECTANTS. As part of the development of the product, the EPA requires companies to conduct efficacy studies on the product. The EPA does not consider algae in POOLS or SPAS to be pathogenic and thus not a direct threat to public health. Since algae are not a public health issue, the EPA does not require companies to submit their efficacy package for an agency data review. Thus, in the registration process the EPA looks carefully at the toxicology of the product but not the efficacy. The state of California does require detailed efficacy studies prior to registration. Products sold in the state of California must have the state registration number on the label. Products registered in California but sold outside of the state usually do but are not required to have the California registration number on the label. Any local agency concerned about the efficacy of a particular algaecide could request the producer supply the California registration number and then verify the status of the product with the California Department of Pesticide Regulation (California Code of Regulations, Title 3. Division 6. Pesticides and Pest Control Operations).

5.7.4.5 Source (Fill) Water

Most public recreational water venues use the PUBLIC WATER SUPPLY as the fill water source. In instances where this is not possible, it is important that the fill water not be a potential source of illness to BATHERS. Since requirements governing water quality vary by jurisdiction, it is not possible to specify every test that might be required by a jurisdiction. Therefore, facilities need to insure that the fill water complies with the jurisdictional requirements. Examples of potential tests that a jurisdiction may require include, but are not limited to the following: bacteria, nitrates, nitrites, iron, manganese, sulfur, and turbidity. It is also recommended that this testing be conducted on an annual basis.

5.7.4.6 Water Balance for Aquatic Venues

Water balance is an important part of proper AQUATIC VENUE operation and maintenance. As such, the Langelier SATURATION INDEX (*LSI*) is a useful tool for MONITORING the CORROSIVE or scale-forming tendencies of AQUATIC VENUE water. Although there is little scientific literature on the *LSI* and AQUATIC VENUE water, it is common industry practice to use this index.

The *LSI* formula is: $LSI = pH + TF + CF + AF - TDSF$

- **pH** Obtained by testing the POOL or SPA water.
- **TF** Temperature Factor - using MAHC Annex Table 5.7.4.6 (*below*), look up the actual AQUATIC VENUE water temperature at the time of sampling, in order to obtain the appropriate TF value.
- **CF** Calcium Hardness Factor - determine the ppm (*mg/L*) of calcium hardness (*CH*) in the water sample. Using the MAHC Annex Table 5.7.4.6 (*below*), use the appropriate calcium hardness (*CH*) reading, in order to obtain the appropriate CF value.
- **AF** Total Alkalinity Factor - determine the ppm (*mg/L*) of total alkalinity (*TA*) in the water sample. Using the MAHC Annex Table 5.7.4.6 (*below*), use the appropriate total alkalinity (*TA*) reading, in order to obtain the appropriate AF value.
- **TDSF** Total Dissolved Solids Factor – If the TDS of the water is less than 1,000 ppm (*mg/L*), use the factor of 12.1. If the TDS of the water is greater than 1,000 ppm (*mg/L*), use the factor of 12.2.

Note: Use the **TF**, **CF**, and **AF** factors closest to your actual reading.

Total Dissolved Solids

A generally accepted level for TDS in AQUATIC VENUES is 1,500 ppm (*mg/L*) above the TDS level in the fill water. For AQUATIC VENUE using CHLORINE GENERATORS, startup TDS level should be measured on the initial fill after adding the salt for the CHLORINE generator. Additional research needs to be done to determine TDS in salt water AQUATIC VENUE, and its impact on water quality. TDS is a measure of the overall quantity of matter in the AQUATIC VENUE that is not water. This matter includes such things as minerals (*calcium, magnesium, etc.*), chemicals, body oils, sunscreen, etc. that are not removed by filtration. There is only one state that has a maximum required TDS level (*2,500 PPM (mg/L)*). However, there is no known scientific data that substantiates any value as a maximum level. The 1,500 ppm (*mg/L*) level is utilized based on the fact that as the concentration of these materials increases in the AQUATIC VENUE they can result in staining, cloudy water, decreased effectiveness of DISINFECTANTS (*by up to 50%*), and an enhanced environment for the growth of algae. Excessively high TDS levels (*greater than 5000 ppm (mg/L)*) may require more drastic measures such as a complete AQUATIC VENUE drain and refill, or additional water filtering, as a complete water drain may damage some AQUATIC VENUE. It is also important to note that the salt required by saltwater chlorination systems will substantially increase the TDS level. Therefore, in saltwater AQUATIC VENUE, it is best to consider the TDS level after the required amount of salt has been added to a freshly filled AQUATIC VENUE as the baseline level.

Table 5.7.4.6 Langelier Index Conversion Chart

TF		CF		AF	
Temp °F/°C	TF	CH ppm (mg/L)	CF	TA ppm (mg/L)	AF
32°F / 0°C	0.0	5	0.3	5	0.7
37°F / 3°C	0.1	25	1.0	25	1.4
46°F / 8°C	0.2	50	1.3	50	1.7
53°F / 12°C	0.3	75	1.5	75	1.9
60°F / 16°C	0.4	100	1.6	100	2.0
66°F / 19°C	0.5	150	1.8	150	2.2
76°F / 24°C	0.6	200	1.9	200	2.3
84°F / 29°C	0.7	300	2.1	300	2.5
94°F / 34°C	0.8	400	2.2	400	2.6
105°F / 41°C	0.9	800	2.5	800	2.9
128°F / 53°C	1.0	1000	2.6	1000	3.0
		1300	2.7		
		1600	2.8		
		2000	2.9		
		2500	3.0		

Water balance should fall within the range of -0.3 to $+0.3$, as determined by the Langelier SATURATION INDEX.

A Low Langelier Index (a value less than -0.3) can result in corrosion, BATHER irritation, and discomfort. AQUATIC VENUE water may cause etching, pitting, dissolving, and staining of walls, grouting, and plumbing.

LSI Decreases as:

- Stabilizer Increases, and
- Total Dissolved Solids Increase.

A **High Langelier Index** (a value greater than +0.3) can lead to scale formation, cloudy water, filtration problems, heater problems, loss of CHLORINE efficiency, and BATHER discomfort. AQUATIC VENUE water may deposit excess minerals on the POOL and equipment. Scale generally appears as white or lightly colored rough blotches on the AQUATIC VENUE walls. It also adheres to other objects in the POOL, piping and filter system. Scale can restrict water flow, shortening filter runs and reducing filtration efficiency.

LSI Increases as:

- Temperature Increases,
- Total Alkalinity Increases,
- pH Increases, and
- Calcium Hardness Increases.

A small positive value is preferred over a negative value because a slight scale layer provides some protection, and is less harmful than corrosion, which causes permanent damage to mechanical and structural components.

Langelier Indexes can be adjusted to the -0.3 to +0.3 range by:

- Adjusting the pH to 7.2 to 7.6, and
- Adjusting the total alkalinity to 60 to 180 ppm (*mg/L*), and
- Adjusting the calcium hardness to
 - 200 to 400 ppm (*mg/L*) for a masonry POOL or SPA, or
 - 80 to 200 ppm (*mg/L*) for a vinyl or fiberglass unit.

While it is always possible to lower the pH, it is not as simple with the total alkalinity or calcium hardness. Lowering the total alkalinity will usually lower the pH as well. Lowering the calcium hardness is not always possible, given the variation in hardness of the fill water. In situations where the calcium level is high, attention should be paid to lowering the pH and / or total alkalinity in order to improve the LSI. It is not always possible to get the pH and total alkalinity within the proper range, due to the nature of the dissolved minerals. pH is the more important parameter, and should be maintained within the proper range. If the AQUATIC VENUE is outdoors, and uses stabilized CHLORINE, in order to get a more accurate reading of the LSI, it is recommended that 30% of the CYA reading be deducted from the total alkalinity test result.

5.7.4.7 Water Temperature

Specialized populations may require specific water temperatures for safe and effective programming. Some general guidelines are as follows:

- Cold water can affect both mental and bodily functions, possibly preventing clear thinking and restricting normal physical activity. It is uncomfortable and can be painful, and puts a strain on the body as you try to rewarm. By definition, water below 70°F (21°C) is considered cold, due to the fact that body heat is absorbed twenty-five times faster in water than air.
- Multi use AQUATIC VENUES are usually kept at 83°F – 86°F (28°C – 30°C), while competitive AQUATIC VENUES are usually maintained at cooler temperatures between 78°F – 82°F (25.5°C – 27.5°C). Depending on the target population, instructional and THERAPY POOL water temperatures usually range between 86°F – 94°F (30°C – 34°C).

The following table adapted from USA Swimming provides guidelines for water temperatures based on activity and population:

Table 5.7.4.7: Water Temperature Guidelines Based Upon Activity and Population

Bather Type	Temperature Range	Notes
Swim Team & Lap Swim	78°-82°F (25.5°-27.5°C)	Slightly warmer may be workable
Resistance Training	83°-86°F (28°-30°C)	---
Therapy & Rehab	91°-95°F (33°-35°C)	Can be as low as 87°F (30.5°C) for many types of therapy
Multiple Sclerosis	80°-84°F (26.5°-29°C)	Warmer water can cause adverse effects
Pregnancy	78°-84°F (25.5°-29°C)	Warmer water can cause adverse effects
Arthritis	84°-90° F (29°-31°C)	Arthritis Foundation min/max
Arthritis	86°-90°F (28°-32°C)	ATRI low function program
Fibromyalgia	86°-96°F (30°-35.5°C)	ATRI
Aerobic Activity	84°-88°F (29°-31°C)	---
Older Adults – Vertical	83°-86°F (28°-30°C)	Moderate to high intensity
Older Adults – Vertical	86°-88°F (30°-31°C)	Low intensity
Children, Fitness	83°-86°F (28°-30°C)	---
Children’s Swim Lessons	82°F (27.5°C)	Varies with age and class length
Obese	80°-86°F (26.5°-30°C)	---

There are no definitive temperatures that are applicable for all uses of an AQUATIC VENUE. The suggested AQUATIC VENUE water temperature is dependent on the person’s activity in the POOL. For example, individuals participating in competitive swimming prefer cooler water (70°-80°F or 21°-27°C) than individuals participating in water fitness for arthritis (83°F or 28°C, *minimum*) based on POOL temperatures suggested by the U.S. Water Fitness Association, see: http://www.uswfa.com/suggested_pool_temps.asp. Water ranging in temperature from 79°-86°F (26°-30°C) is comfortable for most swimmers throughout prolonged periods of moderate physical exertion.⁵⁰¹ However, there are maximum temperatures that can and do have an effect on the health of the PATRON using the facility. Water temperature between 83°-86°F (28°-30°C) is the most comfortable temperature for typical recreational water usage. Water temperature may need to be adjusted based upon specific uses of the facility. The WHO recommends that water temperatures in hot tubs be kept below 104°F (40°C). High temperatures (*above 104°F or 40°C*) in SPAS or hot tubs can cause drowsiness, which may lead to unconsciousness and, consequently, drowning⁵⁰². The CPSC has received reports of several deaths from extremely HOT WATER (*approximately 109°F or 43°C*) in hot tubs. In addition, high temperatures can lead to heat stroke and death. Further examination of data on the health impact of high temperature water on pregnancy, particularly in the first trimester, is needed. Minimum temperature requirements are not included in this CODE. Water that is too cold, simply will not be utilized for any extended period of time, and will not be used by individuals seeking a recreational water experience. Even though minimum temperatures are not included in the CODE, it is important to remember that cold-water basins, such as plunge POOLS, can present health concerns due to water temperature extremes. These small, deep POOLS generally contain water at a temperature of 46-50°F (7°-10°C) and are used in conjunction with saunas or steam baths. Adverse health outcomes that may result from the intense and sudden changes in temperature associated with the use of these POOLS include immediate impaired coordination, loss of control of breathing and, after some time when the core body temperature has fallen, slowed heartbeat, hypothermia, muscle cramps, and loss of consciousness. In general, exposure to temperature extremes should be avoided by pregnant women, users with medical problems, and young children.⁵⁰³

Spa Temperature Maximum

SPA temperature maximum was based on the preponderance of state CODES that currently use this temperature and it is widely accepted and practiced in the industry. See discussion below in MAHC Annex 5.7.4.7.2 that recommends further evaluation.

Comfortable

Water varying from 83°-86°F (28°-30° C) is the most comfortable temperature for typical water fitness classes. This allows the body to react and respond normally to the onset of exercise and the accompanying increase in body temperature. Cooling benefits are still felt and there is little risk of overheating. Program modifications will be required for water temperature outside the recommended range. Aquatic fitness professionals should know the water temperature and modify the program accordingly based upon the population and the program format.

Below Recommendation

Water temperature below the recommended range requires modifications in programming. The primary focus of the warm up should be large, lower impact, rhythmic movements that gradually elevate core temperature of the body and should last for at least 9-15 minutes. The main segment must be of adequate intensity to maintain proper body temperature and prevent injury. Participants may find it necessary to wear specialized clothing to maintain body heat. The cool down and post-stretch must be adjusted, in overall length as well as activity, according to the environmental conditions. Water temperature above the recommended range also requires modifications in programming. The intensity and length of the main segment should be adjusted to prevent overheating. Encourage proper hydration and apparel (*e.g. avoid swimming caps that prevent heat dissipation*). An extended cool down with emphasis on stretching and relaxation is appropriate.

5.7.4.7.2 Maximum Temperature

SPA temperatures of 104°F (40°C) are routinely used in SPAS and hot tubs across the United States. The MAHC is not aware of data that suggests this is too high for use by healthy individuals. Higher temperatures mimic a high fever in the human body and may not be healthy, particularly for prolonged use. However, the high temperature used in SPAS and hot tubs (*MAHC sets it at 104°F / 40°C maximum*) necessitates strong signage to alert users about alcohol use and alert vulnerable groups about the risks potentially associated with use of SPAS and hot tubs. Review of the existing data (*or collection of new data*) is needed to inform the MAHC about whether a maximum length of time in a SPA should be set.

Ethanol Use and Solo Use

Ethanol use may contribute to the likelihood of drowning⁵⁰⁴. Low to moderate doses of ethanol did not appear to significantly impact body temperature or thermoregulatory response systems in healthy males at 104°F (40°C)^{505,506}. However, there did appear to be increased risk of cardiac hypotension and fainting when users stood up that could result in slips or falls, the most common cause of SPA-related injury in the United States⁵⁰⁷. Several studies of sauna-related deaths in Scandinavia find a high percentage of alcohol use and that users were alone^{508,509}. Signage to restrict alcohol use, not to use SPAS when alone, and to exercise caution and use handrails to exit is warranted.

Pregnant Women

Maternal hyperthermia has been shown to be associated with birth defects⁵¹⁰. Some studies have shown an increased risk of birth defects and miscarriages associated with hot tub or SPA use during early pregnancy^{511,512,513,514}. Pregnant women, particularly during the first trimester, should consult their healthcare provider before using hot tubs or SPAS. If women in later pregnancy choose to use hot tubs or SPAS, they should keep exposure to a minimum, and ensure the temperature is at or below recommended STANDARDS. Signage should alert pregnant women about the potential risks of hot tub or SPA use and the need to consult with their physician before use. Further expert review of the data is warranted to see if the data support reducing the water temperature and, if so, what temperature should be adopted to proactively protect women of childbearing age who may not know if they are pregnant.

Young Children

Few studies exist looking at the impact of high temperature on young children although older children do appear to be able to control their temperature as well as adults⁵¹⁵ but the high temperatures in saunas do put great demands on the circulatory system⁵¹⁶. However, infants cannot control their body temperature as effectively as their older siblings and parents. This is because babies have a small body mass compared to body surface area. Being in water even a few degrees different from normal body temperature (98.6°F/37°C) can affect a baby's body temperature. Being in very warm or HOT WATER found in hot tubs/SPAS can cause hyperthermia, a dangerously high body temperature. Signage for SPAS and hot tubs should caution users about bringing infants and young children into SPAS or hot tubs, particularly for prolonged use.

5.7.5 Water Quality Chemical Testing Frequency

Table 5.7.5: Water Testing Frequency Reference Chart

Chemical	Start-up*	Manual Testing	Automated Controllers	Closing*
Free Chlorine	Yes	2 hrs.	4 hrs.	Yes
Combined Chlorine	Yes	2 hrs.	4 hrs.	Yes
pH	Yes	2 hrs.	4 hrs.	Yes
TA	Yes	-	-	-
CH	Yes	-	-	-
CYA	Yes [†]	-	-	-
TDS	Yes	-	-	-

Note: Microbiological testing shall be conducted after a fecal incident.

Note: Manual testing should be done after a significant weather event for outdoor facilities.

* Manual testing to be done at these times.

† Unless TriChlor (trichloro-s-triazinetriene) or DiChlor (sodium dichloro-s-triazinetriene) are used for daily SANITIZER or shock, then weekly.

5.7.5.1 Chemical Levels

When using colorimetric testing methods, combined CHLORINE testing consists of measuring FREE CHLORINE, measuring total CHLORINE, and subtracting the FREE CHLORINE from the total CHLORINE. When using titrimetric methods, it is easiest to perform a direct measure. The analyst should simply count each drop of titrant and multiply by the correct factor to attain the combined CHLORINE level. A properly calibrated automatic chemical MONITORING system which maintains records and can be MONITORED remotely via a secure website could be acceptable for daily testing, if the system allows for the health department to have access to view a read-only log which MONITORS the chemistry at a facility.

5.7.6 Water Clarity

Water clarity is a useful measure of general water quality. Visual observation of main drains is important for BATHER SAFETY to avoid drowning incidents and injury prevention (*for BATHER visibility*). For POOLS, the use of a Secchi disk is not recommended. If a marker tile or suction outlet is not available, an alternate means of measuring clarity, such as a submersible manikin or shadow doll, could be placed at the deepest point of the POOL/attraction to check clarity. For more information about the limitations of Secchi disks, see NOAA Technical Memorandum ERL PMEL-67.

5.8 Decks and Equipment

5.8.1 Spectator Areas

ANSI defines where a trip hazard is considered as a level change that is greater than ¼ inch (6.1 mm). Other definitions include an abrupt or unexpected level change in surfaces.

5.8.1.2.3 Tripping Hazards

Over time changes may occur in DECK elevation, or equipment added to or removed from the DECK surface. The DECK should be inspected to ensure any changes in DECK elevation or the addition or removal of DECK equipment does not cause a tripping hazard.

5.8.2 Diving Boards and Platforms [N/A]

5.8.3 Starting Platforms

See MAHC Annex 4.8.3 for discussion.

5.8.4 Pool Slides [N/A]

5.8.5 Lifeguard and Safety Related Equipment

5.8.5.1 Equipment Inspection and Maintenance

The absence of this required equipment can adversely affect the effectiveness of a rescue and the SAFETY of the lifeguard. It could also hinder the response from emergency services. For this reason, it is the responsibility of the owner/operator to make sure this equipment is in place prior to opening the AQUATIC FACILITY to the public. The equipment should be working so it can be used when needed. The word "safe" denotes the equipment is not modified to be in working condition and thus pose a risk to the user.

5.8.5.2 Safety Equipment Required at All Aquatic Facilities

5.8.5.2.1 Emergency Communication Equipment

5.8.5.2.1.1 Functioning Communication Equipment

As stated in the design section, emergency communication devices should be part of the design but also required to be present in the operation.

5.8.5.2.1.2 Hard Wired Telephone for 911 Call

- The AQUATIC FACILITY must be provided with the tools necessary for rapid and effective emergency communication. These tools might include a telephone, emergency band radio or other effective means of communication.
- Having a reliable telephone available during an emergency is important. Frequently cellular telephones, cordless telephones, and other self-powered devices are not ready for use. Having a hard wired telephone provides that reliability.
- The telephone must be available to all AQUATIC VENUE users for use in an emergency, anytime the AQUATIC VENUE is open for use. Pay telephones must be able to dial 911 without the use of coins or cards and maintained in an operable condition.
- The communication device should be placed in a manner where BATHERS can see and reach the device within about 1 minute and be placed so there are no obstructions to reaching it. The response time by the proper emergency agency has been shown to make a difference in patient outcome⁵¹⁷.

5.8.5.2.1.4 Alternate Communication Systems

The intent is that an emergency phone or alternate communications system or device is immediately available to PATRONS from all AQUATIC VENUES within an AQUATIC FACILITY. Some alternate communication systems might include a handset or intercom system to a location that is constantly manned whenever the AQUATIC VENUE is open for use (*e.g. a front desk at a hotel, the check in desk at a fitness club, or other continuously manned location*); a commercial emergency contact device that connects to a MONITORING service, or directly to 911 dispatch; or devices that alert multiple staff on site when activated (*e.g. pagers systems, cellular telephone systems and radio communication alert systems*). For larger facilities, this could include internal communication processes such as two-way radio use to a central phone to facilitate emergency communications to outside EMS in place of hard wired publicly accessible phones.

5.8.5.2.2 First Aid Equipment

5.8.5.2.2.1 Location for First Aid

This is stated in the design section but also stated in the MAHC operations section to require the operator to designate a first aid location for existing facilities. The supplies should be provided at locations where they can be quickly accessed by staff responding to emergencies.

5.8.5.2.2.2 First Aid Supplies

The first aid supply list is based on ANSI/ISEA Z308.1 for a Workplace First Aid Basic Kit. The listed contents are based on the items needed, but the quantities are not specified to allow for flexibility based on the size of the AQUATIC FACILITY, the anticipated BATHER COUNT, anticipated number and types of injuries, and the number of first aid locations. Topical supplies such as antibiotic cream, burn gels, and antiseptics were removed because this poses a scope of practice issue for the level of training typical to lifeguarding. The operator should provide

enough supplies that the kit does not need continuous restocking. There should be enough supplies to last between first aid kit supply inspections, plus the time needed to obtain and replace the supplies. The contents should be inspected and resupplied often enough to maintain the supplies in good condition. The supplies must be stored in such a manner as to protect them from moisture and extremes of heat and cold that will cause deterioration. Supplies must be periodically checked for expiration dates and replaced as needed. A biohazard cleanup kit was included as lifeguards often deal with body fluids on surfaces such as vomit, feces, and blood. According to OSHA⁵¹⁸, “Generally, lifeguards are considered to be emergency responders and, therefore, would be considered to have occupational exposure. Emergency response is generally the main responsibility of lifeguards, therefore, such duties could not be considered collateral. Although it is the employer's responsibility to determine which, if any, of the employees have occupational exposure, employers of lifeguards should examine all facets of the lifeguard's emergency response duties, not just "retrieval from deep water." As a result, lifeguards are covered under OSHA 29 CFR 1910.1030 Bloodborne Pathogens STANDARD, which speaks to having contact with individuals that may be injured and bleeding. As a result, employers are required to offer all the protections of the Bloodborne Pathogens STANDARD. Management should also consider how bloodborne pathogen training is integrated with training for environmental and/or water-based clean-up of feces and other body fluids (*See MAHC 6.5*). The MAHC chose to compile this list after reviewing the contents of several kits that were commonly available. One complete bloodborne pathogen spill kit is needed at the AQUATIC FACILITY. Example of minimum suggested contents:

- Disposable gloves*;
- Disposable gown or apron, facemask, shoe covers;
- Face Shield;
- Anti-microbial wipes;
- Biohazard Bag;
- DISINFECTANT (*ex. calcium hypochlorite packet – 1 oz.*);
- Absorbent materials or fluid solidifier (*~20 gm*);
- Scoops for solidified material;
- Scraper; and
- Instructions for use.

* Do not use latex gloves due to the potential for allergies. Gloves should be single use, vinyl or nitrile, and non-powdered. Gloves should be disposed of after one use. Fit is important. It is recommended that 4 to 6 mil. gloves be used.

** It is suggested that a kit be assembled, put in a container and sealed to assure the contents are still intact when needed. After use, a new kit is provided or the container is restocked and resealed.

In addition to the AQUATIC FACILITY kit, lifeguards should carry basic PPE for immediate use during initial exposure to feces, vomit, and small amounts of blood until the full kit arrives at the treatment scene. AEDs were considered to be included in this list, but due to the requirement for medical direction for AED use by trained rescuers, it was not included as it may not be within the AHJ's authority to mandate such equipment. However, AEDs are widely used and can be used for submersion events and any cardiac incident. If local protocols can be established, it is recommended to have an AED.

5.8.5.2.3 Signage

5.8.5.2.3.1 Sign Indicating First Aid Location

Effective signage must communicate where first aid assistance can be obtained. This is especially important in smaller AQUATIC FACILITIES and at AQUATIC FACILITIES not requiring lifeguards where the first aid station might be outside the immediate AQUATIC VENUE area. Signage is also important at very large AQUATIC FACILITIES where the first aid station might be harder to find. Effective signage should follow the STANDARDS established by ICC A117.1 and ADA Accessibility Guidelines including sign height, raised or Braille lettering, and placement. Emergency telephones or communication devices are usually in conspicuous locations; however, those locations should be communicated so BATHERS and staff alike so they know where they can rapidly locate them.

5.8.5.2.3.2 Emergency Dialing Instruction

Signage must be posted at the telephone or approved communication system or device with emergency contact number(s) or procedures and the address of the AQUATIC FACILITY. Often a person in an emergency situation can be confused, so having the address of the AQUATIC FACILITY, emergency number(s), and special instructions, if any, at the telephone makes responding easier.

5.8.5.2.3.3 Management Contact Info

An owner/operator contact number must be provided for notification of water quality and SAFETY concerns. At AQUATIC FACILITIES where QUALIFIED OPERATORS are not present at all times, it is important for PATRONS to be able to contact the owner/operator when water quality has been compromised (*e.g. cloudy water, fecal matter in the water, and/or other issues of concern related to water quality or SAFETY*).

5.8.5.2.3.4 Hours of Operation

Operating hours for an AQUATIC FACILITY should be posted and clearly visible at the AQUATIC FACILITY, especially when the AQUATIC FACILITY is not attended at all times by an operator or lifeguard.

5.8.5.3 Safety Equipment Required at Facilities with Lifeguards

5.8.5.3.1 UV Protection for Chairs and Stands

In MAHC 4.8.5.3.3, permanently installed chairs and stands are required to be designed with UV protection. In MAHC 5.8.5.3.1, chairs and stands are required to have the UV protection present. Regardless of when the chair or stand was constructed, UV protection is required to protect the lifeguard from an occupational exposure.

5.8.5.3.2 Backboard

Backboards facilitate extrication of unresponsive victims and immobilization and extrication of a person with a suspected spinal injury. Because these backboards are often used in or around the water, their construction should be of materials that can withstand the environment and be easily SANITIZED/DISINFECTED between uses. Backboards must be properly maintained and in good repair. An example is using a wooden backboard that is worn so the wood is exposed and no longer cleanable. In this case, refinishing it with a waterproof finish should again make it cleanable. Additionally, the head immobilizer and straps are commonly used in lifeguard training programs for spinal injury management and these tools assist in the immobilization of a person on the backboard and should be present during operation. When deciding which straps to be included, one should consider how to best immobilize the person to the backboard. Common locations for straps are at the upper torso, the hips, and legs. The number of backboards available at the AQUATIC FACILITY should be dependent on the size of the AQUATIC FACILITY and allow for a quick access to the backboard(s). It may be difficult to determine the exact number but the MAHC requires that a backboard reach any area of any zone of surveillance within 2 minutes. There should not be a delay in care for the person needing to be extricated from the water.

5.8.5.3.3 Rescue Tube Immediately Available

The 50th percentile adult is at least 64 inches (*1.6 m*) tall. The rationale is that the average adult BATHER'S head would be above the static water line and they could use the AQUATIC VENUE without difficulty. Due to buoyancy considerations at chest level, a short lifeguard could have difficulty doing a rescue safely without equipment. For this reason, the rescue tube is required unless there is less than 3 feet (*0.9 m*) of depth in which their chest would likely be above the static water line. Lifeguard training agencies have determined that the use of a rescue tube makes rescues safer for both the victim and the rescuer. The rescue tube provides a BARRIER between the victim and the rescuer as well as a handhold for both during a rescue. In very shallow water, the rescue tube may not be as effective so the language in the CODE is flexible to allow for the rescue tube to be available immediately, but is not required to be worn. However, as stated above, the rescue tube provides protection for the lifeguard so the operator should determine the level of risk and requirement for wearing the rescue tube based on the AQUATIC VENUE depth, activities, and frequency of rescue.

5.8.5.3.4 Rescue Tube on Person

Being properly prepared to respond to an emergency requires wearing the harness strap attached to the rescue tube and keeping the rescue tube in a position and location where it can be immediately used. It is important to wear the rescue tube in a rescue ready position. Wearing the strap and sitting with the tube at the lifeguard's feet, or in any other position except held against the body, can lead to situations where a lifeguard is injured or cannot respond because the tube's strap is wrapped around handrails, chair pedestals or other catch points. Management

should reinforce through pre-service, in-service, and employment policy that the lifeguards are expected to hold the rescue tube in a manner taught and accepted by the lifeguard training agency.

5.8.5.3.5 Identifying Uniform

There should be no delay in care because a PATRON is unable to find a member of the AQUATIC FACILITY SAFETY TEAM. Distinct uniforms are a STANDARD in most industries to identify workers and their assigned tasks.

5.8.5.3.6 Signal Device

The most basic communication method used by lifeguards is a combination of whistle blasts and hand signals to communicate with each other, PATRONS, and management. Whistle signals can communicate when to clear the POOL, get another lifeguard's or supervisor's attention, and communicate emergencies. The devices and their use can vary depending on the AQUATIC FACILITY and its management. Because of inherent BACKGROUND NOISE, whistles, hand signals, emergency buttons, radios, and telephone handsets are used to provide more effective communication.

5.8.5.3.7 Sun Blocking Methods

Protection from direct sun exposure is a necessary part of lifeguarding at AQUATIC FACILITIES. Gone are the days when the objective of the lifeguard was to get as deep a tan as possible. Today, sun exposure, especially when the skin becomes burned, increases significantly the risk of skin cancers. In a recent study of melanoma, it was noted that the melanoma DNA contained 33,000 mutations, many of which may have come from UV light exposure⁵¹⁹. The best sunscreens available at the present time are broad spectrum or full spectrum and are usually so labeled. More will probably become available as new Food and Drug Administration rules are implemented⁵²⁰. These protect against both UVA and UVB rays as long as re-application is conducted periodically. Because SPF ratings only measure UVB effectiveness there is a lot of variability in UVA protection in sunscreens. The CDC recommends a sunscreen with an SPF of at least 15⁵²¹. There are some questions about the health effects of some of the screening chemicals, but the benefits seem to outweigh the hazards. To minimize exposure to these chemicals, lifeguards should also wear protective clothing, hats, use sun-blocking umbrellas, or any other means to avoid exposure to UV light. Protection is also needed from reflected exposure. Light-skinned individuals can be particularly sensitive to both direct as well as indirect exposure to the sun's UV rays⁵²². Employers should educate lifeguards about the risk and protection options but are exempted from requirements to pay for sunscreen as PPE according to OSHA 29 CFR 1910.132(h)(4)(iii)⁵²³.

5.8.5.3.8 Polarized Sunglasses

Glare and reflected sunlight off the water surface can cause significant visibility problems for lifeguards and potentially impact job performance. Lifeguards working at outdoor AQUATIC VENUES are required to wear polarized eye wear to reduce the risk of glare causing reduced visibility. This polarized eyewear should also be a part of any sun exposure awareness training since it also potentially reduces the harmful short- and long-term effects of UV on eyes that include increased risk for cataracts and macular degeneration^{524,525,526,527,528,529,530}. However, employers are exempted from requirements to pay for sunglasses as PPE according to OSHA 29 CFR 1910.132(h)(4)(iii)⁵³¹. Polarized eyewear can assist with glare indoors as well but should be tested so it does not impede visibility due to lower light levels. Polarized 3-D glasses must not be used as they can be disorienting and can disrupt normal vision.

5.8.5.3.9 Personal Protective Equipment

Appropriate PPE must be provided to all employees that have possible occupational exposures. On-duty QUALIFIED LIFEGUARDS should carry basic PPE (*disposable gloves and resuscitation mask with one-way valve*) or have it attached to the rescue tube so it is available for immediate use during in-water unconscious rescues. This should prevent delay in appropriate care and for protection during initial exposure to feces, vomit, and small amounts of blood until the full facility bloodborne pathogen kit arrives at the treatment scene. This PPE could be in a small pouch to be carried on the lifeguard or in a pouch associated with the rescue tube. The intent is that the lifeguard does not need to leave the immediate area to find PPE nor will it create a delay in response.

OSHA Bloodborne Pathogen Regulations⁵³², require that the employer shall provide, at no cost to the employee, appropriate PPE such as, but not limited to, gloves, gowns, face shields or masks and eye protection, and mouthpieces, resuscitation bags, pocket masks, or other ventilation devices. PPE will be considered "appropriate" only if it does not permit blood or other potentially infectious materials to pass through to or reach the employee's

work clothes, street clothes, undergarments, skin, eyes, mouth, or other mucous membranes under normal conditions of use and for the duration of time which the protective equipment will be used.

NOTE: The Food and Drug Administration (FDA) issued a rule banning powdered gloves that became effective on January 18, 2017. FDA determined that Powdered Surgeon's Gloves, Powdered Patient Examination Gloves, and Absorbable Powder for Lubricating a Surgeon's Glove present an unreasonable and substantial risk of illness or injury and that the risk cannot be corrected or eliminated by labeling or a change in labeling. Health effects documented include inflammation, granulomas, and respiratory allergic reactions. The full rule can be accessed at <https://www.federalregister.gov/documents/2016/12/19/2016-30382/banned-devices-powdered-surgeons-gloves-powdered-patient-examination-gloves-and-absorbable-powder>.

5.8.5.3.10 Rescue Throwing Device

If the single lifeguard is engaged in a rescue and another person is in distress, the rescue throw device allows for an untrained individual to assist the distressed person.

5.8.5.3.11 Reaching Pole

If the single lifeguard is engaged in a rescue and another person is in distress, the reaching pole allows for an untrained individual to assist the distressed person.

5.8.5.4 Safety Equipment and Signage Required at Facilities without Lifeguards

5.8.5.4.1 Throwing Device

A rescue throwing device is a throw bag, buoyant life ring, torpedo buoy or other easily thrown buoyant device that is designed for a person on the DECK to throw to a person in distress in the AQUATIC VENUE. Fifty feet (15.2 m) minimum of ¼ inch (6.4 mm) rope securely attached to the device is required. It has been found that untrained individuals have a reasonable ability to reach 30 feet (9.1 m) with a rescue throw device. A 50 foot (15.2 m) rope would accommodate that distance. The 1.5 times the width of the POOL allows for a SAFETY factor to overthrow the device and pull the rope back toward the person in distress. This also allows for extra rope to hold on to. The device must be kept ready for use, and the rope must be coiled to prevent tangles and to facilitate throwing the device.

5.8.5.4.2 Reaching Pole

The pole is intended to reach out to a swimmer in distress and to allow them to grab hold of the pole. The pole should be submerged when introducing it to the swimmer to prevent injury. In some cases the “hook” can be used to encircle a non-responsive swimmer to draw them to the side. Use of the device involves reaching out to the swimmer and then pulling the pole straight back to the side, along with the swimmer. The pole cannot be swung around to the side as the strength required exceeds that of most people, and the pole is not that durable. Since the pole is pulled back to the side, a telescoping pole is not appropriate as it can pull apart. Ideally the pole can reach to the middle of many smaller POOLS making the entire POOL reachable from the side with the pole. The pole must be equipped with a “life-hook” or “shepherd’s crook”. For SAFETY, the hook must be a looped frame-type hook, not the single metal hook. The hook protects the swimmer from being injured by the pole, as well as allows a non-responsive swimmer to be pulled in. To prevent injury, use only the hook attachment bolts supplied by the manufacturer. This will prevent hooks and snags, caused by using the improper bolts, which can injure the swimmer.

5.8.5.4.3 CPR Posters

CPR performed by bystanders has been shown to improve outcomes in drowning victims⁵³³. CPR started immediately on a drowning victim instead of waiting until emergency responders arrive will have a significant effect on the potential for brain damage in the victim. Posters of CPR explaining basic procedures can be reviewed in seconds and give the provider enough knowledge to assist the victim until emergency responders arrive. Posters can educate PATRONS to recognize potential causes of, prevention, and spread of RWIs. PATRONS need to be educated to what RWIs are, how they are spread, and how they can be prevented.

Resources for RWI education can be found at <http://www.cdc.gov/healthyswimming>. There are many resources for CPR posters that can be found online.

5.8.5.4.4 Imminent Health Hazard Sign

A sign indicating reasons requiring closure especially at AQUATIC FACILITIES where a QUALIFIED OPERATOR or QUALIFIED LIFEGUARD is not present should be posted listing specific incidents which would require the AQUATIC FACILITY to immediately close. Examples of such incidents include fecal incidents, broken/missing drain grates, water clarity, water quality issues, and lightning. A contact number should be provided to notify the owner/operator of conditions considered an IMMINENT HEALTH HAZARD.

5.8.5.4.5 Additional Signage

MAHC 6.3.2 outlines the conditions that require a QUALIFIED LIFEGUARD. For AQUATIC FACILITIES that do not have lifeguards, PATRONS should be informed that no lifeguard is provided so they can comply with any requirements and understand the identified risk. For instance, at a hotel POOL that requires key entry, the sign would notify hotel guests that no lifeguard is provided and persons under the age of 14 are not allowed in without adult supervision.

5.9 Filter/Equipment Room

In a review of POOL chemical incidents documenting 400 incidents, 221 reported two contributing factors. Of the 221 secondary factors, 39.8% listed improper chemical mixing as one of the contributing factors⁵³⁴.

5.9.1 Chemical Storage

5.9.1.1 Local Codes

All chemical containers must be labeled with the following information:

- Chemical identity,
- Manufacturer's name and address,
- Physical hazards,
- Health hazards, and
- Degree or type of risk.

The label should explain necessary precautions to take; how to handle, store, and dispose of chemicals; and sometimes indicate hazard potential with a number from 0 to 4. This number indicates the degree of risk, with the number 4 representing the greatest risk, and shows the hazard categories (see NFPA 704).

5.9.1.2 OSHA and EPA

Chemicals should never be pre-mixed with water by hand before adding the chemical to the AQUATIC VENUE unless specified by the manufacturer. If a dissolution or feed tank is used to dissolve product for feeding into the AQUATIC VENUE, the tank must be equipped with a mechanical mixer, dedicated to a single chemical, and clearly labeled to prevent the introduction of incompatible chemicals to the tank.

Chemicals should be added to water, water should never be added to chemicals.

Pre-mixing in containers that are not clean can result in the generation of heat and toxic gases and may result in fire or explosion. OXIDIZERS such as calcium hypochlorite, monopersulfate or bleach shall not be mixed with any other chemicals.

5.9.1.3 Safety Data Sheets (SDS)

An SDS is a form containing data, potential hazard information, and instructions for the safe use of a particular material or product. An important component of product stewardship and workplace SAFETY, it is intended to provide workers and emergency personnel with procedures for handling or working with that substance in a safe manner, and includes information such as physical data (*melting point, boiling point, flash point, etc.*), toxicity, health effects, impact on the environment, first aid, reactivity, STORAGE, disposal, protective equipment, and spill handling procedures. The exact format of an SDS can vary from source to source. It is important to use an SDS that is supplier-specific as a product using a generic name (*e.g. OXIDIZER*) can have a formulation and degree of hazard which varies between different manufacturers.

Filed

SDSs should be filed anywhere chemicals are being used. An SDS for a substance is not primarily intended for use by the general consumer, focusing instead on the hazards of working with the material in an occupational setting.

OSHA

In the U.S., OSHA requires that SDSs be available to employees for potentially harmful substances handled in the workplace under the Hazard Communication regulation. The SDS is also required to be made available to local fire departments and local and state emergency planning officials under Section 311 of the Emergency Planning and Community Right-to-Know Act (EPCRA).

Hazard Ratings

The SDS will typically contain the hazard ratings according to either NFPA 704 or HMIS systems. The NFPA system may be found in *NFPA 704: Standard System for the Identification of the Hazards of Materials for Emergency Response*. In the NFPA system, the chemicals are rated according to their health, flammability, instability, and special hazards. The degree of hazard is indicated by a number from 0 to 4, with 0 being the least hazardous and 4 being the most hazardous. Either HMIS or NFPA ratings are useful to include on product labels. Most fire CODES require these ratings to be posted on CHEMICAL STORAGE ROOM doors.

5.9.1.5 Protected

In addition to the requirements listed in MAHC 5.9.1.5, the following BEST PRACTICES are recommended:

- Place all chemical containers, drums, boxes, and bags on pallets to raise them off the floor.
- Containers should not be stacked so that they will easily fall over. A general rule of thumb is that they should not be stored more than three high.
- Containers of chemicals shall be closed securely to prevent contamination.
- Any shelving units used to store chemicals should be sturdy enough to support the weight of the chemicals being stored.

5.9.1.6 No Mixing

Particularly keep chlorinated cyanurates, hydantoin bromine, and calcium hypochlorite away from other chemicals, paper, water, petroleum products, or other organic compounds to avoid possible cross-contamination. No liquids should be stored above solids. Chemicals must be stored in the original manufacturers' labeled container. STORAGE containers that held other chemicals previously are unacceptable. Chemicals may be transferred from the original container to a new container if that container was manufactured for the STORAGE of that chemical and properly labeled. Aquatics staff should read and consider findings and recommendations developed from investigations related to POOL chemical-related injuries.

- See "CDC Recommendations for Preventing Pool Chemical-Associated Injuries" at: <http://www.cdc.gov/healthywater/swimming/pools/preventing-pool-chemical-injuries.html>

5.9.1.7 Ignition Sources

NFPA, HMIS, or equivalent hazard rating systems may be used.

5.9.1.9 Lighting

Horizontal-plane illumination must be adequate for SAFETY and navigation, as well as for reading documents. The IESNA recommends a 30 footcandle (323 lux) minimum for Motor & Equipment Observation.

5.9.1.10 Personal Protective Equipment

Common components of PPE for chlorinated AQUATIC VENUE chemicals are as follows:

- **Respiratory Protection:** Wear a NIOSH approved respirator if levels above the exposure limits are possible.
- **Respirator Type:** A NIOSH approved full-face air purifying respirator equipped with combination CHLORINE/P100 cartridges. Air purifying respirators should not be used in oxygen deficient or IDLH atmospheres or if exposure concentrations exceed ten times the published limit.
- **Skin Protection:** Wear impervious gloves to avoid skin contact. A full impervious suit is recommended if exposure is possible to a large portion of the body. A SAFETY SHOWER should be provided in the immediate work area.
- **Eye Protection:** Use chemical goggles. Emergency eyewash should be provided in the immediate work area.

- **Protective Clothing Type:** Neoprene, Nitrile, Natural rubber (*This includes: gloves, boots, apron, protective suit*).

5.9.2 Chemical Handling

5.10 Hygiene Facilities

5.10.1 General [N/A]

5.10.2 Location [N/A]

5.10.3 Bathhouse Design [N/A]

5.10.4 Plumbing Fixture Requirements

5.10.4.1 General Requirements

Toilets and SHOWERS should appear clean and ready to use to attract BATHERS to use them⁵³⁵. Although the MAHC is not aware of any work in this particular setting, studies in child care settings, schools, long term care facilities and food service establishments all support the importance of surface cleaning. The MAHC feels that daily cleaning at a minimum in this setting is reasonable for aesthetics as well as health and SAFETY. It is important to both clean and SANITIZE (or DISINFECT) HYGIENE FACILITY surfaces. EPA regulates all products, including surface cleaning products, that kill germs (<https://www.epa.gov/pesticides>). Therefore, when SANITIZING or DISINFECTING HYGIENE FACILITY surfaces, an EPA REGISTERED product must be used. The general term used by EPA is “pesticides” which are defined as any substance or mixture of substances intended for preventing destroying, repelling or mitigating any pest. Pests include harmful microorganisms such as bacteria, viruses, and mold. During the registration process for pesticides, EPA considers both the ecological and human health risks of products as well as their efficacy. Consideration can also be given to the overall environmental impacts that these cleaning products have. UL 2759 is a publicly available STANDARD that establishes human health and environmental criteria for hard surface cleaners. This STANDARD is designed to reduce environmental impacts by specifying criteria for safer chemicals and materials, use of recycled and recyclable materials, and minimizing pollution generated by the production, use, and disposal of these products and their packaging.

5.10.4.3 Rinse Showers

Soap is not needed at RINSE SHOWERS because it can have a negative effect on water chemistry.

5.10.4.5 Diaper-Changing Stations

It is the responsibility of PATRONS to clean diaper changing surfaces after each use. This is consistent with practice in other public settings where diapering takes place. However, staff should keep an eye on stations and clean when necessary.

5.10.4.6 Non-Plumbing Fixture Requirements

Associations between AQUATIC VENUES and disease outbreaks have been well documented in the literature. Though an outbreak has never been connected to the materials used specifically, wood and other porous materials have been shown to have bacterial growth on them that can be hard to remove. Non-porous materials used as matting at AQUATIC FACILITIES were found to be contaminated with bacteria and biofilm scum layers, although conventional cleaning was documented to remove the contamination⁵³⁶. Biofilms are a complex collection of microbes that attach to a wet surface and form a scum layer that harbors bacteria and other microbes that could cause illness. Once established, biofilms provide a home for a variety of microbes such as *Pseudomonas* and are hard to remove. Biofilm-associated bacteria are much more resistant to HOCl compared with free swimming microbes. Design options to reduce biofilm formation as well as SANITIZING systems with effective validation, could be useful for reducing biofilm formation.

5.10.5 Provision of Suits, Towels, and Shared Equipment

5.10.5.1 Towels

The drying temperature is more important than the wash temperature when destroying potential infectious pathogens.

- See CDC recommendations for laundering entitled, “Environmental Cleaning & Disinfecting for MRSA” at: <http://www.cdc.gov/mrsa/community/enviroment/>.

5.10.5.4 Shared Equipment Cleaned and Sanitized

Research has demonstrated that play features, mat materials, and other shared equipment found at AQUATIC FACILITIES and water parks can harbor bacteria, even while submerged in chlorinated water. Damp materials that were not submerged in water contained the highest populations of bacteria. Damp play features designed for infants and toddlers were found to be likely vehicles for transference of gastrointestinal bacteria.⁵³⁷ SANITIZATION is defined as reducing the level of microbes that are considered safe by public health STANDARDS. This may be achieved through a variety of chemical or physical means including chemical treatment, cleaning, or drying. Associations between swimming POOLS and disease outbreaks have been well-documented in the literature. Though an outbreak has never been connected to play features or the type of play feature material specifically, the possibility could exist due to biofilms found on these materials. Outbreaks may be more likely if the AQUATIC FACILITY is not maintained properly. Biofilms are structured communities of microorganisms encapsulated within a self-developed polymeric matrix that adhere to a living or inert surface. In AQUATIC VENUES, biofilms form readily in water distribution and recirculation lines, filters, collector tanks, and swimming POOLS. Biofilms form when bacteria begin to excrete a slimy, sticky substance that allows them to adhere to surfaces. The biofilm mass usually consists of many species of bacteria, and can also include fungi, algae, and protozoa. Biofilms are resistant to CHLORINE and are difficult to remove once initial adhesion occurs. The biofilm slime shelters disease-causing microorganisms, protecting them from CHLORINE DISINFECTION. In addition, biofilms exert an oxidant demand, consuming CHLORINE residuals in the distribution line and requiring higher doses at the treatment station for residual maintenance at the end of the line. Design options to reduce biofilm formation as well as SANITIZING systems with effective validation, could be useful for reducing biofilm formation.

Contact

Shared equipment that contact mucous, saliva, eyes, or ears require SANITIZING to prevent transmission of potential disease causing pathogens.

5.10.5.5 Other Equipment

Shared equipment which is hand held or used as a flotation device used in aquatic therapy or play have also been found to harbor potential harmful microorganisms, even while submerged in properly chlorinated water. Bacteria found in these environments are most likely from biofilms that have attached to these surfaces. Soaking in DISINFECTANTS may not be enough to penetrate the biofilm; so to control biofilm growth, it is recommended to physically remove the slimy film by scrubbing equipment on a routine basis. The array of organisms isolated from damp features suggests that features need to be cleaned, SANITIZED, and thoroughly dried on a routine basis using a combination of chemical and physical methods, preferably as recommended by the manufacturer⁵³⁸.

5.11 Water Supply/ Wastewater Disposal [N/A]

5.12 Special Requirements for Specific Venues

5.12.1 Spas

5.12.1.2 Drainage and Replacement

For example, a 600 gallon SPA divided by 3 yields 200 divided by 25 (*the average users per day*) produces an 8 day water replacement interval.

5.12.2 Waterslides and Landing Pools

Weight is a key variable in the operation of WATERSLIDES. ASTM 2376 contains STANDARDS for manufacturer and operator responsibilities regarding WATERSLIDE systems. Manufacturer's responsibilities include specifying the maximum number of riders that are to ride in the FLUME at one time and rider weight requirements. Owner/operator responsibilities include specific WATERSLIDE operation policies and procedures including signage addressing maximum/minimum height and weight. See further Annex discussion at MAHC 6.4.2.2.3 on sign messages

5.12.3 Wave Pools

5.12.3.1 Life Jackets

The intent is to make lifejackets readily available at the AQUATIC FACILITY/VENUE to ensure PATRONS have easy access and use of such drowning prevention devices. This should mean that PATRONS are not discouraged from using them due to cost, visibility, or having to request them. Management should plan for the simplest solution to ensure all PATRONS have access. Consideration should be given to how many life jackets should be available on hand and a mechanism for accomplishing proper sizing.

5.12.4 Therapy Pools

5.12.5 Lazy Rivers

5.12.6 Moveable Floors

5.12.7 Bulkheads

5.12.8 Interactive Water Aquatic Venues

5.12.9 Wading Pools

5.12.10 Floatation Tanks

See MAHC 4.12.10 for general discussion

5.12.10.8 Treatment System-Required Operation Time

In a FLOATATION TANK, adequate treatment to mitigate the possibility of disease transmission must occur between users as the system does not run while a user/BATHER is in the tank. UV and ozone systems are dependent on the RECIRCULATION SYSTEM TURNOVERS to treat the tank water. Therefore, as there will be no DISINFECTANT residual in the FLOATATION TANK solution in the tank, adequate/acceptable DISINFECTION is totally reliant on consecutive dilution of the tank water CONTAMINANTS through the process of bringing the FLOATATION TANK solution to and through the filter and UV or ozone systems, 3-log reduction per pass through the DISINFECTION systems (required ozone and UV device DISINFECTION efficacy), returning the FLOATATION TANK solution with reduced pathogens to the tank, etc. until an acceptable percentage of the total water in the FLOATATION TANK has passed through the ozone or UV system. Five volumetric TURNOVERS was selected which, based on Gage-Bidwell laws of dilution work, provides for 99.3% of the total volume of the FLOATATION TANK SOLUTION passing through the filter and DISINFECTION system. Upon additional discussion, review of submitted comments and technical data, the proposal was amended to require a minimum of three volumetric TURNOVERS which provides for 95% of the total volume of the FLOATATION TANK SOLUTION passing through the filter and DISINFECTION systems. This decision was based on consideration of the potential concentration of pathogens that may be expected in a FLOATATION TANK. *Pseudomonas aeruginosa*, one of the pathogens of concern/interest was used as an example to examine what concentrations could be expected in a FLOATATION TANK, the infectious dose, and other factors which could lead to infection. When looking at the studies involving whirlpools,^{539,540} the worst case contamination load of the organisms brought in by the user was used, then the dilution factor, based on number of gallons typical of a FLOATATION TANK (250 gallons) yielded a final concentration 1000 times below the estimated threshold for infectivity. Further, the article concludes that super-hydration of the skin is the vital change required for invasion and subsequent inflammation from *Pseudomonas*. Due to the high salt concentration in FLOATATION TANK water, super-hydration will not happen. Due to osmotic pressure the changes to skin hydration are not equivalent to SPAS. This makes entry of viable and infective Pseudomonad cells into the skin even less likely.

5.12.10.12 Cleaning

It is important to prevent the build-up of a slime or biofilm layer so as not to provide an environment conducive to organisms such as *Pseudomonas aeruginosa* and others. This is especially important since there is no halogen residual present in the FLOATATION TANK solution.

5.12.10.13 Fecal/Vomit/Blood Contamination Response

FLOATATION TANK solution contamination response is being addressed separately and specific to FLOATATION TANKS due to the existing MAHC requirements in this regard being based on CHLORINE concentrations.

5.12.11 Other Aquatics Venues

2018 Annex to the Model Aquatic Health Code

Scientific Rationale

POLICIES AND MANAGEMENT



6.0 Policies and Management

6.0.1 Staff Training

Chemical injuries are a common occurrence as discussed in MAHC Annex 4.9.2. These injuries have been caused by eye splashes, skin exposures, and inhalation following improper handling and/or lack of use of PPE. Some incidents have involved the release of gases affecting multiple BATHERS or staff. There is a need to reinforce appropriate POOL chemical handling and STORAGE. This applies to both longer-term staff but also seasonal employees and young workers who may be less likely to receive appropriate training. Discussion of PPE, hazard communication, and bloodborne pathogens provisions are required since they are part of OSHA regulation. All employers, including swimming POOL programs, are required to comply with OSHA regulations and ensure training is adequate.

6.0.1.6.1 Training Topics

Special attention should be given to recognition of symptoms of acute exposure to CHLORINE gas per the Safety Data Sheet (SDS) [cough; throat irritation; choking; eye irritation with watering, pain, or redness; shortness of breath, skin irritation, vomiting, delirium], ozone if used at facility as a SECONDARY DISINFECTANT [throat irritation; nasal dryness or irritation; shortness of breath; cough; eye irritation; nausea; headache; drowsiness; chest pain], or any other chemicals used for DISINFECTION.

6.0.1.8 Body Fluid Exposure

CDC's Healthy Swimming Site contains additional information on Recreational Waterborne Illnesses (RWI). Employees should not swallow the AQUATIC VENUE water and should thoroughly wash their hands after the response.

- CDC's Healthy Swimming Site:
<http://www.cdc.gov/healthywater/swimming>
- See OSHA 1910.1030 Bloodborne Pathogens:
 - http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10051
- CDC's guidance on Cleaning Up Body Fluid Spills on Pool Surfaces:
 - <http://www.cdc.gov/healthywater/swimming/pools/cleaning-body-fluid-spills.html>

6.1 Qualified Operator Training

6.1.1 Qualified Operator Qualifications and Certification

AQUATIC VENUE operation and maintenance violations are common. POOL inspection data from 15 jurisdictions across the United States indicate that over half (61.1%) of inspections identified one or more violation(s) and 12.1% of inspections resulted in immediate closure because of the seriousness of identified violation(s). In addition, violations regarding the following issues were frequently identified:

- DISINFECTANT level (10.7% of inspections),
- pH level (8.9%),
- Other water chemistry (12.5%),
- Filtration/RECIRCULATION SYSTEM (35.9%),
- Water test kit (3.3%),
- Record keeping (10.9%), and
- Licensure (2.7%)⁵⁴¹.

Review of SPA inspection reports from these same jurisdictions found over half (56%) of inspections identified one or more violation(s) and 11% of inspections resulted in immediate closure because of the seriousness of identified violation(s). In addition, SPA inspection data indicated that the following violations regarding the following issues are frequently identified:

- DISINFECTANT residual (17% of inspections),
- pH level (15%),

- Other water chemistry (17%),
- Filtration/RECIRCULATION SYSTEM (27%),
- Water test kit (2%), and
- Record keeping (13%)⁵⁴².

The authors conclude that the number of overall violations highlights the need for POOL and SPA staff training, which includes information about RWI transmission, and the potential benefits of mandating training for POOL operators throughout the United States. In addition, it underscores the need for operator training courses to include the topic areas related to the common violations listed above. The PATHOGENS causing approximately 13.7%-18.2% of reported RWI outbreaks of acute gastrointestinal illness associated with treated facilities are CHLORINE sensitive⁵⁴³. This CHLORINE sensitivity of PATHOGENS involved in outbreaks indicates that these AQUATIC FACILITIES were poorly operated or maintained. The authors conclude that preventing RWI outbreaks, particularly those associated with inadequate public operation of AQUATIC FACILITIES, calls for required AQUATIC FACILITY operator training⁵⁴⁴. Of 36 reported POOL chemical-associated health events in New York State (1983–2006), 69% (n=25) were caused by poor chemical handling or STORAGE practices and 81% (n=27) resulted from mixing incompatible chemicals. The authors conclude that preventing these events calls for educating public POOL operators and residential POOL owners about safe chemical handling and STORAGE practices⁵⁴⁵.

Operator Training Reduces Pool Inspection Violations

Studies have shown that POOLS with operators who have successfully completed formal training in POOL operation, have better water quality than POOLS without a trained operator. Results from a study in Nebraska demonstrated that FREE CHLORINE violations and concurrent pH and FREE CHLORINE violations were twice as likely in local jurisdictions not requiring certification compared with jurisdictions requiring training. The authors conclude that these results demonstrate the benefit of requiring POOL operator certification to help prevent RWI.^{546,547}

6.1.2 Essential Topics in Qualified Operator Training Courses

See section 6.1.1 for discussion.

6.1.2.1 Course Content

6.1.2.1.1 Water Disinfection

Many other DISINFECTION chemicals or systems with varying effectiveness and suitability are being offered in the market to AQUATIC FACILITY operators for water treatment. In general terms, discuss the evaluation steps that should be used by the AQUATIC FACILITY operator, including required AHJ acceptance of the chemicals or systems for public AQUATIC FACILITIES, in their decision process on using these types of supplemental systems or treatments.

- *DISINFECTANTS* – Training should address OSHA “Right-to-Know” and Hazard Communication Standards and other SAFETY aspects.
- *CHLORINE* – Special emphasis should be given to safe handling of erosion feeders/chemical mixing. See MAHC Annex 4.9.2 for discussion on chemical injuries.
- *Combined CHLORINE* – A discussion of deterioration of buildings, machinery, and structures due to the effects of airborne chloramines in INDOOR AQUATIC FACILITIES is appropriate.
- *SECONDARY DISINFECTION SYSTEMS*– It is appropriate to include a discussion of the effectiveness of in-line treatment versus side stream treatment.
- *SUPPLEMENTAL TREATMENT SYSTEMS* – It is appropriate to include a discussion of the effectiveness of in-line treatment versus side stream treatment.
- *Water Balance* – Water balance elements may also include options for treatment including priority of factors to be adjusted.
- *Water Clarity* – Discussions should include treatment priorities to improve clarity.
- *pH* – It is also important to remember that there are limits on Phenol Red readings when very low or very high pH readings occur.

- *Mechanical Systems* – Common current alternative filter media types that can be mentioned include perlite, zeolite, and food-grade cellulose.
- *Circulation Pump & Motor* – The operator should also become familiar with submerged pumps such as turbine, mixed flow, and others used in waterpark applications. Additionally, the operator needs to have an understanding of the winterizing needs for these types of equipment.
- *Filter Backwashing/Cleaning* – In these days of energy and water conservation, it is increasingly important that water conservation be practiced. Backwash water can be responsible for wasting an unnecessary amount of water if not done properly or too frequently.

If properly treated to meet water quality STANDARDS, AQUATIC FACILITIES can obtain savings with water costs. However, in some cases, it may not be cost effective for an AQUATIC FACILITY to expend funds on retreatment of backwash water. In those cases, it is most important that all water is discharged properly in accordance with the regulations of the local jurisdiction.

6.1.2.1.4 Health and Safety

6.1.2.1.4.1 Recreational Water Illness

The number of outbreaks associated with recreational water has continued to significantly increase since reporting began in 1978, most notably in 1982, 1987, 2004, and 2007. CDC recommends that public health and the aquatic sector collaborate on educating the swimming public, an important source of recreational water contamination, about RWIs and what swimmers can do to protect themselves and others⁵⁴⁸.

6.1.2.1.4.3 RWI Prevention

The operator should be aware of the need for frequent manual testing, STANDARDIZATION of automatic controllers, and adequately sized chemical feeders. Note the need for larger feeders for waterpark type attractions as compared with FLAT WATER POOLS.

6.1.2.1.4.6 Chemical Safety

It is important that the operator be able to read chemical labels and SDS. These include but are not limited to, NFPA 400 “Oxidizer Hazard Classifications and Storage” recommendations. Reporting of POOL chemical-associated health events in the United States is not universally mandated, and no single surveillance system exists to characterize completely the number of exposures or associated injuries. However, one study of POOL chemical-related events showed 71.9% of the events involved human error⁵⁴⁹. NEISS and the NPDS data indicate that POOL chemical exposures and associated injuries are common. Data from NEISS show that inhalation of chemical fumes and splashing POOL chemicals into the eyes or onto the skin were the primary POOL chemical-associated injuries for which patients sought emergency treatment. NPDS data reveal that nearly all single POOL chemical exposures likely were unintentional. Additionally, poor chemical handling and STORAGE practices at public AQUATIC FACILITIES, particularly those leading to mixing of incompatible chemicals, were the primary contributing factors of POOL chemical-associated health events reported in New York State. Although no one data source alone clarifies completely the epidemiology of POOL chemical-associated injuries, together they reveal multiple commonalities that suggest these injuries are preventable. CDC recommendations⁵⁵⁰ for preventing injuries associated with POOL chemicals were based on a review of the New York State health events and other government regulatory guidance. These recommendations focus on improving facility design, engineering, education, and training that stresses safe chemical handling and STORAGE practices and safe and preventive maintenance of equipment⁵⁵¹.

6.1.2.1.4.7 Entrapment Prevention

The CPSC reports injuries and fatalities regarding entrapment in residential and commercial POOL and SPA settings⁵⁵².

6.1.2.1.5 Operations

Types of AQUATIC FACILITIES that are recommended to be discussed include POOLS, INTERACTIVE WATER AQUATIC VENUES, LAZY RIVERS, THERAPY POOLS, SPAS, WAVE POOLS, WATERSLIDES, competition POOLS, and WADING POOLS. Settings of AQUATIC FACILITIES that are recommended to be discussed include community POOLS, apartment complex/condominium/homeowners’ association POOLS, hotel/motel POOLS, and water parks.

6.1.2.1.5.4 Daily/Routine Operations

SVRS Systems: See MAHC Annex 4.7.1.6 for discussion of SVRS systems.

6.1.3 General Requirements for Operator Training Courses

6.1.3.3 Course Length

The MAHC intentionally does not prescribe a particular length of time for courses. Instead, the MAHC is more PERFORMANCE-BASED by requiring that all of the essential topics in MAHC 6.1.2.1 be covered during the course. Most nationally recognized operator training courses run approximately 16 hours, and the MAHC assesses that it would be unlikely that all essential topics could be effectively taught in a shorter time period.

6.1.3.4 Instructor Requirements

Recognized training on AQUATIC FACILITY operation and maintenance as well as instruction (*without work experience*) is sufficient to qualify an individual to be an instructor if the requirements in MAHC 6.1.3.4 are met. It is, however, ideal to have both work experience and training in operation and instruction.

6.1.3.5 Final Exam

The final exam is intended to assess the knowledge and skills of the POOL operator. Key components of the exam should include questions on the essential topics outlined in MAHC 6.1.2, performing essential calculations, reading meters and electronic equipment. In the future, it would be ideal if course final exams included more than just knowledge testing and have skills testing. This should include an on-site evaluation of skills such as proper calculations of quantity and chemicals needed to be added to the AQUATIC VENUE, how to operate the filtration/RECIRCULATION SYSTEM, including backwashing the filters, and water testing (*chemical and physical parameters*). The Conference for Food Protection established Food Protection Managers Certification Program Standards⁵⁵³. The MAHC has established the CMAHC (www.cmahc.org), which in turn may establish POOL operator certification program STANDARDS at a future date. These STANDARDS will address issues such as examination development, test administration, and computer-based testing development and administration.

6.1.3.6 Course Certificates

The MAHC recommends that each certificate have a unique identifier to minimize the likelihood of mistaking the identity of QUALIFIED OPERATORS.

At this time, a certification process for QUALIFIED OPERATORS is not established. This may make it advisable for some group to develop a certification program similar to that of the Food Code. Thus, the Food Protection Managers Certification Program Standards, Section 7.7, “Responsibilities to the Public and to Employers of Certified Personnel” reflect the following, “A certification organization shall maintain a registry of individuals certified.” These STANDARDS reference certified food operators; however, the same STANDARD shall apply to operator training certificates. Thus, “any title or credential awarded by the course approved organization shall appropriately reflect the” AQUATIC FACILITY QUALIFIED OPERATOR responsibilities and “shall not be confusing to employers, consumers, related professions, and/or interested parties.”⁵⁵⁴

6.1.3.7 Continuing Education

It is recommended that a QUALIFIED OPERATOR continue their education by attending seminars or training courses to keep up-to-date in AQUATIC FACILITY operation and SAFETY. In the long term, there is a need for development of a system for CEUs. However, it may not be prudent to make the leap to require CEUs all at once, especially since the MAHC 1st edition had provisions for all AQUATIC FACILITIES to have QUALIFIED OPERATORS for the first time. To have new requirements for operators at all AQUATIC FACILITIES and for CEUs may be overly burdensome at this time.

6.1.3.8 Certificate Renewal

Nationally recognized operator training courses require renewal of certificates. However, most professional certifications do not require retaking an entire course to renew certification, just passing an exam. Most states require these certificates or copies to be readily accessible to the AHJ. Copies of certificates should be kept on file at the site and made available upon request. If photocopies are provided as proof of certificate, or certificate renewal, the original documents should be provided within 72 hours upon request from the AHJ.

6.1.3.9 Certificate Suspension and Revocation

The AHJ is expected to contact course providers with questions about the validity of any certificate or with questions about an operator's performance. In turn, course providers are expected to readily provide verification of certificates and suspensions and revocations of certificates and to notify the AHJ of actions taken in response to its reported concerns. The Food Protection Managers Certification Program Standards, Section 7.5 reflect the following, "A certification organization shall have formal certification policies and operating procedures including the sanction or revocation of the certificate. These procedures shall incorporate due process."⁵⁵⁵

6.1.3.10 Additional Training or Testing

Reasons for requiring such training or testing include but are not limited to operator performance or new developments in technology or operation. Such situations include but are not limited to repeat or serious violations identified on inspection, an investigation implicating operation as a contributing factor to illness or injury, or implementation of substantial rule changes. Training can range from brief dialogue during POOL inspection to full-day seminar for all operators in a jurisdiction. Testing can range from questions during inspection to paper- or computer-based exams.

6.1.3.11 Certificate Recognition

The MAHC aims to delegate authority to the AHJ both to choose to recognize individual certificates and to reverse its decisions if operators with certificates demonstrate inadequate knowledge or poor performance or due cause.

6.1.3.12 Course Recognition

The MAHC aims to delegate authority to the AHJ to choose to recognize operator training courses and to reverse its decisions if operators demonstrate inadequate knowledge or poor performance or due cause.

6.1.3.13 Length of Certificate Validity

A number of operator training course providers, including the American Swimming Pool & Spa Association, Aquatic Training Institute, National Swimming Pool Foundation, and National Recreation and Park Association, have set the maximum length of operator certificate validity and certificate renewal at 5 years.

6.2 Lifeguard Training

This portion of the MAHC deals directly with providing QUALIFIED LIFEGUARDS in an AQUATIC FACILITY to first, reduce the risk that could lead to injury and, secondly, appropriately respond to incidents when they happen. The duties of an AQUATIC FACILITY lifeguard have been compared with a number of other occupations including comparing the role of the police officer to that of a lifeguard at a swimming POOL.⁵⁵⁶ "The majority of the time, the task is very sedentary, sitting and watching. A quadriplegic could do it; until someone needs rescuing. Then the quadriplegic could not perform the required functions. It does not often happen to a lifeguard that someone needs rescuing, perhaps 0.1 percent of the time. But the ability to jump into the water and save the drowning victim is critical to the job. This is the reason why there has been someone sitting and watching for the other 99.9 percent of the time." Bonneau and Brown's⁵⁵⁷ position is that, because the disabled lifeguard is unable to perform the critical and essential part of the job, he is incapable of doing the job of lifeguard. Even if he can do 99.9% of the job, he should not be employed as a lifeguard. The perception of the public is that all lifeguards can perform all that is critical and essential to their job set. Unfortunately, this has sometimes been proven to be false. Many drowning deaths resulted from omissions of basic SAFETY precautions,^{558,559,560,561,562,563,564,565}. These include absent or inadequate POOL fencing, unattended young children at aquatic venues, faulty POOL design resulting in victims becoming trapped below the surface of the water, poor POOL maintenance resulting in murky or cloudy water that obscured sight of submerged bodies, lifeguards being distracted by socializing with others and doing other chores such as manning admission booths and doing housekeeping chores while on lifeguard duty, and poorly trained lifeguards who did not recognize a person in trouble in the water or had not been properly trained in rescue and resuscitation techniques. In some cases, these are correctable issues that could prevent drowning deaths. We anticipate that if POOL and water SAFETY STANDARDS are strictly enforced, and as lifeguards continue to become better trained and adhere to important basic principles of surveillance, rescue, and resuscitation, the death rate in public AQUATIC FACILITIES should decline. The goal of this section is to give POOL owners and operators BEST PRACTICE guidelines for guarded and unguarded POOLS as tools to make AQUATIC FACILITIES safer for the general public.

6.2.1 Lifeguard Qualifications

Every day, about ten people die from unintentional drowning⁵⁶⁶. Of these, two are children aged 14 or younger. Drowning is the fifth leading cause of unintentional injury death for people of all ages, and the second leading cause of unintentional injury death for children 1 to 14 years of age⁵⁶⁷. From 2005-2009, there were on average 3,533 fatal unintentional drowning (*non-boating related*) in the United States per year and more than one in five people who die from drowning are children 14 and younger⁵⁶⁸. More than 50% of drowning victims treated in emergency departments require hospitalization or transfer for higher levels of care (*compared with a hospitalization rate of 6% for all unintentional injuries*)^{569,570}. Nonfatal drowning can cause brain damage that may result in long-term disabilities including memory problems, learning disabilities, and permanent loss of basic functioning (*e.g., permanent vegetative state*).^{571,572} Appropriately trained lifeguards are one way to reduce this risk at public AQUATIC VENUES.

6.2.1.1 Course Content

This section defines a broad scope of lifeguard training which is further described in the section below. These topics are universally found in all currently recognized national lifeguard training programs.

6.2.1.1.1 Hazard Identification and Injury Prevention

Lifeguards have an obligation to know and understand common hazards associated with AQUATIC VENUES, and how they may be mitigated or prevented. A vital component of this obligation is to provide PATRON surveillance, commonly referred to as scanning. In order to prevent injuries, a lifeguard must be taught how to recognize various swimmer conditions that need intervention such as "active," "passive", and "distressed", and to use scanning strategies and techniques to be able to see and identify the emergency. This instruction is incomplete without also teaching lifeguards how to identify factors and circumstances which cause victim recognition to become impeded such as overcrowding, cloudiness of the water, glare, or obstacles on the DECK or in the water such as SLIDES, inner tubes, or structures.

6.2.1.1.2 Emergency Response Skill Set

Lifeguards should have a clear understanding of the responsibilities and actions of not only the physical skills, but also the cognitive and decision making skills involved in an emergency response. Training agencies should develop appropriate skills to address the variety of water depths in which a victim may be found. These skills should be trained not only for the technical aspects of the skill, but also how the skill is incorporated into a venue's EAP. Lifeguards should be trained to respond within the scope of, at a minimum, Basic First Aid skills to provide care for illness or injury that may occur on land within the AQUATIC FACILITY until EMS arrives.

6.2.1.1.3 Resuscitation Skills

Lifeguards should be competent in CPR/AED at the professional rescuer level. The predominant body for the research of such skills is the ILCOR. ILCOR currently reviews available research every 5 years and is composed of physicians and medical researchers from across the globe. One organization from each country/region of the world is assigned to interpret the science-based evidence and prepare guidelines for voluntary use by training agencies in that country/region. In the United States, this designated agency is the American Heart Association. The AHA collaborates with host groups, training agencies, as well as leaders in the field from nonprofit, educational, and commercial organizations to create the "Guidelines for CPR and ECC".⁵⁷³ These recommendations are also commonly known as "AHA Guidelines". ECCU (www.citizencpr.org) conferences are held biennially to present research and recommendations for guidelines. Detailed Information about the process and current research is available on the ILCOR and the Citizen CPR Foundation websites.

6.2.1.1.4 First Aid

The evidence-based application of first aid skills is currently reviewed through the National First Aid Science Advisory Board and recommendations published as a separate section of the AHA CPR and ECC Guidelines and are available at the website identified in MAHC 6.2.1.1.3.

6.2.1.1.5 Legal Issues

Lifeguards are part of the pre-hospital chain of response and should have basic understanding of critical legal concepts such as consent, refusal of care, and negligence. Legal topics to be covered are not limited to these listed topics. Training agencies are strongly recommended to add topics based on the typical environment in which the trained lifeguard will be employed.

6.2.1.2 Lifeguard Training Delivery

6.2.1.2.1 *Standardized and Comprehensive*

A STANDARDIZED method of training with comprehensive materials is essential to the implementation of a consistently-delivered lifeguard training program. A specific method is not being recommended by the MAHC.

6.2.1.2.2 *Skills Practice*

While much of the necessary cognitive knowledge may be obtained through self-directed study, especially in an interactive online format, physical skills practice is necessary to develop an understanding of how to apply knowledge and identify the various needs in an emergency situation. During skills practice an instructor can provide individualized learning approaches, corrective feedback, and lead simulations and scenarios.

6.2.1.2.3 *Shallow Water Training*

It is important that the student lifeguard be able to practice and be tested in the deepest water specified in their certification.

6.2.1.2.4 *Deep Water Training*

It is important that the student lifeguard be able to practice and be tested in at least the minimum water depth specified in their certification.

6.2.1.2.5 *Sufficient Time*

This CODE does not prescribe a particular length of time for courses. Instead, this CODE is more performance based by requiring that all of the essential topics in MAHC 6.2.1.2 are covered by the training agency. National lifeguard training courses (*not renewal courses*) currently range from approximately 20 to 30 hours based on the type of training received for specific AQUATIC VENUES such as waterfronts or waterparks and the AHJ approval. Numerous factors make a uniform course length difficult to specify. Pre-existing knowledge, student-to-teacher ratio, internet-based learning formats, and course level are examples of these factors.

6.2.1.2.6 *Certified Instructors*

The instruction of an instructor course by an individual not directly authorized by the training agency as a lifeguard instructor trainer is extremely problematic and risks the quality controls established by the training agency. This also places public SAFETY at risk, in that the unauthorized instructor may not be fully qualified to teach the materials as intended. It also affects the training agency in that there is no direct recourse against an unauthorized, and unqualified, instructor. Lifeguard certifications, obtained from a lifeguard training course taught by an instructor who is not currently certified or authorized by the training agency to teach lifeguarding courses, will not be recognized as certified or trained by the AHJ per MAHC 6.2.1.3.

6.2.1.2.6.1 *Minimum Prerequisites*

The creation of minimum instructor prerequisites is a crucial piece to create quality and consistency for the training agency.

6.2.1.2.6.2 *Completed Training*

Although the MAHC requires only completion of a lifeguard and lifeguard instructor training course as a prerequisite, an effective instructor understands the demands, stresses, and practical application of skills that can be gained from actual lifeguarding experience or the benefit of extensive training in an AQUATIC FACILITY environment. Instructors who lack such experiences may not fully understand the requirements and demands of a lifeguarding position and may not provide an experienced instructor's insight to students on how to apply the skills and knowledge found in the training agency curriculum. It is necessary that lifeguard instructors have a firm understanding of the course they will be teaching. While it may be possible for an individual to pass a lifeguard instructor course without first taking a basic course, such an instructor would lack a firm understanding of the skills required by the training agency. It should be noted however, that training agencies should have the ability to create curriculum that would allow an individual from another training agency, or an individual who chooses to take an alternative to a full basic level course, to become instructors.

A Lifeguard Instructor Training Course must also provide information to the instructor candidates on how to safely and effectively conduct a course including:

- Knowledge of how to provide for the health and SAFETY of the students. (*example knowing how to DISINFECT manikins for use*);
- Ability to maintain adequate supervision at all times during in water skills and have a lifeguard on duty;
- Knowledge of how to effectively use program materials and training equipment as listed in MAHC 6.2.1.2.7;
- Ability to supervise student skill practice and provide timely, positive and corrective feedback; and
- Knowledge and ability to evaluate students as to meeting the criteria set forth by the training agency for which they are an instructor.

6.2.1.2.6.3 Instructor Renewal/Recertification Process

The training agency must have a process in place for renewal/recertification of instructors. The process should identify the criteria when reauthorization is required such as an instructor must teach a certain number of lifeguard courses in a certain time period (*years*) and/or do in-person or on-line updates as needed (*e.g., when course materials or content have been revised*).

6.2.1.2.6.4 Quality Control

Quality instruction is crucial to the survival of a training agency and, in the case of lifeguard training, crucial to the SAFETY and well-being of millions of swimmers every year. Training agencies must have procedures that allow for the correction, remediation and, if necessary, the revocation of instructor credentials.

6.2.1.2.7 Training Equipment

These pieces of equipment are required to accomplish the objectives of lifeguard training as outlined in the CODE. It is educationally sound to provide enough equipment based on the number of students who will be using it at the same time. Below is a listing of ratios recommended by several agencies; however, the training agency can adjust ratios based on their own delivery method.

American Heart Association

- Adult, child, and infant CPR training manikins (*one manikin per three students per class period*);
- CPR masks (*one per three students*);
- Valves for CPR masks (*one per student*);
- AED trainers (*one per three students*);
- Bag-valve-mask resuscitators (*one per three students*); and
- Manikin cleaning supplies (*as needed between students and after class*).

American Safety & Health Institute

Recommended student to equipment ratio: 3 to 1

American Red Cross

- Rescue tubes (*one for every two participants*);
- Adult and infant manikins (*one of each for every two participants*);
- Adult and pediatric bag-valve-mask resuscitators;
- AED training devices (*one for every two participants*);
- Adult AED training pads (*one set for each training device*);
- Pediatric AED training pads (*one set for each training device*);
- External bleeding control materials for each pair of participants, including:
 - Two 3-inch roller bandages, and
 - Four non-sterile dressings or gauze pads;
- Splinting materials for each pair of participants, including:
 - Four triangular bandages,
 - One 3-inch roller bandage,

- A blanket or pillow, and
- a rigid splint such as a magazine, cardboard, or long and short boards;
- Spinal immobilization materials;
- Backboards, each equipped with three straps and head immobilizers (*one backboard for every three participants is recommended*); if fewer backboards are available, additional time may be required.

6.2.1.3 Competency and Certification

6.2.1.3.2 Requirements

The readiness of lifeguard candidates to respond to aquatic-based emergencies should be assessed thoroughly for skill mastery, knowledge, and practical application prior to being issued a certificate. In regards to a written exam, all nationally recognized training agencies currently require an 80% correct answer rate as the minimum threshold for passing.

6.2.1.3.3 Instructor Physically Present

The physical presence of the instructor of record assures that students are evaluated accordingly in both cognitive and physical testing. This also significantly reduces the risk of individuals becoming certified who lack the basic skills and knowledge necessary through either acts of omission caused by the substitution of another individual to provide testing, or by student fraud. In addition, the instructor of record should be actively overseeing/conducting the testing to ensure quality control and that all testing objectives have been met.

6.2.1.3.4 Certifications

A certification issued at the end of a lifeguard course indicates that the individual successfully met the training requirements on the day of assessment. A completion certificate does not imply future performance or suitability in all circumstances. It is the responsibility of the employer to verify skills and ongoing competency suitable for the environment in which the lifeguard will be assigned through pre-service and in-service training.

6.2.1.3.5 Number of Years

The USLSC final report⁵⁷⁴, the scientific review by the ARC⁵⁷⁵, and the MAHC agree that lifeguarding skills need to be refreshed as often as possible. The ARC reviewed 12 peer-reviewed publications on CPR skill retention in healthcare providers (*retraining intervals of 6 weeks to 24 months*) and 28 papers focused on non-healthcare providers (*retraining interval of 3 to 48 months*).⁵⁷⁶ The data from these 40 studies (*all measured manikin skills, none measured patient outcomes*) showed significant CPR skill degradation within the first year after training in both job categories and the majority of skill degradation occurred in the first year. None of the 40 studies documented adequate skill retention after 2 years but several showed improved retention if a brief refresher was given at 6-12 months. As a result of this review and the low probability that lifeguards use the skill often enough in their job to retain the skill, the MAHC felt that the skills needed to be refreshed every year through re-certification. They did not think that the convenience of aligning the length of valid certifications for lifeguarding and first aid at 2 years overrode the strong data showing CPR skill degradation over 2 years that could put BATHER health at risk. The time periods listed in the MAHC are acceptable only if ongoing in-service and pre-service STANDARDS are followed.

6.2.1.3.6 Documentation

In order to verify compliance with MAHC 6.2.1.3.5, requiring the expiration date of the certification allows employers and the AHJ to identify that the lifeguard has a current certification. Providing the level of training gives guidance for the employer or AHJ for suitability in specific AQUATIC VENUES. Examples of level of training include: Lifeguard, Waterpark Lifeguard, Waterfront Lifeguard, and Shallow Water Lifeguard. Such descriptions are not necessarily universal among all current training agencies. The ability to identify the lifeguard instructor allows for higher quality control by the training agency. It also aids in the prevention of fraudulent certifications. Clearly stating the restrictions on water depth for which the lifeguard is qualified allows the employer and the AHJ to quickly ascertain the basic abilities of the lifeguard that were assessed during training.

6.2.1.3.7 Expired Certificate

A 45-day grace period after certificate expiration, was added to accommodate the numerous lifeguards attending college. Consider a senior in high school who takes their course in April. Subsequently they are now in college and typically will not return from college until early May. A grace period of up to 45 days after certificate

expiration allows renewal by taking a challenge exam as opposed to completing a new training course, however the lifeguard is not permitted to lifeguard until renewal training is successfully completed. Expiration beyond 45 days requires the retaking of the course

6.2.1.3.7.1 Challenge Program

A challenge course is one in which a lifeguard demonstrates the essential skills and knowledge required by the training agency. This demonstration is performed without prior review and/or instruction at the time of the challenge with the certified instructor present. Prompting or coaching is not performed unless necessary to adequately assess skill level (*e.g.*, “*the victim is not breathing*”).

6.2.1.3.7.2 Certificate Renewal

A renewal course can also be described as a recertification course. Review / Recertification courses are abbreviated courses designed to be used to assess that a currently certified lifeguard has the necessary skills and knowledge to perform essential competencies required of the training agency. Although some skills and information are universal to all lifeguard training agencies, there are differences in physical skills. A lifeguard attempting to recertify through a different agency is not likely to have ample time to master these different physical skills. This should not be confused with “crossover” type courses which are specifically designed to teach a currently certified lifeguard the different skills and information from another training agency.

6.2.1.3.8 Certificate Suspension and Revocation

The AHJ is expected to contact course providers with questions about the validity of any certificate or with questions about a lifeguard's performance. In turn, course providers are expected to readily provide verification of certificates and suspensions and revocations of certificates and to notify the AHJ of actions taken in response to its reported concerns. The Food Protection Managers Certification Program Standards, Section 7.5 reflect the following, “A certification organization shall have formal certification policies and operating procedures including the sanction or revocation of the certificate. These procedures shall incorporate due process.”⁵⁷⁷

6.2.2 Lifeguard Supervisor Training

6.2.2.1 Lifeguard Supervisor Candidate Prerequisites

The MAHC agreed that 18 years and above was an adequate age level to consider a person as being mature enough for this position but there are many examples of good supervising at a younger age. This was a starting point but many other factors with regard to experience, training, management skills, and others were equally or more important. For this reason, the minimum age for a LIFEGUARD SUPERVISOR is not specified and is limited to meeting the minimum age requirement of a lifeguard and having the experience that equates to one season of lifeguarding (*3 months*). Concerning having successfully completed a lifeguard training course in the past, the MAHC considers it necessary for a LIFEGUARD SUPERVISOR to have had this training and experience, but it is not necessary to have a current certification. However, the MAHC suggests that the training course should have been completed in the recent past such as within a 5-year period. The requirement of the ability to communicate in English is related to the ability to effectively activate the EAP and deliver instructions as well as interface with emergency services. This is similar to the requirement on airlines for emergency exit row seating.

6.2.2.2 Lifeguard Supervisor Training Elements

As of the writing of the MAHC, lifeguard supervision and management training courses are limited. In the development of the MAHC, the MAHC recognizes the importance of ongoing AQUATIC VENUE supervision with adequate training in injury prevention and response. What constitutes supervisor and management training was heavily discussed. The concept of “supervisor training” lends itself to far more than simply MONITORING lifeguards and performing essential functions of the lifeguard as needed. Required skills for the supervisor include staff management skills, emergency response, decision making, knowledge of aquatic industry STANDARDS, etc. This list is obviously not comprehensive. This leads to a main concern in the development of a LIFEGUARD SUPERVISOR course which is course content and length. Training agencies are encouraged to develop a system of training LIFEGUARD SUPERVISORS that incorporates the critical components of supervising lifeguards and responding to incidents in an AQUATIC FACILITY as these items directly affect BATHER SAFETY. This may include a variety of levels that address this information in various ways and as appropriate for the intended audience of each level course. The skills and knowledge found in this section are considered by the MAHC to be essential to any LIFEGUARD SUPERVISOR training course, regardless of intended depth of scope. The course outline and

requirements mirror that of the lifeguard training course requirements. LIFEGUARD SUPERVISORS need to have knowledge beyond that of the lifeguard training program. The LIFEGUARD SUPERVISOR is responsible for keeping the lifeguard accountable for their own performance and as such should MONITOR scanning and vigilance within the zone of PATRON responsibility. As situations occur, the LIFEGUARD SUPERVISOR will also need to react to reduce risk while they understand the legal responsibilities of the job. Due to the nature of the content in the LIFEGUARD SUPERVISOR training, it is possible for this content to be delivered in person or online utilizing various methods such as video and interactive media to establish competency.

6.2.2.3 Lifeguard Supervisor Training Delivery

6.2.2.3.1 *Standardized and Comprehensive*

The term STANDARDIZED is meant to convey that the materials are STANDARD, in writing, and are consistent from one course to another when delivered. This would require that providers, whether an agency or an AQUATIC FACILITY, have a STANDARD method to deliver the course.

6.2.2.3.2 *Sufficient Time*

A course length is not specified as each training agency may have their own program that incorporates all the requirements but may also add other topics. The method used to effectively instruct is up to the training agency. Some may take more time than others. The MAHC is not prescriptive on timing but rather on a course timeline that allows for covering the course content.

6.2.2.3.4 *Lifeguard Supervisor Course Instructor Certification*

This is the same rationale as for lifeguard training.

This allows for an AQUATIC FACILITY to have its own internal LIFEGUARD SUPERVISOR training course or use a training course through a training agency.

6.2.2.3.4.2 *Minimum Prerequisites*

This allows for experienced supervisors that may not have the physical skills to do the current lifeguard course as defined by the MAHC but still require the knowledge of lifeguarding. The LIFEGUARD SUPERVISOR instructor training course utilizes the same rationale as the lifeguard Instructor training course.

6.2.2.3.4.3 *Quality Control*

This is the same rationale as for lifeguard training.

6.2.2.4 Competency and Certificate of Completion

6.2.2.4.1 *Lifeguard Supervisor Proficiency*

LIFEGUARD SUPERVISOR testing could be in many forms from situational-based observations, shadowing with an experienced supervisor, or testing technical knowledge. Some LIFEGUARD SUPERVISOR skill proficiencies can be subjective so the methodology for testing is not prescribed in the CODE.

6.2.2.4.2 *Lifeguard Supervisor Certificate of Completion*

This uses the same rationale as for the lifeguard instructor training course found in MAHC 6.2.2.3.4.1. It is the intent of the MAHC to require completion of a course meeting the described requirements. At this time, it is not intended to be an ANSI-defined certification process, which will require such items as delivering training instruction independently from the testing and assessment process.

6.3 Facility Staffing

6.3.1 Qualified Operators Requirements and Availability

6.3.1.2.5 *Onsite Responsible Supervisor Duties*

The RESPONSIBLE SUPERVISOR should know how and when to contact the contracted off-site QUALIFIED OPERATOR. This includes every time that there is a suspected compromise to the recirculation and DISINFECTION system for which the RESPONSIBLE SUPERVISOR does not immediately understand the cause and any mechanical malfunctions or personnel errors that have led to suspected chemical exposure of PATRONS and/or staff.

6.3.2 Aquatic Facilities Requiring Qualified Lifeguards

6.3.2.1 List of Aquatic Facilities Requiring Qualified Lifeguards

There are many conditions that result in higher risk for BATHERS in an AQUATIC FACILITY and/or higher risk for any persons attempting to assist a BATHER in distress. These conditions each have their own distinct features that the MAHC felt a QUALIFIED LIFEGUARD presence would reduce those risks. These requirements only apply to AQUATIC VENUES with standing water.

- 1) **Deeper than 5 Feet:** The 50th percentile female adult is at least 63.7 inches (*162 cm*) tall.⁵⁷⁸ The rationale is that the average adult BATHER'S head would be above the static water line and they could use the AQUATIC VENUE without difficulty. If a BATHER were in distress, another adult BATHER would be able to assist with equipment or without equipment. Under these conditions, assuming adults are present, the likelihood of providing assistance by untrained persons is high compared with water depths deeper than 5 feet (*1.5 m*). The MAHC thinks it necessary to begin working to prevent some of the deaths caused by greater water depth combined with the lack of lifeguard supervision. The hardship this could cause unguarded AQUATIC FACILITIES is recognized. As a result, the MAHC requirements still allow for existing AQUATIC FACILITIES to be unguarded if they follow the requirements outlined in the MAHC, such as posting required signage. However, new construction of unguarded AQUATIC VENUES will require them to be less than 5 feet (*1.5 m*) deep.
- 2) **14 years of Age or Younger:** Many STANDARDS recognize that a person who is under the 14 years of age is considered to be a child and that their ability to make decisions, especially when complying with rules, require adult supervision.⁵⁷⁹ Because the AQUATIC VENUE presents the risk of drowning at any depth and despite rules being posted, adult supervision is required for compliance with those rules. The 50th percentile female at 14 years of age is 63.4 inches (*161.0 cm*) tall while the 50th percentile female at 13 years of age is less than 62.4 inches (*157.7 cm*) tall.⁵⁸⁰ This is a critical time frame in which the 1+ inches (*3.3 cm*) are the difference between water over one's nose/mouth or the ability to keep the nose/mouth above the static water line.

The phrase "allows for unsupervised children" implies that an AQUATIC FACILITY that does not allow unsupervised children would not need a QUALIFIED LIFEGUARD. The intent for supervision of children is that parents/guardians or other similar adults responsible for the children are present at POOLSIDE with the children and the children are in sight. The critical component is how this is enforced. In some cases, the facility may have a sign posted that persons under the 14 years of age are not allowed, such as a hotel POOL. In these cases, mechanisms should be in place for MONITORING and enforcing the rule, understanding that by posting a sign, it is the responsibility of the adult supervising these persons under 14 years of age to also comply with the rule.

- 3) **Dedicated Surveillance:** The responsibilities of a QUALIFIED LIFEGUARD are different from the responsibilities of the chaperone of a youth group. The MONITORING of children in these environments is often more than six children to every chaperone. These responsibilities must be separated by having the presence of a QUALIFIED LIFEGUARD that is not distracted by the activities of the group and is focused on their zone of PATRON surveillance. The chaperone, even if trained as a lifeguard, cannot manage both PATRON surveillance and the activities of individual children. If the chaperone is not trained as a lifeguard, it puts them at risk if a rescue is required.
- 4) **Group Practice or Instruction:** Competitive swimming, sports, lifeguard training, exercise programs, and group swimming lessons all include multiple persons being instructed by one or more persons for a distinctly different objective. The primary focus is on the activity and not on PATRON surveillance. Similar to the rationale for youth groups, there is a need to separate the responsibility of the coach/instructor from that of providing dedicated PATRON surveillance. Group swim lessons are an obvious reason to have a QUALIFIED LIFEGUARD as participants are not proficient at swimming, thus at higher risk for drowning. Lifeguard training, sports, exercise programs, and competitive swimming involve exertion and could result in a BATHER in distress. If the instructor is focused on an individual, the risk of a different person drowning unnoticed is higher than if a QUALIFIED LIFEGUARD was assigned just to PATRON surveillance.
- 5) **Large AQUATIC VENUES:** Aquatic rescue throwing devices have been found to have a reasonable ability to reach 30 feet (*9.1 m*) in distance or less by untrained individuals. AQUATIC VENUES with distances

greater than what it is reasonable for SAFETY equipment to be used from the DECK need to be supervised with QUALIFIED LIFEGUARDS.

- 6) **Moving Water:** Anywhere there is moving water, there is a greater chance for a PATRON to be moved by the force of the water in an unwanted manner. This could include moving the PATRON a distance from SAFETY, causing the PATRON to lose their balance and have a sudden submersion, and other disruptive problems. This is not intended to include "normal" flow from filtration system wall INLETS. The MAHC agrees these AQUATIC VENUES need to have QUALIFIED LIFEGUARD supervision.
- 7) **WATERSLIDE LANDING POOLS** have an induced current from the lift pump providing water as lubrication on the SLIDE. This is not to be confused with POOL SLIDES that are on a POOL DECK and do not have water flowing down them. Some smaller SLIDES have a small amount of water on them to lubricate the surface but generally do not have a dedicated POOL to "catch" or "land" riders and do not generate a significant current. INTERACTIVE WATER AQUATIC VENUES that do not include standing water are not included in this line item as they have an induced water movement but do not have standing water. There is no QUALIFIED LIFEGUARD requirement for an AQUATIC VENUE with no standing water.
- 8) **Starting Platforms and Diving Boards:** The risk of spinal injuries increases with activities involving head first entries from starting platforms and diving boards. As such, the need for QUALIFIED LIFEGUARDS to MONITOR behaviors and control the use of starting platforms and diving boards is important.
- 9) **Alcohol Use** is frequently reported as a contributing factor in drowning incidents and spinal injuries involving adults in swimming POOLS and similar environments and alcohol consumption by caregivers has also contributed in drowning incidents related to lapses of supervision of children. Where alcohol is sold or served at an AQUATIC VENUE it introduces additional hazards. A requirement to provide lifeguards where alcohol is sold or served will help to mitigate the risk of serious injury or death introduced by PATRON'S use of alcohol through active surveillance, enforcement of rules, and rescue and emergency care where needed.

6.3.3 Safety Plan

The MAHC agreed that there needs to be a SAFETY PLAN that is specific to the AQUATIC FACILITY. Training agencies, ANSI/APSP-1 and -9 STANDARDS for public swimming POOLS and aquatic recreation facilities all speak to having plans written, rehearsed, and reviewed. The MAHC agreed that there are other types of plans that detail processes that directly affect PATRON SAFETY. In the CODE, the SAFETY PLAN is outlined to contain several PATRON-SAFETY components. The SAFETY PLAN is written dependent on whether or not QUALIFIED LIFEGUARDS are present. *Note that the SAFETY PLAN components are different for guarded and unguarded AQUATIC FACILITIES.*

The AQUATIC FACILITY staffing plan is meant to identify positions in the AQUATIC FACILITY that address specific risks as well as support staff that would be present to assist in cases of emergency or provide support by MONITORING performance of QUALIFIED LIFEGUARDS (*for AQUATIC FACILITIES requiring them*). In unguarded AQUATIC FACILITIES, this plan would include other staff in the STAFFING PLAN. Training agencies, ANSI STANDARDS for public swimming POOLS, and AQUATIC FACILITIES all speak to having plans written, rehearsed, and reviewed for emergency action. Pre-employment testing as well as scheduled training is needed to verify that staff members are qualified for the environment. The MAHC agreed that ongoing in-service training programs for lifeguards, attendants, QUALIFIED OPERATORS, and other aquatic personnel should be required. To address this, the definition for QUALIFIED LIFEGUARD requires ongoing in-service training. Such programs should include drills aimed at raising the awareness of AQUATIC FACILITY surveillance, victim recognition, emergency response, CPR/water drills, and simulations incorporating daily challenges. In addition, in-service training needs to be documented.

6.3.3.1 Code Compliance Staff Plan

In consideration of the requirements of the CODE as it relates to staff, the MAHC recognizes the need for identifying an individual or individuals to be responsible for compliance with the CODE and the general operation of the AQUATIC FACILITY. For this reason, certain functions are identified and the AQUATIC FACILITY should designate persons to be responsible for each function even if multiple functions are accomplished by a single person. The AQUATIC FACILITY staffing plan is meant to identify risks and create accountability for the prevention and/or mitigation of such risks by identifying person(s) responsible for each.

Risk Management Responsibility

It is important to not only address identified risks but to designate persons who shall be responsible for conducting periodic SAFETY inspections to be proactive about finding and mitigating risk as well as making decisions on closure for imminent hazards. Determining who is responsible for deciding on closure of the AQUATIC FACILITY is important as it empowers the designated person but also creates a clear point-person for staff to go to for making this decision. The AHJ may be conducting periodic reviews and may have recommendations or need additional information. It would be beneficial to identify the individual or position responsible for interfacing with the AHJ to most effectively address changes or to provide background information. This makes it clear to stakeholders where to direct information or requests.

Maintenance and Repair of Risks

Once risks are identified, it is critical to determine who is responsible for mitigating those risks. In some cases, it may be a facility maintenance person responsible for conducting repairs, but ultimately it is the responsibility of management to make sure these risks are addressed. Failure to maintain water and air quality can result in illness and it is the responsibility of the AQUATIC FACILITY to maintain proper air and water quality. In some cases, a maintenance team manages these systems and in some cases it may be a third party contractor or the QUALIFIED LIFEGUARD staff. Nonetheless it is important to determine who is responsible for these systems to minimize the risk to BATHERS.

Enforcing Rules and Responding to Emergencies

It is important to identify who is responsible for rule enforcement. One may assume the QUALIFIED LIFEGUARD is the person responsible for rule enforcement, but by identifying the function here, it will make it clear that their primary role is in preventing injury. QUALIFIED LIFEGUARDS will generally be the first responder to an incident but other support staff may participate in the EAP, whether QUALIFIED LIFEGUARDS are present or not. Identifying QUALIFIED LIFEGUARDS, LIFEGUARD SUPERVISORS, medical specialists, and management are critical pieces of an EAP and should be identified as a part of the staffing plan in any SAFETY PLAN.

Supervising Staff

It is important to have a person designated as the person responsible for the critical SAFETY functions of an AQUATIC FACILITY. Although each QUALIFIED LIFEGUARD is accountable for their zone, the LIFEGUARD SUPERVISOR makes sure each individual is doing what is expected and is present for responding to emergencies and taking the lead in making decisions about imminent hazards. Accountability for rotations and breaks lies with the LIFEGUARD SUPERVISOR and should be clearly identified in the SAFETY PLAN to show the ability to comply with the CODE.

Training

QUALIFIED LIFEGUARDS who cannot demonstrate proficiency in their lifeguarding skills may be a danger to BATHERS and to themselves. Serious deficiencies that are not immediately corrected may cause the serious injury or death of a BATHER, the QUALIFIED LIFEGUARD, or other staff member. For this reason, it is important to identify who is responsible for conducting pre-service evaluations and in-service training. In both cases, it may be someone specifically trained in evaluating skills or trained in training others.

6.3.3.1.1 Zone of Patron Surveillance

The zones of PATRON surveillance are identified in the SAFETY PLAN so that all stakeholders are aware of the zones, how many QUALIFIED LIFEGUARDS are required to effectively cover all parts of the AQUATIC VENUE(S), and show that each zone can be effectively MONITORED by a QUALIFIED LIFEGUARD in accordance with the CODE. The MAHC agrees that having identified zones of PATRON surveillance was one of the most needed components for all AQUATIC VENUES. QUALIFIED LIFEGUARDS should be able to determine their area of responsibility and be able to focus on that area. With the proper coverage, all areas of the AQUATIC VENUE needing to be covered would be assigned. The MAHC thought that one of the challenges in AQUATIC VENUE management is to ensure that QUALIFIED LIFEGUARDS understand the exact scope of their zone of PATRON surveillance. Training agencies and the ANSI STANDARDS for AQUATIC FACILITIES speak to “lifeguards understanding their responsibilities to their assigned stations.” This would include understanding what type of position (*e.g., elevated, roaming*) the QUALIFIED LIFEGUARD should be in for the most effective PATRON surveillance. Both the ANSI/APSP-1 and ANSI/APSP-9 STANDARDS state that the lifeguard “shall be positioned and provided equipment in order to reach the victim within 20 seconds of identification of a trauma or incident (*e.g., response time*).” Note that this time (*20 seconds*) addresses the time the rescuer must reach the furthest extent of the zone, which would include

addressing size and shape of each zone, among other factors. It does not include the "recognition phase" in this time. For the purposes of maintaining effective surveillance of a zone of PATRON responsibility, the zone is generally set up based on the location of the QUALIFIED LIFEGUARD and their ability to see the entire zone. In some cases, it requires the QUALIFIED LIFEGUARD roam to see the entire zone and in some cases the QUALIFIED LIFEGUARD must be elevated to see the whole zone. For this reason, the SAFETY PLAN must stipulate by what method the QUALIFIED LIFEGUARD can see the whole zone. Additional responsibilities may include MONITORING of adjacent DECKS or MONITORING activities on a structure such as a WATERSLIDE, play element, or other AQUATIC FEATURE. As the aquatics industry has added other AQUATIC FEATURES to traditional AQUATIC VENUES, it is important to identify these additional responsibilities that may not be apparent if the zone were strictly a flat-water POOL. An AQUATIC FACILITY may have more than one AQUATIC VENUE and for each AQUATIC VENUE, may have multiple zones of PATRON responsibility. These zones may overlap in some areas and it is important to show there are not unassigned areas. The MAHC does not speak to a time STANDARD for identification of an incident versus the response time, as there are too many variables in the circumstances leading to an incident.

6.3.3.1.2 *Rotation Procedures*

Studies have documented the effect of critical and non-critical signals on maintaining vigilance in tasks; these may be useful in understanding lifeguarding duties. Jerison and Pickett demonstrated that a high number of critical signals could be processed by the lifeguard for up to 60 minutes with tolerable effects on vigilance.⁵⁸¹ However, the study found that low numbers of critical signals indicated that detrimental effects on vigilance occurred after only 20 minutes. This study also referenced the Mackworth Clock Test, commissioned in 1950 by the British Royal Navy, which found that optimal vigilance cannot be maintained for more than 30 minutes.⁵⁸² Researcher N.H. Mackworth developed the visual sensitivity loss model. Using classic clock-task experiments, signal detection performance often declined during the first half hour of the watch. Later experiments found five- to 10-minute breaks reset the vigilance level to its original point.⁵⁸³ The SAFETY PLAN should specify how breaks or changes in duties will be instituted into the rotation plan without reducing the number of QUALIFIED LIFEGUARDS on PATRON surveillance. For single QUALIFIED LIFEGUARD AQUATIC FACILITIES, the plan needs to address procedures for keeping PATRONS out of the water while the QUALIFIED LIFEGUARD is on break or performing other alternation of task activities. Other AQUATIC FACILITY staff may need to be at POOLSIDE to ensure that PATRONS stay out of the water, unless all PATRONS leave the AQUATIC VENUE and it is appropriately secured against entry. The "off-duty" QUALIFIED LIFEGUARD cannot be responsible for this activity as it does not meet the intent, which is to accomplish a reset of the vigilance level. Having a sound lifeguard rotation plan and procedures is crucial to the ability of the QUALIFIED LIFEGUARDS to be effective in PATRON surveillance. During the rotation of QUALIFIED LIFEGUARDS there can potentially be a lapse of PATRON surveillance if not done correctly. Because of this, the rotation system must be practiced and evaluated as to eliminate or minimize the lapse of PATRON surveillance time. Heat, humidity, and high BATHER COUNTS are stresses for QUALIFIED LIFEGUARDS, which may warrant more frequent breaks. Note that DECK areas are part of the zone of PATRON surveillance for some lifeguard stations to prevent incidents from occurring (*e.g., stop running on DECK, stop diving from DECK to shallow water, and otherwise enforcing rules*).

6.3.3.2 *Emergency Action Plan*

The MAHC agreed that there needs to be an emergency closure policy that is retained and available for review by the AHJ. Training agencies educate lifeguards to expect a written EAP created by the AQUATIC FACILITY where they will work that addresses the reasonably foreseeable emergencies that could occur. There is a need to identify how emergencies are communicated within the AQUATIC FACILITY and external to the AQUATIC FACILITY. The types of emergencies that could occur in AQUATIC FACILITIES include but are not limited to: chemical spills, submersion events/drowning, fire, violent acts, lost children, contamination (*fecal incidents and water clarity*), and inclement weather. AQUATIC FACILITY staff will likely be the persons to observe any imminent hazards and should be empowered to close POOLS or other areas of the AQUATIC FACILITY should those hazards be present. In particular, fecal incidents, water clarity, and inclement weather may be encountered more often and the AQUATIC FACILITY staff should know procedures for dealing with those imminent hazards and their authority to close the AQUATIC FACILITY.

6.3.3.2.1 *Coordination of Response*

The EAP identifies the individuals available and expected to respond. The goal of an EAP for a life-threatening emergency should be to activate EMS and provide for other individuals to assist the QUALIFIED LIFEGUARD with the actions identified in the EAP (*such as CPR if needed*) as soon as possible. Performing effective compressions

is difficult to maintain for more than a few minutes, and the presence of at least one person to take over compressions creates a cycle of rest. In AQUATIC FACILITIES where there are multiple QUALIFIED LIFEGUARDS and/or other staff persons such as desk or maintenance personnel who are always closely available when the AQUATIC FACILITY is open, it is feasible for many persons who are trained in CPR/AED and first aid to respond within 3 minutes. Having a person who is CPR trained who can respond within minutes greatly improves survivability.⁵⁸⁴ At an AQUATIC FACILITY with a single QUALIFIED LIFEGUARD, the SAFETY PLAN should identify the options for obtaining assistance, which is likely to include use of bystanders. If bystanders are part of the EAP, pre-service and in-service training should include how to direct bystanders in an emergency.

6.3.3.3 Pre-Service Requirements

6.3.3.3.1 Safety Team EAP Training

The MAHC agreed that there needs to be a SAFETY PLAN specific to each AQUATIC VENUE. Training agencies, ANSI STANDARDS for public swimming POOLS, and AQUATIC FACILITIES all speak to having plans written, rehearsed, and reviewed for emergency action. It is imperative that EAP training take place before the staff begins their work as an emergency can happen at any time. Providing a copy or posting a copy for staff ensures staff has access to the information at any time.

6.3.3.3.2 Safety Team Skills Proficiency

Responding to emergencies may require more specific skills and physical abilities, which once learned, must be maintained as emergencies can occur at any time. This demonstration of skill and/or knowledge verifies the staff person is ready to fulfill their role.

6.3.3.3.3 Qualified Lifeguard Emergency Action Plan Training

The QUALIFIED OPERATOR is required to prepare the SAFETY PLAN as a set of policies for the AQUATIC FACILITY. It is imperative that the employees be aware of their responsibilities and have access to the information at all times the AQUATIC FACILITY is open, so they may refresh their memory or seek further information. Training during pre-service will allow the QUALIFIED LIFEGUARD to become trained in the SAFETY PLAN of the AQUATIC FACILITY.

6.3.3.3.4 Qualified Lifeguard Skills Proficiency

It is imperative that all lifeguards hired are currently able to perform effectively in the workplace. AQUATIC FACILITIES need to assess the lifeguard's ability to perform the job skills necessary to be a QUALIFIED LIFEGUARD at the AQUATIC FACILITY, including at any AQUATIC VENUES within the AQUATIC FACILITY where the lifeguard may be assigned, before allowing the lifeguard to be on duty. When first hired, lifeguarding skills should be assessed during pre-service training prior to the first duty assignment. In-service training should assess skills on a regular basis to determine ability for ongoing duty assignments. Training agencies require that employees have training, knowledge and the proper equipment to protect the employee and the PATRON against disease transmission. This level of awareness must be in place before active PATRON surveillance takes place. All lifeguard training agencies require lifeguards to be able to perform a combined rescue skill with equipment to receive completion certification. All lifeguard training agencies train their lifeguards that they must be able and ready to recognize, respond, rescue, and resuscitate a victim as quickly as possible. The employer should verify that the lifeguard maintains these skills in the workplace.

6.3.3.3.6 Documentation of Pre-Service Training

Documentation provides a method for the AHJ to verify compliance. An example of the type of documentation required is a skills check-off form with a participant attendance sheet.

6.3.3.4 In-Service Training

6.3.3.4.1 Documentation of In-Service Training

All lifeguard training agencies support the need for ongoing in-service training. Both ANSI/APSP -1 and -9 state that certain topics be covered in this training. These in-service trainings should include all the SAFETY PLANS and in and out of water rescue skills for lifeguards. The USLSC final report⁵⁸⁵, the scientific review by the ARC⁵⁸⁶ and the MAHC agree that lifeguarding skills need to be refreshed as often as possible. The Texas Administrative Code requires at least 4 hours of in-service a month. Other states require that in-service training be documented and signed. The MAHC agrees that all AQUATIC FACILITIES should have an ongoing in-service program for their

SAFETY TEAM members. The term “periodic” is to offer flexibility to the QUALIFIED OPERATOR based on their seasonality, staff scheduling, and the training agency requirements. Much of in-service training is focused on skill building and maintenance as well as competency demonstration and testing so it is clear that those aspects should be delivered by qualified personnel (e.g., lifeguard instructors). However, in addition to the required in-service training in the MAHC, instruction from individuals that may not be lifeguard instructors but that have particular skill sets, training, or unique qualifications that would enhance a lifeguard’s skills over and above the in-service training requirements of the MAHC can be provided. For instance, ancillary qualified persons such as EMS personnel, health inspectors, police officers, certified counselors, teachers, public health officials, and others could provide in-service training that could enhance the abilities and knowledge of a lifeguard. In addition to providing the required in-service training, LIFEGUARD SUPERVISORS and managers should be able to draw upon subject matter experts with expertise in areas that, in their professional opinion, would provide instruction related to the lifeguard’s responsibilities and duties.

6.3.3.4.2 In-Service Documentation

Documentation is maintained at the AQUATIC FACILITY to provide a method for the AHJ to verify compliance during an inspection. Documentation is crucial to prove that the in-service training took place, and this documentation should include a list of the topics covered, who was in attendance, and the date and time of the training.

6.3.3.4.3 In-Service Training Plan

Requiring QUALIFIED LIFEGUARDS to have the ability to respond to a victim and complete a rescue is critical. To not specify this requirement would allow a QUALIFIED LIFEGUARD to demonstrate the individual skills but not necessarily have the ability to do all the skills in consecutive order to complete the whole rescue. Physical fitness is a critical part of performance when conducting a rescue. QUALIFIED LIFEGUARDS who are newly certified must maintain their physical fitness and skill proficiency throughout the term of their certificate as those skills can be called upon at any time. The required level of physical fitness can be determined by several means. Schultz and colleagues showed that in order to do CPR at 80 compressions a minute (*training now requires 100 compressions a minute*) over a 10 minute period of time, the METS required to perform this task was 4.6 ± 0.7 ⁵⁸⁷. One would expect this number to increase using the current protocol for CPR. METS values are used for a variety of activities that lifeguards might be expected to perform.^{588,589,590} For example, if someone swims 500 yards (457 m) in 10 minutes, they exert 8 METS/min (*so, almost double the CPR cost discussed above*); Similar levels of exertion are given by:

- Running at 5 mph on a level grade (*running 1 mile in 12 min or 0.8 mile in 10 minutes*)
- Riding a bicycle at 14 mph on level grade (*riding 2.3 miles in 10 minutes*)

If the metabolic cost of doing CPR is about 4.75 METS, then lifeguards that are able to do the above tasks, should be able to do CPR almost indefinitely BECAUSE (*and this is important*), the metabolic cost of doing CPR is only 60% of the cost of the above exercise. Importantly, this means that when doing CPR, the metabolic cost is not so intense that they will be doing effort that will increase the amount of lactate in their blood (*i.e. they won't go above lactate threshold*) and if they stay below lactate threshold (*60-65% max intensity*) they should be able to do CPR a long time.

6.3.3.4.5 Competency Demonstration

The point of this section is to have the skills performed consecutively and not individually as they may be done in some training classes. If all of these skills cannot be done consecutively, it is difficult to expect a successful rescue. This is not intended to preclude scenario-based activities that accomplish the same.

6.3.3.5 AHJ Authority to Approve Safety Plan

Some jurisdictions will have the resources to review the SAFETY PLAN and others may not. These line items allow for that flexibility but as a matter of enforcement, the submittal of the SAFETY PLAN is required in either scenario. Should an incident occur in which the jurisdiction is investigating, the SAFETY PLAN on file would be a good point of reference. The MAHC agreed that there needs to be an SAFETY PLAN that is retained and available for review by the AHJ as a point of reference detailing the intended operation to compare to the operation observed in the field.

6.3.3.5.1 Safety Plan on File

The SAFETY PLAN itself should be a tool for facility staff to utilize and as such should be present at the AQUATIC FACILITY and not merely a book sitting on a shelf in an administrative office.

6.3.3.5.2 *Safety Plan Implemented*

These MAHC sections are written to be performance-based and since each AQUATIC FACILITY is different, each SAFETY PLAN may be different. The SAFETY PLAN is developed to be a written document that establishes the processes the AQUATIC FACILITY will employ to be compliant with the CODE. It is important to also put in the CODE that those processes, although written, are also practiced and in evidence for the AHJ to see and compare the operation to what is written in the SAFETY PLAN and therefore compliant with the CODE. During routine inspections, the AHJ may want to see the SAFETY PLAN for the AQUATIC FACILITY as a point of reference but also to enforce a requirement of the CODE to have a plan.

6.3.4 **Staff Management**

6.3.4.3 **Lifeguard Staff**

6.3.4.3.1 *Minimum Number of Lifeguards*

Parts of POOLS or additional POOLS within the same AQUATIC FACILITY may not be open at all times during any given day. For example, only three lanes of a large POOL may be open during early morning lap swim. All zones of PATRON surveillance must be staffed unless the AQUATIC FACILITY can effectively limit access to only the lap lanes. A potential problem arises though, when the entire POOL is not under surveillance because a PATRON in the open section may move to a section/zone not intended to be open. Without surveillance, it may go unnoticed. So, the ability to restrict access and MONITOR or otherwise assure that no one enters the un-opened section/zone must be able to be effectively addressed and those details must be included in the SAFETY PLAN.

6.3.4.3.2 *Lifeguard Responsibilities*

QUALIFIED LIFEGUARDS are the front line personnel at an AQUATIC FACILITY to witness most of the situations in which an AQUATIC FACILITY or AQUATIC VENUE should be closed. The QUALIFIED LIFEGUARD must be aware of these emergency closure issues in order to enforce them – examples include an inability to see the bottom or main drains, fecal accidents, severe weather, and others developed by the MAHC. The MAHC agreed that since there is no established guideline for vision needed for the job of a QUALIFIED LIFEGUARD that if the individual QUALIFIED LIFEGUARD has corrected vision via lenses that they should wear them while conducting PATRON surveillance. Further research needs to be done in this area. Some professions require a minimum vision STANDARD non-corrected while others accept corrected vision to a certain level.

6.3.4.3.3 *Shallow Water Certified Lifeguards*

If a training agency issues a shallow water certification, the shallow water lifeguard is not qualified to be stationed in a zone that has a water depth greater than that identified for the certification. If any part of the zone has a depth of water greater than that depth, the shallow water lifeguard is not qualified to be assigned to that zone.

6.3.4.3.4 *Direct Surveillance*

The factors of recognition, intrusion, and distraction have been identified as major contributor to drowning in guarded venues. Nothing should be allowed to interfere with a lifeguard's duty to perform PATRON surveillance. The MAHC agreed that QUALIFIED LIFEGUARDS performing PATRON surveillance should not be doing other tasks that could distract them. When on duty, a QUALIFIED LIFEGUARD should scan and supervise the AQUATIC VENUE with no other distracting activities such as cleaning, water testing, and minimize unnecessary conversing with PATRONS.

6.3.4.3.5 *Distractions*

When QUALIFIED LIFEGUARDS are engaged in conversations while performing PATRON surveillance activities, their attention is distracted from surveillance. As a parallel, research has shown that even hands-free cell phone conversations can cause drivers to be distracted.^{591,592}

6.3.4.4 **Supervisor Staff**

6.3.4.4.1 *Lifeguard Supervisor Required*

The LIFEGUARD SUPERVISOR fulfills the role of making QUALIFIED LIFEGUARDS accountable for performing well and making sure the rotations are conducted properly. It is critical that QUALIFIED LIFEGUARDS perform their

duties as trained and that the risk factors that affect the QUALIFIED LIFEGUARD'S ability to perform have been mitigated. In addition, someone should be responsible for maintaining equipment and knowing when an AQUATIC FACILITY should close and how to mitigate hazards. This level of skill is different from that of the QUALIFIED LIFEGUARD, and each of these skills is important to have on-site anytime the AQUATIC FACILITY is open. The MAHC considered requiring a LIFEGUARD SUPERVISOR for all AQUATIC FACILITIES; but for small facilities with only one or two guards, there is no requirement. A single QUALIFIED LIFEGUARD doubling as a supervisor would be a redundancy. The SAFETY PLAN should address the means of providing oversight and direction to QUALIFIED LIFEGUARDS at single guard facilities.

6.3.4.4.2 *Designated Supervisor*

For any AQUATIC FACILITY, someone must be designated to make decisions and provide oversight of expected performance. When an AQUATIC FACILITY is required to have two or more QUALIFIED LIFEGUARDS, one of the QUALIFIED LIFEGUARDS may be designated as the LIFEGUARD SUPERVISOR as long as they comply with the training requirements. The QUALIFIED LIFEGUARD cannot fulfill LIFEGUARD SUPERVISOR duties while on scanning duty. For small AQUATIC VENUES, the MAHC was sensitive to requiring an additional person simply to be the LIFEGUARD SUPERVISOR. In this scenario, one of the QUALIFIED LIFEGUARDS is designated as the LIFEGUARD SUPERVISOR to make decisions when appropriate.

6.3.4.5 Emergency Response and Communications Plans

6.3.4.5.1 *Emergency Response and Communication Plan*

CHEMICAL STORAGE and EAP/evacuation info also must be filed with local fire/hazmat agency according to quantities and chemical types stored.

6.3.4.5.5 *Training Documentation*

It is recommended that EAP Drills are conducted with the staff on a quarterly basis as specified by the American Heart Association; however each operation is unique. Some operations may only be open during specific seasons, etc.

6.3.4.5.8 *Communication Plan*

6.3.4.5.8.2 *Notification Procedures*

Refer to EPA 550-B-01-003 at https://www.epa.gov/sites/production/files/2015-03/documents/list_of_lists.pdf

6.3.4.5.9 *Inclement Weather Plan*

It is recommended that employees MONITOR real time weather sources along with other techniques recommended by organizations such as NOAA. Also, include guidance on securing equipment in preparation for inclement weather. Consider having an evacuation plan to relocate PATRONS to a safe location during the storm. Be prepared by MONITORING weather and closing the AQUATIC FACILITY in time to evacuate.

6.3.4.6 Remote Monitoring Systems

Remote MONITORING systems may be used as an additional tool to help protect health and SAFETY but are not to replace or substitute for aquatics staff or their duties.

6.3.4.6.1 *Lifeguard-Based*

A remote SAFETY MONITORING system is an added value but should not be a substitute for having a lifeguard present when conditions deem that a lifeguard is necessary. The following excerpts from YMCA guidance provide an overview and discussion of lifeguard-based remote SAFETY MONITORING systems:

- “Speed is critical in recognizing and responding to aquatic emergencies. Time lost in the recognition phase of an EMERGENCY ACTION PLAN can prevent lifeguards from quickly reaching a swimmer in trouble and reduces the likelihood of a positive outcome. Appropriate protocols, combined with aquatic SAFETY technology, such as a surveillance system or alarms, may save valuable time during an emergency.
- “The following are types of aquatic SAFETY technology currently available on the market:

- **Video Camera Surveillance Systems:** Underwater and surface video MONITORING systems can help analyze activity in the AQUATIC VENUE and be used to assist lifeguards in MONITORING swimmers. Some systems can alert the lifeguard when a swimmer is in trouble.
- **Wireless Alarm or Water Activated Alarms Systems:** A water-activated alarm or wireless sensor button is a portable aquatic emergency summoning device. Such a device allows the lifeguard and/or others to be notified almost immediately to a potential aquatic emergency. Lifeguards can immediately respond, rather than having to first travel to the emergency call button and counselors and day care staff can immediately notify lifeguards of an unintentional submersion.
- “These technology systems DO NOT replace the need for continuous lifeguard surveillance, but they can assist a lifeguard in their surveillance duties. Use of these systems requires assessment and evaluation of current emergency protocols to incorporate the system within your EMERGENCY ACTION PLANNING. Integration of technology requires new approaches to lifeguard in-service training programs to emphasize recognition, surveillance, and prevention of over reliance on technology. Additionally, plans to address power outages or other system failures should be developed.”⁵⁹³

Operator-Based

Operator-based remote water quality MONITORING systems can be useful in conjunction with but should not be used instead of manual testing of the AQUATIC VENUE.

6.3.4.7 Employee Illness and Injury Policy

Open wounds may become entry points for pathogens and are the greatest risk to the wounded person. Water-related work could be allowed with healthcare provider approval or if the wound is covered with an occlusive, waterproof bandage.

6.4 Facility Management

Facility management is critical in preventing illness and injury as summarized in this section. The CDC identifies the most frequently reported contributing factors to the spread of infectious pathogens that cause RWIs, in particular gastroenteritis. Another report identified the most frequently reported type of RWI outbreak as gastroenteritis, the incidence of which is increasing.⁵⁹⁴ Prevention of RWIs at treated venues requires POOL operators to:

- Maintain appropriate DISINFECTANT concentration and pH to maximize DISINFECTANT effectiveness, and
- Ensure optimal water circulation and filtration.

A study of POOL inspection data underscored the need for improved maintenance.⁵⁹⁵ A total of 4,873 (11.6%) of 42,161 inspections identified serious violations that threatened the public's health and resulted in immediate POOL closure. Of 40,585 inspections, 3,549 (8.7%) identified DISINFECTANT concentration violations; of 38,247 inspections, 4,506 (11.8%) identified pH violations. Automated chemical feeder violations were documented during 2,260 (6.3%) of 36,137 inspections. Only one (6%) of 16 included data on AQUATIC FACILITY setting; almost all POOL (99.5% [55,622/55,913]) and hot tub/SPA (99.1% [20,259/20,449]) inspection records were missing data on AQUATIC FACILITY setting. Use of the setting algorithm increased the number of inspection records with setting data; however, after the setting algorithm was run, 75.6% (42,249/55,913) of POOL and 84.2% (17,213/20,449) of hot tub/SPA inspection records still were missing AQUATIC FACILITY setting data, thus no analyses stratified by setting were conducted. The process of submitting, reformatting, STANDARDIZING, and analyzing these data highlighted several areas where the collection and STORAGE of AQUATIC FACILITY inspection data could be improved. To optimize collection and analysis of AQUATIC FACILITY inspection data and thus utility in informing program planning, implementation and evaluation, a collaboration of federal, state, and local partners from different disciplines is needed. This collaboration should include environmental health practitioners with technical knowledge about the operation and maintenance of public AQUATIC FACILITIES and with inspection experience, epidemiologists skilled in conducting surveillance and data analysis, and information technology specialists with expertise in database construction. This collaboration could provide input on identifying public AQUATIC FACILITY CODE elements deemed critical to protecting public health and on the creation of needed resources (e.g., STANDARD inspection forms, training for inspectors, criteria for the construction of databases, and of tools to analyze data). Kiddie/WADING POOL inspections had the highest percentage of immediate closures (21.6%). Inspections of kiddie/WADING POOLS identified the highest percentage of DISINFECTANT concentration

violations (19.2%), followed by inspections of INTERACTIVE WATER PLAY VENUES (10.1%). See MAHC Sections 1.2.1 (RWI Outbreaks), 1.2.2 (Significance of *Cryptosporidium*), 1.2.3 (Drowning and Injuries), and 1.2.4 (Pool Chemical-Related Injuries) for further discussion and background. The information identified in these reports, along with existing recreational water injury data and first hand inspector experience, drove the development of the critical risk factors for recreational water injury and illness at treated AQUATIC VENUES. The eight broad critical risk factors for recreational water illness and injury are:

- Management; supervision; training; operation;
- Lifeguard services;
- DISINFECTANT residual;
- pH (*low or hi*);
- Water clarity;
- Facility ENCLOSURE / entry protection;
- Entrapment protection; and
- Water supply / waste disposal.

Low concentration or absent DISINFECTANT leads to reduced inactivation of pathogens and these conditions have been associated with infectious disease outbreaks.⁵⁹⁶ Low pH has been associated with loss of dental enamel^{597,598,599}. Dental erosion begins to occur below pH 6.0 and rapidly accelerates as the pH drops. High pH reduces the efficacy of CHLORINE-based DISINFECTION by reducing the amount of molecular HOCl, the active form that is available for DISINFECTION. At pH 7.0, about 70% of the HOCl is molecular, at pH 7.5 about 50% is molecular, at pH 8.0 about 20% is molecular, and at pH 8.5 only 10% is molecular. As a result, the MAHC decided to set upper and lower limits for pH (recommended pH range 7.2–7.8) as an IMMINENT HEALTH HAZARD.

6.4.1 Operations

6.4.1.1 Operations Manual

6.4.1.1.1 Develop

The facility design consultant can provide valuable assistance with preparation of a manual based on their knowledge of the physical system. The facility owner/operator must provide their preferences for operation and maintenance activities, based on location, climate, programs, budget, etc.

6.4.1.1.2 Include

A manual for the operation of AQUATIC FACILITIES should be kept at the facility, in both printed and digital formats. The manual should include basic information, chemical data, and operation and maintenance instructions about each POOL, SPA and INTERACTIVE WATER PLAY FEATURE at the facility. The manual should be updated on a regular basis to include added features, renovation work, and new CODE requirements.

Safety Related Info

PATRON and staff SAFETY are paramount to responsible operation of an AQUATIC FACILITY. Provide SAFETY related information in the operations manual including, but not limited to the following:

- Diving, drowning and electrocution hazards and risk reduction procedures;
- SAFETY signage locations and message information;
- Chemicals (*type and quantity stored, SDS information, delivery procedures*);
- Chemical SAFETY equipment and procedures;
- Emergency procedures for staff;
- Emergency procedures for PATRONS;
- Inventory of PATRON SAFETY equipment (*first aid kit, backboard, head restraints, rescue tubes, throw ropes, rescue pole, etc.*);
- Fire SAFETY equipment locations, operation and Public Safety Department notification plan (*fire extinguishers, hydrants, sprinkler system*);
- Staff training and practice drill schedule and procedures;

- Electrical system, controls, and GFCI's;
- Lighting and ventilation system description and controls;
- Vehicle and pedestrian accessibility;
- Lightning and storm evacuation plan;
- Emergency phone location and access;
- Emergency plan for evacuation and area notification; and
- Injury log

Aquatic Venue Info

Key criteria for each AQUATIC VENUE should be summarized including, but not necessarily limited to the following:

- Basin materials (*wall and floor structures, gutter system*);
- Coating materials;
- Flotation protection (*underdrain system, sump pump, hydrostatic relief valves, etc.*);
- Surface area (*square feet of water or PERIMETER DECK for INTERACTIVE WATER AQUATIC VENUES*);
- Volume (*gallons*);
- TURNOVER period (*TURNOVERS per day*);
- Recirculation rate (*GPM*);
- Filter loading rate (*GPM per square foot of filter surface area*); and
- Special features flow rates (*GPM for SLIDES, sprays, LAZY RIVERS, current channels, vortex areas, surf features, play features, etc.*).

Chemical Data

The operations manual should also provide chemical data for each chemical system in the facility. This includes but is not necessarily limited to the following:

- Description of chemicals provided for primary DISINFECTANT, pH adjustment, alkalinity adjustment, stabilizer, SUPERCHLORINATION, coagulant, filter aid, etc.;
- SECONDARY DISINFECTION SYSTEM description, if provided (*UV, ozone, other*);
- Type of chemical feed equipment and rated capacities;
- Discussion of water treatment goals and range of chemical targets;
- Description of chemical testing equipment;
- Testing frequency and location for each test;
- Chemical controller information, probe cleaning, and calibration procedures;
- Water testing log forms for chemical results; and
- Chemical supplies (*STORAGE quantity, providers, SAFETY procedures*).

Facility Operation Info

The operations manual should also provide instructions for AQUATIC FACILITY operations. These instructions should include, but not necessarily be limited to the following:

- Filter backwash or cleaning schedule and procedure;
- Periodic vacuuming and cleaning schedule and procedures;
- Seasonal cleaning procedures;
- SUPERCHLORINATION basis and procedure;
- Controller sensor maintenance (*if applicable*);
- Preventive maintenance tasks and schedule;
- Winterizing procedures; and

- Start-up and closing procedures.

Maintenance Instructions

The operations manual should provide instruction for proper maintenance for the facility. Both daily and seasonal or periodic maintenance will be required for the AQUATIC FACILITY. Available time and budget must always be balanced with the maintenance need. Regardless of whether the facility is large or small, frequent maintenance is more effective and more efficient than waiting until a larger problem occurs.

- Provide an inventory of available maintenance equipment and materials;
- Develop a daily maintenance schedule;
- Develop a schedule for periodic or seasonal maintenance; and
- Create a maintenance log with date and activity for future planning and budgeting.

Office Management

The operations manual also provides office management information for the facility. This manual should include, but not be limited to the following:

- Active and inactive records and general file information;
- Forms for water test results and filter cleaning frequency;
- Forms for inventory of chemicals, equipment, cleaning supplies, etc.;
- Maintenance inspection forms for facility, equipment, and structures;
- Maintenance work forms;
- Requisition forms for purchasing based on facility policies;
- Staff evaluation forms log;
- POOL operation log (*water quality, attendance, weather, open hours, injuries, complaints, equipment issues, etc.*); and
- Security (*opening and closing, underwater lighting, overhead lighting, doors, windows, alarms, bank deposits, etc.*).

Personnel Records

Accurate records should be maintained for all personnel. The options for this category are varied and numerous. The following list of personnel items is offered as an outline and a starting point for developing an operations manual including, but not limited to the following:

- Staff qualifications and job descriptions;
- Payroll procedures;
- Facility policies;
- Schedules and work attendance;
- Vacation and sick leave;
- Benefits;
- Conferences and education;
- Training programs;
- Termination basis, and
- Accident prevention.

Budget Considerations

An accurate and feasible budget is critical for ongoing AQUATIC FACILITY operation. Budget considerations should be included, but not limited to the following:

- Program fees and policies;
- Rental rates and policies;
- Staff wages and benefits;

- Facility expenditures for utilities, chemicals, concession supplies, equipment, training and program supplies, repairs and maintenance, insurance and office administration; and
- Financial report including monthly and annual summaries, projections and trends.

6.4.1.4 Illness and Injury Incident Reports

Aquatic injuries and illnesses can occur after normal office working hours; therefore, a 24/7 system for reporting and responding to injury and illnesses at AQUATIC VENUES must be maintained. Early reporting and intervention could reduce the spread of illness or prevent additional injury.

6.4.1.4.3 Notify the AHJ

The POOL owner/operator should immediately report to the permit issuing official any injuries or exposures resulting in death or that require emergency medical response, resuscitation or transport to a medical facility, chemical decontamination, or any illness suspected of being associated with bathing water quality or use of the AQUATIC FACILITY. The POOL owner/operator will have posted and available for use the routine phone numbers and after hours phone numbers necessary for reporting to the permit issuing official. This will facilitate a rapid investigation of the incident and could result in limiting further spread of infectious pathogens that cause disease and additional injuries. Most jurisdictions have some reporting requirements. This section is more comprehensive than the existing reporting requirements of many jurisdictions. Prompt reporting of significant injuries or waterborne illness allows for the permit issuing agency to immediately assess the conditions at the AQUATIC VENUE to determine if it can continue to operate safely or must be closed. Prompt reporting and investigation also allows for more accurate investigations to determine the causes of injury and illness. This information can be used to prevent future injuries or illness.

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6.4.1.4.3 Lifeguard Rescue Records

The POOL owner/operator shall keep accurate records of all lifeguard rescues. A rescue is helping a BATHER that would not be able to get to the POOL surface or to the DECK without lifeguard intervention and/or would result in activation of the EAP. An assist occurs when a guest is helped by the lifeguard in the water or from the DECK while the lifeguard still maintains surveillance of their assigned zone. The EAP is not activated for an assist. Reports and records of assists are not required to be kept.

6.4.1.6 Daily Water Monitoring and Testing Records

These duties include but are not limited to:

- Measure and record (*or supervise and ensure the measurement and recording of*) all information as required by MAHC operations, testing, MONITORING, and reporting requirements;
- Maintain the filtration and RECIRCULATION SYSTEM as required to maintain minimum flow rates required by MAHC 4.7.1;
- Backwash the filtration system when the filter gauge pressure differential reaches a level specified by the equipment manufacturer or as specified in the MAHC 4.7.2;
- Maintain DISINFECTANT residuals according MAHC 4.7.3;
- Maintain water chemistry according to MAHC 5.7.3;
- MONITOR water temperature to ensure it is within range specified in MAHC 5.7.4.7;
- Clean accessible POOL surfaces as necessary to remove slime/biofilm accumulation (see MAHC 5.10.5.4 for further explanation);
- Add replacement water as needed to meet all MAHC requirements; and
- Ensure HYGIENE FACILITIES are clean, sanitary, and supplies needs for swimmer hygiene such as toilet paper and soap or hand SANITIZER are available for use as per MAHC 5.10.

6.4.1.8 Body Fluids Remediation Log

See the Fecal, Vomit, and Blood Provisions in MAHC 6.5 for specific STANDARDS. For the CDC protocol for cleaning body fluid spills from POOL DECKS, see the document entitled “Cleaning up Body Fluid Spills on Pool Surfaces” which can be found on the CDC Healthy Swimming/Recreational Water website at <http://www.cdc.gov/healthywater/swimming/pools/cleaning-body-fluid-spills.html>.

6.4.1.8.1 Contamination Incidents

The Body Fluid Contamination Response Log is an important part of the administrative procedures for the venue and will document, in the case of a subsequent fecal, vomit, or blood contamination incident, that an appropriate response was conducted. A sample Body Fluid Contamination Response Log is provided below:

Body Fluid Contamination Response Log

Person Carrying out Contamination Response	
Supervisor on Duty	
Date of Contamination Response (mm/dd/yyyy)	
Time of Response	
Location Contaminated	
Number of People in Water (if applicable)	
Type/Form of Contamination: <i>Fecal Accident (Formed Stool or Diarrhea), Vomit, Blood</i>	
Time that Contaminated Area was Closed	
Is Stabilizer Used in Water Feature (Yes/No) (if applicable)	
<i>If Yes, Stabilizer Concentration at Time of Contamination Response</i>	
Date that Contaminated Area was Reopened (mm/dd/yyyy)	
Time that Contaminated Area was Reopened	
Total Contact Time <i>Time from when disinfectant reached target level to when disinfectant levels were reduced prior to opening</i>	
Remediation Procedure(s) Used and Comments/Notes	

Water Quality Measurements <i>Columns 1-4 are measurements spread evenly through the closure time.</i>	Level at Closure	1	2	3	4	Level Prior to Reopening
Free Residual Chlorine						
pH						

6.4.2 Patron-Related Management Aspects

6.4.2.1 Bather Count

6.4.2.1.1 User Guidelines

Overcrowding can interfere with visual surveillance, the ability to quickly evacuate, and response times. Maximum capacities are established for AQUATIC VENUES. Knowing and enforcing capacities minimizes overcrowding. MAHC 6.4.2.2.3 and 6.4.2.2.3.5 allow larger multiple attraction facilities to address individual aquatic attraction capacities in their signage.

6.4.2.2 Signage

The purpose of these requirements is to limit injuries and the spread of communicable disease. The wording used is not prescriptive since it is the intent that must be covered; this allows managerial creativity to be used as long as the intent of the wording is conveyed. Healthy swimming messages can also be put on posters to be hung in bathroom stalls, at the AQUATIC FACILITY entrance, on the back of ticket stubs, and in group-event contracts. Ideally, signage should be provided to encourage BATHERS to take a second SHOWER after using the toilet before reentering the AQUATIC VENUE. While this requirement may be difficult to enforce, the posting of such signs may encourage compliance or, at a minimum, raise awareness about the importance of BATHER hygiene. Consider the needs of clients and provide effective communication which could include signs in more than one language, Braille, etc.

6.4.2.2.3 Sign Messages

Need for adult supervision: The American Academy of Pediatrics, Policy Statement- Prevention of Drowning⁶⁰⁰ states: Whenever infants and toddlers (or weak swimmers) are in or around water, be it in a POOL or an open BODY OF WATER, a supervising adult with swimming skills should be in the water, within an arm's length, providing "touch supervision." With older children and better swimmers, the eyes and attention of the supervising adult should be constantly focused on the child, and the adult should not be engaged in other distracting activities that can compromise this attention, such as talking on the telephone, socializing, tending chores, or drinking alcohol. The MAHC needs to further discuss the term and implications of requiring "touch supervision". Although it may be appropriate for some children at some AQUATIC FACILITIES, it may not be appropriate at other AQUATIC FACILITIES. Regardless of whether the term is used, it is good practice for each AQUATIC FACILITY to set a minimum age under which parental/caregiver supervision is required. Suggested content for WATERSLIDES should also include content on their signs to comply with the manufactures recommendations. Minimum content should include:

- Rider position,
- Number of riders allowed at a time,
- Dispatch instructions,
- Water depth at SLIDE exit,
- Weight limit as established by manufacturer, and
- Height requirement if specified by manufacturer.

For sign message #13) ("No animals in the AQUATIC VENUE and no animals on the DECK, except service animals, if applicable"), this exception applies to the DECK, not for the POOL water. Service animals are regulated under the Americans with Disabilities Act (ADA). An ADAAG interpretation found on ADA's "Frequently Asked Questions about Service Animals and the ADA," found at www.ada.gov/regs2010/service_animal_qa.html. See question 33 below:

- Question: Are gyms, fitness centers, hotels, or municipalities that have swimming POOLS required to allow a service animal in the POOL with its handler?
- Answer. No. The ADAAG does not override public health rules that prohibit dogs in swimming POOLS. However, service animals must be allowed on the POOL DECK and in other areas where the public is allowed to go.

6.4.2.2.3.7 Spa Signs

See discussion on temperature and relevant data pertaining to SPA temperatures in MAHC 5.7.4.7.2. These data have been used to support wording for SPA venue signs regarding use by young children and pregnant women.

Suggested Spa Sign Content

- Post signs with suggested time limits (*15 minutes*);
- It is recommended that all SPAS have the following statement included on the signage. “Depth of spa is variable. Enter with caution;”
- Other suggested SPA and SAFETY equipment;
- Place time clocks with numbers large enough to read from a distance on a nearby wall in clear view of all users;
- Place a thermometer on the wall with numbers large enough to read from a distance or place the thermometer in the SPA itself;
- Place a 15-minute timer on the water jets. The reset button should be placed at least 10 feet (*3 m*) from the tub so users must physically leave the tub to turn the water jets on again.

Infants and Toddlers

Infants and toddlers are not recommended in a SPA. Small children are still developing internal temperature regulations, and infants in particular have a small body mass compared to body surface area. HOT WATER also could cause hyperthermia, and a SPA seat is not designed for a small child to sit properly to keep their head above water. For more information on infants, see the CDC Guidance titled “Breastfeeding in Pools & Hot Tubs/Spas”:

- <https://www.cdc.gov/healthywater/swimming/swimmers/breastfeeding-in-pools.html>

6.4.2.2.5 Diaper-Changing Station Signage

Signage requirements were adapted from the diapering procedure laid out in CFOC⁶⁰¹.

6.4.2.3 Swimmer Empowerment Methods

6.4.2.3.1 Public Information and Health Messaging

The MAHC 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 in MAHC Appendix 1: Summary of Health and Exposure Data for Chemical and Biological Contaminants.

6.4.2.3.2 Post Inspection Results

There are only a relatively small number of municipal organizations that require public or web-based disclosure of inspection reports. However, as inspection activity is tax-payer supported, there is a growing trend toward requiring public disclosure. One recent example is the Beaches Environmental Assessment and Coastal Health (*BEACH*) Act of 2000, a Federal Act that requires public disclosure of coastal beach closings. Additionally, DeKalb County, Georgia requires the public posting of inspection results for AQUATIC FACILITIES as well as posting them on the internet, which is similar to the ever expanding requirement for posting inspection results at food service establishments. The posting of inspections at AQUATIC FACILITIES will increase public awareness of aquatic SAFETY and health and encourage aquatic operators to comply with all CODE requirements. Most jurisdictions require the permit to be conspicuously posted. This is to inform the public that the facility has met the minimum SAFETY STANDARDS required by law.

6.5 Fecal/Vomit/Blood Contamination Response

The following discussion gives the rationale behind the remediation recommendations. Fecal contamination of recreational water is an increasing problem in the United States and other countries. Since the mid-1980s, the number of outbreaks of diarrheal illness associated with recreational water has been increasing in the United States.⁶⁰² Of these outbreaks, DISINFECTED, man-made swimming venues, the target of the MAHC, have had the greatest increase. These outbreaks are usually a result of people swimming while they have infectious, pathogen-containing diarrhea caused by pathogens such as *Cryptosporidium*, *Giardia*, *Shigella*, *Salmonella*, or *E. coli* O157:H7. Contamination of swimming water by infected persons and subsequent swallowing of contaminated

water by other swimmers continues the spread of infectious pathogens that cause diarrheal illness. Diarrheal illness is common in the United States with surveys indicating that 7.2-9.3% of the general public have had diarrhea in the previous month.⁶⁰³ Additional studies demonstrated that people routinely have a mean of 0.14 grams (*range = 0.1 to 10 grams*) of fecal contamination on their buttocks and peri-anal surface.⁶⁰⁴ The increase in outbreaks, the high prevalence of diarrheal illness in the public, and likelihood of frequent fecal contamination of POOLS by BATHERS raised the question of how to respond to overt fecal releases, particularly formed stools that were more visible, in POOLS. The need to develop a response plan was amplified by the emergence of the CHLORINE-tolerant parasite *Cryptosporidium* as the leading cause of DISINFECTED venue-associated outbreaks of diarrheal illness. First, formed stools were thought to be a significantly lower risk for spreading illness compared to diarrhea, since most pathogens are shed in the greatest numbers in diarrhea. As the highest risk material, diarrhea was considered the worst case contamination scenario that could potentially contain *Cryptosporidium*. As a result, a response should require the extreme treatment conditions needed to inactivate *Cryptosporidium*. Formed stool was assessed as a lower risk than diarrhea but several questions remained. Should formed stools be treated as potentially infectious materials? If so, then should the stool be treated as a potential *Cryptosporidium* contamination event like diarrhea (*i.e., longer inactivation time*) or could it be treated to inactivate all other pathogens other than *Cryptosporidium* (*i.e., shorter inactivation time*). To collect data relevant to answering the questions above, a study to collect fecal releases from POOLS in the United States was conducted in 1999. POOL staff volunteers from across the United States collected almost 300 samples from fecal incidents that occurred at water parks and POOLS.⁶⁰⁵ The CDC then tested these samples for *Cryptosporidium* and *Giardia*. *Giardia* was chosen as a representative surrogate for moderately-CHLORINE resistant pathogens like hepatitis A virus and norovirus. Using conditions to inactivate *Giardia* would inactivate most pathogens other than *Cryptosporidium*. None of the sampled feces tested positive for *Cryptosporidium*, but *Giardia* was found in 4.4% of the samples collected. These results suggested that formed fecal incidents posed only a very small *Cryptosporidium* threat but should be treated as a risk for spreading other pathogens such as *Giardia*. As a result of these data and the discussion above, it was decided to treat formed stools as potential *Giardia* contamination events, and liquid stool as potential *Cryptosporidium* contamination events. It was thought that norovirus contamination posed the greatest threat from vomit contamination and that the virus would be inactivated by a formed stool response using *Giardia* inactivation times as discussed above. Further assessment also suggested that blood contamination of POOL water posed little health risk due to the sensitivity of bloodborne pathogens (*e.g., viruses, bacteria*) to environmental exposure, dilution in the water, and chlorination. In addition, POOL water exposures would lack the requisite bloodborne exposure routes needed to spread the pathogens to other people.

6.5.1 Contamination Response Plan

The Fecal/Vomit/Blood CONTAMINATION RESPONSE PLAN is a vital part of the administrative procedures for the venue. All staff associated with the operation of the POOL should be aware of the response plan and trained in implementation procedures. At least one responder should be available on- site during all hours of operation.

6.5.1.2 Contamination Training

6.5.1.2.1 Minimum

A staff member trained in fecal/vomit/blood contamination response should be on site during all operational hours. OSHA discusses occupational issues related to potential bloodborne pathogen exposure in the Bloodborne Pathogens Standard, 29 CFR 1910.1030⁶⁰⁶ with further discussion under General Guidance⁶⁰⁷ and the OSHA Fact Sheet: OSHA's Bloodborne Pathogens Standard.⁶⁰⁸

6.5.2 Aquatic Venue Water Contamination Response

6.5.2.2 Physical Removal

6.5.2.2.2 No Vacuum Cleaners

Questions are often received concerning the MAHC recommendation to **NOT VACUUM** fecal material from the POOL. When the material is drawn through the vacuum, the vacuum itself is then contaminated and must be DISINFECTED. At the present time, the MAHC is not aware of any manufacturer that has a decontamination protocol for DISINFECTING fecal-, vomit-, or blood-contaminated POOL vacuum units.

6.5.2.3 Treated

Many conventional test kits cannot measure FAC levels up to 20 mg/L. Operators should use, in order of preference, a FAS-DPD titration test kit with or without dilutions using CHLORINE-free water, or use test strips that measure FAC in a range that includes 20 mg/L. The inactivation time should only be started once testing indicates that the intended FREE CHLORINE level (*20 ppm or other FREE CHLORINE concentration based on inactivation time in table above*) has been reached in the POOL. FAS-DPD should be used instead of a color comparator DPD test. It is important that the operator use a non-stabilized CHLORINE product when raising the FREE CHLORINE RESIDUAL particularly when raising to high levels such as 40 mg/L. If a stabilized product such as dichlor or trichlor were used, a high level of CYA would remain in the POOL after the HYPERCHLORINATION process. The CYA level in POOL water can only be lowered by dilution of POOL water with make-up water. Since CHLORINE products degrade over time, it is not recommended that non-stabilized CHLORINE products be stored in case of a fecal incident. The operator could either purchase a non-stabilized product at a POOL supply store or buy unscented household bleach (*sodium hypochlorite*) product that has a label indicating it is EPA-REGISTERED for use as a drinking water DISINFECTANT.

6.5.3 Aquatic Venue Water Contamination Disinfection

6.5.3.1 Formed-Stool Contamination

For *formed-stool contamination*, a FREE CHLORINE value of 2 mg/L was selected to keep the POOL closure time to approximately 30 minutes. Other CHLORINE concentrations or closure times can be used as long as the CT INACTIVATION VALUE is kept constant. The CT INACTIVATION VALUE is the concentration (*C*) of FAC in mg/L multiplied by time (*T*) in minutes: (*CT INACTIVATION VALUE = C x T*).

For formed-stool contaminated water the CT INACTIVATION VALUE for *Giardia* (45) is used as a basis for calculations:

Table 6.5.3.1: Giardia Inactivation Time for Formed-Stool Contamination

Chlorine Levels (mg/L)	Disinfection Time*
1.0	45 minutes
2.0	25 minutes
3.0	19 minutes

*These closure times are based on a 99.9% inactivation of *Giardia* cysts by chlorine, pH 7.5, 77°F (25°C). The closure times were derived from EPA.⁶⁰⁹ The closure times do not take into account “dead spots” and other areas of poor POOL water mixing.

6.5.3.1.1 Pools Containing Chlorine Stabilizers

CHLORINE stabilizers such as CYA slow DISINFECTION; therefore, higher CHLORINE levels are likely necessary to reach the CT INACTIVATION VALUE for *Giardia* inactivation in POOLS using CHLORINE stabilizers. However, at this time there is no STANDARDIZED protocol to compensate for CHLORINE stabilizers and no data determining how the inactivation of *Giardia* is affected by CHLORINE stabilizers under POOL conditions. A SAFETY value of 2 has been incorporated until these data can be gathered.

6.5.3.2 Diarrheal-Stool Contamination

For *diarrheal-stool contamination*, inactivation times are based on *Cryptosporidium* inactivation times. The CT INACTIVATION VALUE for *Cryptosporidium* is 15,300.^{610,611} If a different CHLORINE concentration or inactivation time is used, an operator must ensure that the CT INACTIVATION VALUES remain the same.

For example, to determine the length of time needed to DISINFECT a POOL at 20 mg/L after a diarrheal accident, use the following formula: $C \times T = 15,300$.

Solve for time: $T = 15,300 \div 20 \text{ mg/L} = 12.75 \text{ hours}$.

Therefore, it would take 12.75 hours to inactivate *Cryptosporidium* at 20 mg/L. See table below:

Table 6.5.3.2: Cryptosporidium Inactivation Time for Diarrheal Contamination

Chlorine Levels (mg/l)	Disinfection Time
1.0	15,300 minutes (255 hours)
10.0	1,530 minutes (25.5 hours)
20.0	765 minutes (12.75 hours)

The CT_{3log} used is for a 3-log inactivation to achieve a decrease in the concentration of OOCYSTS below one infectious dose per volume of water swallowed (1 OOCYST/100 mL). Similar to the assumptions made for SECONDARY DISINFECTION (See MAHC 4.7.3.3.2.5), this calculation assumes a single contamination event (e.g. diarrheal incident) of ~100 mL could introduce 10⁸ *Cryptosporidium* OOCYSTS into the water.^{612,613} This allows for a SAFETY factor to include smaller volume venues and still achieve the required concentration. An additional SAFETY factor not included is the impact of the filtration system since filter OOCYST removal efficacy varies widely. This may be more quantifiable in the future so that it could be included in the calculation. Volume calculations indicate that small volume AQUATIC VENUES like splash pads should be able to achieve this goal by using the CT INACTIVATION VALUE cited:

$$\begin{aligned}
 &10^8 \text{ OOCYSTS} / 10,000 \text{ gallons} = \\
 &10^8 \text{ OOCYSTS} / (10,000 \text{ gallons} \times 3785.4 \text{ mL/gallon}) = \\
 &2.64 \text{ OOCYSTS/mL} = 264 \text{ OOCYSTS} / 100 \text{ mL}
 \end{aligned}$$

With the 3-log inactivation, this volume will contain 0.264 OOCYSTS per 100 mL which is below the required one OOCYST/100 mL and larger volume facilities will exceed this requirement.

6.5.3.2.1 Pools Containing Chlorine Stabilizers

CHLORINE stabilizers such as CYA slow DISINFECTION (see MAHC Annex 5.7.3.1.3.1 for more discussion) therefore, higher CHLORINE levels are necessary to reach the CT INACTIVATION VALUE for *Cryptosporidium* inactivation in POOLS that use CHLORINE stabilizers.⁶¹⁴ As the stabilizer concentration rises, parasite inactivation is inhibited to the point where inactivation is similar to natural decay of the parasite.⁶¹⁵ As a result, higher levels of stabilizer must be reduced to reach 3-log inactivation levels using HYPERCHLORINATION. Recent data show that 3-log inactivation of *Cryptosporidium* is possible with CYA concentrations of 15-16 ppm or less.⁶¹⁶ A 3-log inactivation could not be achieved with 50 ppm or 100 ppm CYA. A 1-log inactivation of OOCYSTS was achieved with 50 ppm cyanurate concentrations after an average contact time of 61.9 hours with 20 ppm FREE CHLORINE RESIDUAL, for an average estimated CT INACTIVATION VALUE for 1-log inactivation of 76,500 mg min/L. With 40 ppm FREE CHLORINE RESIDUAL and 50 ppm CYA, a 1-log inactivation of OOCYSTS was achieved after an average contact time of 17.2 hours, giving an average estimated CT INACTIVATION VALUE for 1-log inactivation of 40,000 mg min/L. Increasing the concentration to 100 ppm CYA showed even more limited OOCYST inactivation, which did not differ much from natural decay curves for *Cryptosporidium* in water. Because 3-log OOCYST inactivation was achieved with 16 ppm CYA and was not achieved with 50 ppm CYA, the remediation protocol must be conducted in water with ≤15 ppm CYA. If the CYA concentration is above 15 ppm, the POOL will need to be partially drained to reduce the concentration. Alternate methods of reducing the CYA concentration are acceptable, as long as test data shows that the CYA concentration is at or below 15 ppm. The CHLORINE concentrations specified in the CODE must be used. Using CHLORINE concentrations other than those listed (multiplying to get the CT using other concentrations as can be done using HYPERCHLORINATION in the absence of stabilizer) assumes a linear response for inactivation but the data do not support linearity so only the listed concentrations are warranted. Along with the pH level and FREE CHLORINE RESIDUAL, the CYA level should be checked and adjusted if necessary prior to reopening the POOL. Temperature is a critical parameter of measuring a CT INACTIVATION VALUE. Although pH changes with temperature, the more critical aspect is that inactivation of pathogens is well documented to decrease with falling temperature. As a result, the limited data available for POOLS requires the protocol to be conducted at the temperature where the data was collected, or above, as higher temperatures are known to speed inactivation. Most inactivation research on *Cryptosporidium* has been conducted to aid drinking water treatment. As a result, the data are at lower temperatures (e.g., 41°F [5°C] to simulate winter conditions) and pH values (e.g., pH 6), which are more typical of real-life drinking water conditions but of little benefit to AQUATIC FACILITY operation. Any data to document how a 5°C drop in temperature would impact the 3 log CT INACTIVATION VALUE at pH 7.5 is not currently available and, due to the difficulties, time, and cost of such research, may never be collected. AQUATIC VENUES with SECONDARY DISINFECTION SYSTEMS could be

closed and allowed to circulate for the length of time calculated in MAHC 4.7.3.3.2 to reduce the level of *Cryptosporidium* below one OOCYST/100mL. Other AQUATIC VENUES without SECONDARY DISINFECTION SYSTEMS may choose to completely drain the water from the AQUATIC VENUE and replace with fresh water if they are unable to reduce the stabilizer level or hyperchlorinate.

6.5.3.3 Vomit-Contamination

For vomit contamination, the CT INACTIVATION VALUE for norovirus is thought to be in the same range as *Giardia*, so the same CT INACTIVATION VALUES are used as for a formed stool contamination.⁶¹⁷

Table 6.5.3.3: *Giardia* Inactivation Time for Vomit Contamination

Chlorine Levels (mg/L)	Disinfection Time*
1.0	45 minutes
2.0	25 minutes
3.0	19 minutes

*These closure times are based on a 99.9% inactivation of *Giardia* cysts by chlorine, pH 7.5, 77°F (25°C). The closure times were derived from the EPA.⁶¹⁸ The guidance does not take into account “dead spots” and other areas of poor POOL water mixing.

6.5.3.4 Blood-Contamination

If the CHLORINE or bromine residual and pH are in a satisfactory range, there is no public health reason to recommend closing a POOL due to blood contamination. Data suggest that the risk posed by potential bloodborne pathogens is greatly diminished by dilution and normal FREE CHLORINE RESIDUAL levels. However, the operator may wish to temporarily close the POOL for aesthetic reasons or to satisfy PATRON concerns.

6.5.3.5 Procedures for Brominated Pools

There are no inactivation data for *Giardia* or *Cryptosporidium* for bromine or any developed protocols for how to hyperbrominate a swimming POOL and inactivate pathogens that may be present in fecal matter or vomit. Therefore, POOL operators should use CHLORINE in their DISINFECTION procedures. It should also be noted that DPD test kits cannot differentiate between CHLORINE and bromine. This is because DPD undergoes the same chemical reaction with both CHLORINE and bromine. Therefore, it is important that the POOL’S bromine residual be measured before CHLORINE is added to the POOL. This bromine residual should be taken into consideration when determining that the FREE CHLORINE RESIDUAL necessary for the type of contamination has been met (*i.e.*, the FREE CHLORINE RESIDUAL measured minus the bromine residual should be equal to or greater than the intended FREE CHLORINE RESIDUAL). If a DPD test kit with a CHLORINE comparator is used; the total bromine residual can be determined by multiplying the FREE CHLORINE RESIDUAL by a factor of 2.2.

6.5.3.6^A Legionella Contamination

Continued *Legionella* testing may be considered on a case-by-case basis to ensure complete elimination of *Legionella*. The protocol is posted on the CDC website at <https://www.cdc.gov/legionella/downloads/hot-tub-disinfection.pdf>.

6.5.4 Surface Contamination Cleaning and Disinfection

6.5.4.1 Limit Access

Body fluids, including blood, feces, and vomit are all considered potentially contaminated with pathogens. Therefore, spills of these fluids on the POOL DECK should be cleaned up immediately. Visible contamination should be removed first, followed by DISINFECTION of the contaminated surfaces.

6.5.4.2 Clean Surface

The CDC protocol for cleaning body fluid spills from POOL DECKS entitled “Cleaning up Body Fluid Spills on Pool Surfaces” can be found on the CDC Healthy Swimming/Recreational Water website at <https://www.cdc.gov/healthywater/swimming/aquatics-professionals/cleaning-body-fluid-spills.html>. These procedures are based on hospital infection control guidelines.⁶¹⁹

6.5.4.3 Contaminant Removal and Disposal

Currently, there are no STANDARDIZED procedures for removing CONTAMINANTS, particularly those found in biofilms/slime layers, in piping, or AQUATIC FEATURES that spray or dump water. All water features should be well drained and DISINFECTED per manufacturer's instructions. Development of appropriate guidelines deserves further investigation and data gathering.

6.5.4.4 Disinfect Surface

The efficacy of DISINFECTANTS is greatly impacted by the organic load on the surface to be DISINFECTED. Reducing the organic load as much as possible through cleaning and removal of all visible contamination **BEFORE** adding DISINFECTANT is critical to successful DISINFECTION. Contact times apply only if all visible organic material has been removed before DISINFECTION.

6.6 AHJ Inspections

6.6.1 Inspection Process

The AHJ has the authority to enter the facility for both routine inspections and to investigate reports of illness and injury. At the time of investigation, all records and facility personnel required for interviews must be available.

6.6.2 Publication of Inspection Forms

6.6.3 Imminent Health Hazard Violations

6.6.3.1 Violations Requiring Immediate Correction or Closure

IMMINENT HEALTH HAZARD violations must be corrected at the time of inspection or the POOL must be closed until the violations are corrected. Whenever a POOL is closed due to a public health violation, signage must be posted stating that the facility is closed due to an IMMINENT HEALTH HAZARD. Before removing the closure sign and reopening in the feature, a follow-up inspection or other evidence of correction of the violations is required to ascertain correction and re-open the POOL. The factors being considered IMMINENT HEALTH HAZARDS cover known risk areas:

- Low or absent DISINFECTANT levels lead to reduced inactivation of pathogens and these conditions have been associated with infectious disease outbreaks.
- Low pH has been associated with loss of dental enamel. Dental erosion begins to occur below pH 6.0 and rapidly accelerates as the pH drops.^{620,621,622} High pH reduces the efficacy of CHLORINE-based DISINFECTION by reducing the amount of molecular HOCl, the active form that is available for DISINFECTION. At pH 7.0, about 70% of the HOCl is molecular, at pH 7.5 about 50% is molecular, at pH 8.0 about 20% is molecular, and at pH 8.5 only 10% is molecular. As a result, the MAHC decided to set upper and lower limits for pH (recommend pH range: 7.2–7.8) as an IMMINENT HEALTH HAZARD.
- Injuries/deaths occur to persons using equipment such as vacuums and reach poles at swimming POOLS when this equipment contacts overhead wires which are too close to the POOL.
- Clearance in any direction from the water, edge of POOL, etc. is to protect people using rescue and service equipment at POOLS, which are typically aluminum.
- Clearance in any direction to the diving platform, tower, WATERSLIDE or other fixed POOL related structure is to protect a swimmer using these items.
- Follow-up procedure for observance of electrical lines within 20 feet (6.1 m) of a swimming POOL during an inspection:
 - Determine whether the electrical lines are owned by the utility company or by the owner/operator of the swimming POOL/property.
 - If they are owned by the utility company, the operator should obtain a letter from the utility company stating that these lines are in compliance with NEC 680 STANDARDS.
 - If the lines are owned by the owner/operator, and there is no waiver or variance, it is a public health hazard.
 - This requirement does not apply to wiring inside walls/ceilings, etc. at an indoor POOL.

6.6.4 Enforcement

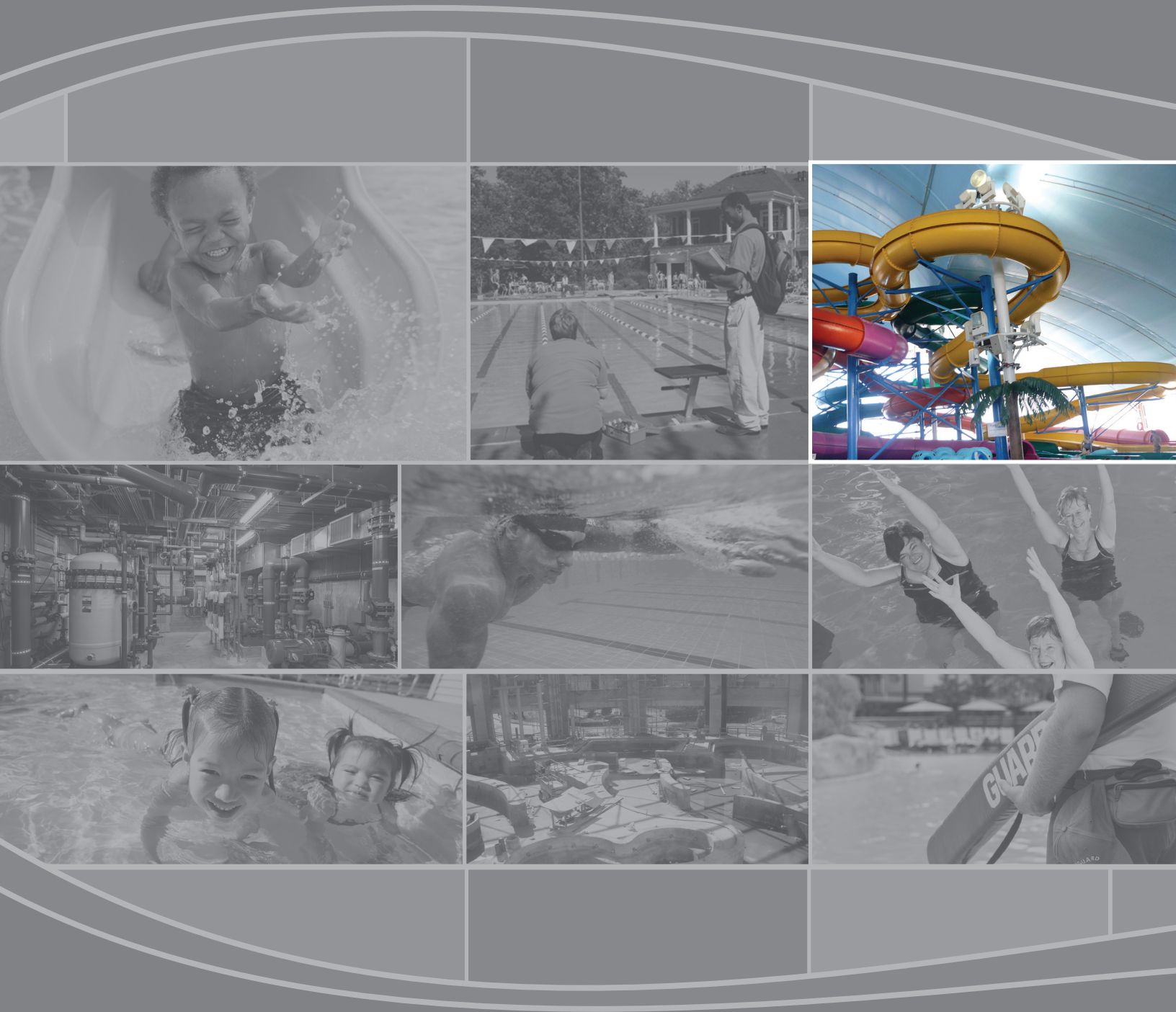
6.6.5 Enforcement Penalties

This is meant to apply to an AQUATIC FACILITY not making a good faith effort to correct recognized problem(s). This is not meant to apply to a closed AQUATIC FACILITY that is working on correcting an IMMINENT HEALTH HAZARD or other violation (*e.g., parts on order, maintenance scheduled*). It is up to the AHJ to determine if an AQUATIC FACILITY is making such an effort.

2018 Annex to the Model Aquatic Health Code

Scientific Rationale

APPENDICES



7.0 Appendices

Appendix 1: Summary of Health and Exposure Data for Chemical and Biological Contaminants

Appendix 2: Air Quality Formula

Appendix 3: Dye Testing Procedure

Appendix 4: Acknowledgement of MAHC Development Members

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.⁶²³
- Methods for sampling include⁶²⁴
 - 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 TLV for a short-term exposure limit (TLV-STEL¹) of 1.5 mg/m³ and an allowable time weighted average (TLV-TWA²) of 0.5 mg/m³ for TRICHLORAMINE.⁶²⁵
- Health complaints from teenage swimmers and soccer players showed a significant increase in respiratory complaints at chloramine concentrations of 0.37 mg/m³ or greater.⁶²⁶
- Symptoms, in a separate study, were not observed until the chloramine concentrations reached 0.5 mg/m³, and everyone reported symptoms when the levels reached 0.7 mg/m³.⁶²⁷
- 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/m³ was 86% for eye irritation, 61% nose irritation, 29% throat irritation, and 42% dry cough.⁶²⁸
- 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/m³, with the highest concentration reaching 1.34 mg/m³. General respiratory symptoms were significantly higher in POOL employees compared to the Dutch population sample (odds ratios ranged from 1.4 to 7.2).⁶²⁹
- Researchers generated TRICHLORAMINES at 0.5 mg/m³ 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.⁶³⁰
- TRICHLORAMINE is the most volatile and prevalent chloramine compound in the air around swimming POOLS⁶³¹, has low solubility, and decomposes rapidly in sunlight.
- The World Health Organization proposes a 0.5 mg/m³ 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.⁶³²
- 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/m³, there have been some concerns that this level may not be low enough to prevent symptoms.⁶³³

¹ 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.)

² 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.

THM threshold research reference synopses:

- Animal toxicity studies demonstrate and characterize hepatotoxicity and nephrotoxicity.⁶³⁴
- 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.⁶³⁵
- 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.⁶³⁶
- 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 spectrometry⁶³⁷. *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.⁶³⁸
- Mycobacteria are prevalent in POOL water and in air. They tend to aerosolize more than other POOL water CONTAMINANTS.⁶³⁹
- *Legionella* presence increased in HOT WATER, in water with pH greater than 7.8 and CHLORINE less than 0.2 ppm.⁶⁴⁰
- *Legionella* was more prevalent in SHOWERS than POOLS⁶⁴¹. 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 in hot tub were considered a contributing factor to acute illness of BATHERS in Wisconsin.⁶⁴²
- 45 - 400 EU (endotoxin units)/m³ was associated with acute airflow obstruction, mucous membrane irritation, chest tightness, cough, shortness of breath, fever, and wheezing.^{643, 644, 645, 646}
- Chronic health effects associated with airborne endotoxin exposures include chronic bronchitis, bronchial hyper-reactivity, chronic airways obstruction, hypersensitivity pneumonitis, and emphysema.⁶⁴⁷
- "Lifeguard lung" has been associated with indoor swimming POOL use.⁶⁴⁸
- A permanent decrease in pulmonary function, along with respiratory symptoms, has been reported in epidemiological studies.⁶⁴⁹
- The *Limulus* amebocyte lysate (LAL) assay used to analyze for endotoxin LAL assay, is a comparative bioassay.⁶⁵⁰ 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 RLVs³, rather than the more usual TLVs, be used as a reference for endotoxin.⁶⁵¹

³ 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.

Appendix 2: Air Quality Formula

NOTE: Included from 2014 MAHC (1st Edition) 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 MAHC Committee decided to defer to ASHRAE outdoor air requirements in this version of the MAHC. The 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 2 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 Appendix 2 Table below in addition to ASHRAE 62.1:

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

Appendix 2 Table: 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)	10.0	25.0	60.0	10.0	7.5	None
Average density in the pool (sq ft/person)	20.0	15.0	10.0	50.0	6.6	Based on designer / engineer rationale
cfm / person / ft ²	0.5	1.67	6.0	0.2	1.14	
R _{MAHC} (Total cfm / sq ft)	0.98	2.15	6.48	0.68	1.2	

R_a = ASHRAE 62.1 Equivalent (cfm / square foot)

R_p = Occupant driven cfm/person

R_{MAHC} is the number of cfm of outdoor air required for the area.

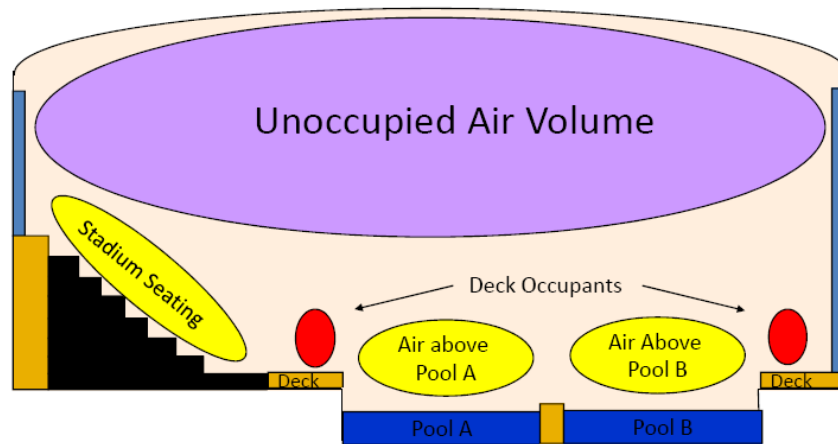
For Example:

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

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

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 Appendix Figure 1.

Appendix Figure 1: Side view of a typical INDOOR AQUATIC FACILITY



- 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 (32°C).
- DECK – area of floor spaces at or near the same elevation as POOL surfaces often used for observation and access.
- 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 Appendix 2 Table 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 (1.9 m^2) per person, but when designing a FLAT WATER WADING POOL, which has a higher density of BATHERS, the number could be modified to 15 ft^2 (1.4 m^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 cfm of outdoor air for an INDOOR AQUATIC FACILITY shall be calculated with the following equation:

$$\begin{aligned}
 & \text{Area of FLAT WATER in ft}^2 \times \text{FLAT WATER } R_{\text{MAHC}} \\
 & \quad + \\
 & \text{Area of AGITATED WATER in ft}^2 \times \text{AGITATED WATER } R_{\text{MAHC}} \\
 & \quad + \\
 & \text{Area of HOT WATER in ft}^2 \times \text{HOT WATER } R_{\text{MAHC}} \\
 & \quad + \\
 & \text{Area of DECK in ft}^2 \times \text{DECK } R_{\text{MAHC}} \\
 & \quad + \\
 & \text{Area of STADIUM SEATING in ft}^2 \times \text{STADIUM SEATING } R_{\text{MAHC}} \\
 & \quad = \\
 & \text{Total cfm of required outdoor air for INDOOR AQUATIC FACILITY}
 \end{aligned}$$

Appendix 2 Table 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, THEORETICAL PEAK OCCUPANCY, and water surface area (*splashing, aeration*).

The following outlines the discussion by the MAHC 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 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 project⁶⁵² 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 Committee identified that made these AQUATIC VENUES different was the expected THEORETICAL PEAK OCCUPANCY 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
 - a. Contribute to poor air quality only when there are BATHERS splashing, releasing TRICHLORAMINE and other DBPs into the air.
 - b. These AQUATIC VENUES generally are for swimming.
 - c. The density was established at 20 ft² (1.9 m²) per person. This represents an average horizontal swimmer occupying a 5 foot by 4 foot area.
 - d. Assuming a person is swimming horizontally; a full body length is an average 5 feet (152 cm) with a 5 foot span to equal 25 ft² (2.3 m²). 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 ft² (1.9 m²).
2. AGITATED WATER
 - a. 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.
 - b. These AQUATIC VENUES generally are for wading and enjoyment of features without swimming.
 - c. The density was established at 15 ft² (1.4 m²) per person. This represents an average vertical user occupying a 5 foot (152 cm) by 3 foot (91 cm) area. This also complies with the Illinois State Pool Code.
3. HOT WATER
 - a. 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 feature requires the most outside air.
 - b. These AQUATIC VENUES generally are for lounging such as hot tubs, warming POOLS, etc.
 - c. The density was established at 10 ft² (0.93 m²) per person. This represents an average user sitting in a 3 foot (91 cm) by 3 foot area.
4. DECK and Spectator Areas
 - a. For leisure POOLS, one can assume 50 ft² (4.6 m²) per person based on Illinois Pool Code. Adding seating and tables, which separates groups, the square footage allows for less density.

- b. For spectator area, the Committee used 6.6 ft² (0.61 m²) 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 Appendix 2 Table, the formula is:

$$\text{Minimum outside air in cfm} = (R_a \times \text{AQUATIC VENUE and DECK area in ft}^2) + [\text{AQUATIC VENUE A area in ft}^2 \times (R_p / \text{Density factor})] + [\text{AQUATIC VENUE B area in ft}^2 \times (R_p / \text{Density})] + [\text{DECK area in ft}^2 \times (R_p / \text{Density factor})] + (R_a \times \text{Spectator area in ft}^2) + [\text{Spectator area in ft}^2 \times (R_p / \text{Density factor})]$$

- **R_a** = cfm of outside air needed for an aquatic space of any type without PATRONS. Using factor from ASHRAE 62.1 See Appendix 2 Table 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 Appendix 2 Table 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 Appendix 2 Table 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/ft². 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 =

$$(R_a \times \text{AQUATIC VENUE and DECK area in ft}^2) + (\text{AQUATIC VENUE A area in ft}^2 \times (R_p / \text{Density factor})) + (\text{AQUATIC VENUE B area in ft}^2 \times (R_p / \text{Density})) + (\text{DECK area in ft}^2 \times (R_p / \text{Density factor})) + (R_a \times \text{Spectator area in ft}^2) + (\text{Spectator area in ft}^2 \times (R_p / \text{Density factor}))$$

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 / ft² feature / deck area	0.83

Aquatic Venue	Area (ft ²)	Fresh Air Required (cfm)
Spectator Area minimum	6,500	390
Spectator additional	6,500	7,386
	Total cfm	32,676
	Total cfm / ft² 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
	Feature Area Subtotal	89,067
	Total cfm / ft² feature / deck area	1.48

Aquatic Venue	Area (ft ²)	Fresh Air Required (cfm)
Spectator area minimum	2,500	150
Spectator area additional	2,500	2,841
	Total cfm	92,058
	Total cfm / ft² w/ spectator area	1.47

Appendix 3: Dye Test Procedure

Dye testing should be performed to determine and adjust the performance of the RECIRCULATION SYSTEM. Dye studies tend to be qualitative in nature.⁶⁵³

Some judgment is generally required to determine whether a dye study should be classified as passing or a failing. In general, dead zones (*or areas of poor circulation*) would indicate a failure that could be fixed by adjusting the INLETS or other system hydraulics. If the POOL does not reach a uniform color within 15 minutes, then adjustments are required.

Materials

- Crystal violet ($C_{25}N_3H_{30}Cl$) (20 g/ 50,000 gal)
- Sodium thiosulfate penta-hydrate ($Na_2S_2O_3 \cdot 5H_2O$) (1.2 oz/ 1 ppm FREE CHLORINE/ 10,000 gal)
- Sodium hypochlorite (Bleach 5.7% AVAILABLE CHLORINE) (6.64 L/ 50,000 gal)
- Two containers (20 L or 5 gal)
- Video camera
- Photo camera (*optional*)
- Tripod
- CHLORINE detection kit
- Pump (*capable of 700 mL/min or 0.18 gpm*)
- Tubing (*~6.4 mm or 1/4 inch ID*)
- Tubing clamps
- Fittings, adapters, and Teflon tape (*for threaded connections*)
- Scale
- Gloves
- Timer

Procedure

1. Use a scale to weigh out the correct amount of crystal violet needed. Be sure to wear proper SAFETY equipment when handling any chemicals.
2. Make the stock crystal violet solution by mixing the crystal violet and 3 gallons of non-chlorinated water in a container.

3. If you do not plan to use the POOLS existing DISINFECTION system during the dye removal process, then it will be necessary to prepare a sodium hypochlorite solution. To do this follow the recommended dose of 6.64 liters of bleach (5.7% AVAILABLE CHLORINE) per 50,000 gallons of POOL water. Place the correct amount into a separate container.
4. Two days prior to the dye study, cut off the POOL's DISINFECTION system, and then measure the CHLORINE concentration of the POOL. On the same day as the DISINFECTION system is turned off, weigh out enough sodium thiosulfate penta-hydrate to neutralize the CHLORINE that is present and dump it around the perimeter of the POOL. It is necessary to neutralize the CHLORINE because it will react with the dye. Come back the following day to make sure there is no CHLORINE, and likewise on the day of the dye study.
5. Prepare the pump by attaching the tubing to the existing piping and calibrate the flow rate to 700 mL/min. At this flow rate, the stock solution of dye will be injected into the POOL over a 16 minute period. Tube clamps may be used to secure the connection between the tubing and the connectors.
6. Prepare the filter room by laying down a trash bag (or similar item) as protection from a potential chemical spill/leak. Then place the pump and containers containing the dye stock solution and sodium hypochlorite solution on the plastic cover.
7. Prepare a location in the pipe network (preferably after the filter) to inject the chemicals. If a location does not already exist (e.g., an existing CHLORINE feed or acid feed point) then one will need to be made by tapping the pipe and inserting the proper fitting.
8. Attach the tubing from the pump to the existing or newly created injection point. Depending on what fitting is present you might need an adapter for the tubing. The other end of the tubing should be placed in the chemical container holding the dye.
9. Make sure all assistants are in place to record video, take pictures, collect data, and time injection to 15 minute pass/fail observation point.
10. When ready to start, turn on the pump. The dye should begin to flow into the POOL. Start the timer at the same time as the pump is turned on (pump on, time $(t) = 0$ min). The stock dye solution should be depleted in 16 minutes. After 16 minutes, turn the pump off so that air will not be introduced into the system.
11. Record the time when the dye is first observed coming into the POOL.
12. Record the time when the POOL water is completely dyed (having uniform color).
 - a. Most POOLS should be uniformly dyed within 15-20 minutes (and generally no more than 30 minutes) when the RECIRCULATION SYSTEM is hydraulically balanced.
13. Record any observations or patterns, including dead spots and/or short circuiting, and the corresponding times that they were noticed throughout the test.
 - a. Adjustments should be made to the RECIRCULATION SYSTEM to correct for any problems observed. Adjustments could include the following:
 - i. the direction of INLETS (up and down as well as left and right),
 - ii. the velocity of water through the INLETS (when adjustable by INLET modification or TURNOVER TIME adjustment), and
 - iii. the proportion of water from the surface overflow and main drain components of the RECIRCULATION SYSTEM.
14. Remove the dye by re-chlorinating the POOL. Switch the tubing from the container of dye to the one containing the sodium hypochlorite and turn the pump back on. Another option would be to restart the POOL's current DISINFECTION system.
15. Observe and record what you see as the dye is removed from the POOL through chlorination.

Appendix 4: Acknowledgement of MAHC Development Members

CDC is repeating here the original Acknowledgement section from the 2014 MAHC 1st Edition. The MAHC still includes considerable amounts of material from the 2014 MAHC 1st Edition that warrants highlighting the continued impact of those individuals that were part of the 7-year process to create and launch the MAHC. This Appendix recognizes CDC's continued gratitude towards the individuals who gave their time and expertise over 7 years to bring the MAHC from dream to product.

Acknowledgments from 2014 MAHC 1st Edition

Creating the MAHC has been a long process starting with the passage of a 2004 Council of State and Territorial Epidemiologists position statement, the subsequent 2005 national workshop, creation of the MAHC Steering Committee in 2007, recruitment for the 12 Technical Committees, two public comment periods, and a comprehensive cycle of editing and revising individual modules and incorporating them into the “knitted” version. As a result, many individuals have contributed greatly by devoting considerable time and effort to addressing concerns and developing recommendations that are now reflected in the MAHC 1st Edition. They brought this key national workshop recommendation to fruition. These individuals represent a diverse group of public health officials, educators, aquatics sector leaders, and consumer representatives acting through their agencies, companies, professional groups, or trade organizations.

It is only through the dedicated efforts and contributions of experienced professionals that a scientifically sound, well-focused, and up-to-date MAHC is possible. CDC acknowledges with immense gratitude the substantial assistance of those who contributed to public health and aquatic safety in the development of the MAHC. They deserve our heartfelt thanks and appreciation for volunteering their time, energy, and creativity to create the MAHC. In addition, we would like to also give our thanks to all the reviewers across the country who provided more than 4,400 public comments and spent a great deal of time combing through the detail of the MAHC code and annex and making suggestions for improvement. Their effort was worth the time investment; the MAHC was greatly improved after each of the two public comment periods.

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2018 Annex to the Model Aquatic Health Code

Scientific Rationale

RESOURCES



8.0 MAHC References

A Note about References:

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. References by endnote number are listed after the alphabetical reference list.

References Organized Alphabetically

- Aggazzotti G, Fantuzzi G, Righi E, Predieri G. Blood and breath analyses as biological indicators of exposure to trihalomethanes in indoor swimming pools. *Science of the Total Environment* (1998);217:155-163.
- Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. 2011 Compendium of physical activities: A second update of codes and MET values. *Med Sci Sports Exerc.* (2011) Aug;43(8):1575-81.
- Alberta. Pool standards, 2006 for the swimming pool, wading pool, and water spray park regulation. Accessed on July 6, 2016 at: <https://open.alberta.ca/dataset/f2e84a9a-2e3c-43b4-8542-5762624c499a/resource/ef958320-f00b-43df-881d-0ecf6e67236e/download/Standards-Pools.pdf>.
- Albrand OW, Walter J. Underwater deceleration curves in relation to injuries from diving. *Surg Neurol.* 1975;4(5):461-4.
- Alhadj M, Nelson NG, McKenzie LB. Hot tub, whirlpool, and spa-related injuries in the U.S., 1990-2007. *Am J Prev Med.* 2009 Dec;37(6):531-6.
- Allen LM, Briggles TV, Pfaffenberger CD. Absorption and excretion of cyanuric acid in long-distance swimmers. *Drug Metab Rev.* 1982;13(3):499-516.
- Allison TG, Reger WE. Thermoregulatory, cardiovascular, and psychophysical response to alcohol in men in 40 degrees C water. *J Appl Physiol.* 1992 Jun;72(6):2099-107.
- Amburgey JE, Walsh KJ, Fielding RR, Arrowood MJ. Removal of *Cryptosporidium* and polystyrene microspheres from swimming pool water with sand, cartridge, and precoat filters. *J Water Health.* 2012;10(1):31-42.
- American Academy of Pediatrics, American Public Health Association, and National Resource Center for Health and Safety in Child Care and Early Education (2002). *Caring for our children: national health and safety performance standards; guidelines for out-of-home child care programs*, 2nd edition. Elk Grove Village, IL: American Academy of Pediatrics and Washington, DC: American Public Health Association. Available at <http://nrckids.org>.
- American Academy of Pediatrics. Committee on injury, violence, and poison prevention. Prevention of drowning. *Pediatrics.* 2010;126(1):178-85.
- American Heart Association Guidelines. Available at : http://www.heart.org/HEARTORG/CPREandECC/Science/Guidelines_UCM_303151_SubHomePage.jsp.
- American Red Cross. ACFASP Scientific Review. CPR Skill Retention review. Scroll to "Scientific Advisory Council SCIENTIFIC REVIEW - CPR Skill Retention" Accessed at <https://www.instructorcorner.org/s/science>.
- American Society of Heating, Refrigerating and Air-Conditioning Engineers. 2015 ASHRAE handbook: Heating, ventilating and air-conditioning applications. Atlanta: 2015. Noise and Vibration Control.
- American Water Works Association. Operational control of coagulation and filtration processes: AWWA Manual. 2010;M37, 3rd ed. American Water Works Association, Denver, CO. ISBN: 978-1-58321-801-3.
- Anderson AR, Welles WL, Drew J, Orr MF. The distribution and public health consequences of releases of chemicals intended for pool use in 17 states, 2001-2009. *J Environ Hlth* 2014;76:10-15.
- Anderson JR. A study of the influence of cyanuric acid on the bactericidal effectiveness of chlorine. *Am J Public Health.* 1965 Oct;55(10):1629-37.
- Andersson M, Hedman L, Nordberg G, Forsberg B, Eriksson K, Rönmark E. Swimming pool attendance is related to asthma among atopic school children: a population-based study. *Environ Health.* 2015 Apr 15;14:37.
- 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.

- Anipsitakis GP, Tufano TP, Dionysiou DD. Chemical and microbial decontamination of pool water using activated potassium peroxymonosulfate. *Water Res.* 2008 Jun;42(12):2899-2910.
- ANSI S12.60:2002. American national standard acoustical performance criteria, design requirements, and guidelines for schools. Acoustical Society of America, Melville, New York 11747.
- ANSI S12.602010 American national standard acoustical performance criteria, design requirements, and guidelines for schools: Part 1: Permanent schools, Melville, New York: Acoustical Society of America; 2010.
- APHA, AWWA, and WEF. (2017) Standard methods for the examination of water and wastewater, 22nd ed. E.W. Rice, R.B. Baird, A.D. Eaton, and L.S. Clesceri (eds). New York: American Public Health Association.
- Armstrong TJ, Ashton-Miller J, Woolley C, Kemp J, Young J, Kim H. Development of design interventions for preventing falls from fixed ladders. The Center for Construction Research and Training, CPWR Small Study Final Report, April 2008. Available at <https://www.cpwr.com/sites/default/files/publications/Armstrong-Ladder-Study.pdf>. Accessed on April 29, 2018.
- ASHRAE. 2013 ASHRAE Handbook—Fundamentals. Accessed 12/11/13 from <https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ashrae-handbook--fundamentals>
- ASTM International. 2014 annual book of ASTM standards: section four: construction volume 04.06: thermal insulation; building and environmental acoustics. West Conshohocken, PA. ASTM Standard C6342013, Standard Terminology Relating to Building and Environmental Acoustics.
- ATSDR. Toxicological profile for chlorine. Available at: <https://www.atsdr.cdc.gov/toxguides/toxguide-172.pdf>. Accessed on April 17, 2018.
- Australian NSW Environmental Protection Agency. Noise guide for local government. Accessed April 21, 2018 at <http://www.epa.nsw.gov.au/your-environment/noise/regulating-noise/noise-guide-local-government>
- Barbee SJ, Thackara JW, Rinehart WE. Acute inhalation toxicology of nitrogen trichloride. *Am Ind Hyg Assoc J.* 1983;44(2):145-6.
- Barss P, Djerrari H, Leduc BE, Lepage Y, Dionne CE. Risk factors and prevention for spinal cord injury from diving in swimming pools and natural sites in Quebec, Canada: a 44-year study. *Accid Anal Prev.* 2008;40(2):787-97.
- Beaudet S, Eykelbosh A. Float tanks: Review of current guidance and considerations for public health inspectors. Vancouver, BC: National Collaborating Centre for Environmental Health; July 2016. http://www.nccch.ca/sites/default/files/Float_Tanks_Review_Current_Guidance_July_2016.pdf. Accessed April 23, 2018.
- Beech JA, Diaz R, Ordaz C, Palomeque B. Nitrates, chlorates and trihalomethanes in swimming pool water. *American Journal of Public Health* (1980); 70(1): 79-82.
- Beede KE, Kass SJ. Engrossed in conversation: The impact of cell phones on simulated driving performance. *Accid Anal Prev.* 2006 Mar;38(2):415-21.
- Beer CW, Guilmartin LE, McLoughlin TF, White TJ. 1999. Swimming pool disinfection: efficacy of copper/silver ions with reduced chlorine levels. *J Environmental Health*, 61(9): 9-12.
- Belgian Superior Health Council. Publication no. 8748: The issue of chlorine in swimming pools: Risk attendant on baby swimming and reflections on the different methods used to disinfect swimming pools.
- Beranek L. Noise and vibration control, rev. ed. Washington, DC: The Institute of Noise Control Engineering; 1988. 672 p.
- Berger EH, Royster LH, Royster JD, Driscoll DP, Layne M, eds. The Noise Manual. 5th ed. Fairfax: American Industrial Hygiene Association; 2000. 796 p.
- Bernard A, Carbonnelle S, Michel O, Higué S, de Burbure C, Buchet JP, Hermans C, Dumont X, Doyle I. Lung hyperpermeability and asthma prevalence in schoolchildren: unexpected associations with the attendance at indoor chlorinated swimming pools. *Occupational and Environmental Medicine* (2003); 60: 385-394.
- Bessonneau V, Derbez M, Clément M, Thomas O. Determinants of chlorination by-products in indoor swimming pools. *Int Hyg Environ Health.* 2011;215:76-85.
- Betancourt WQ, Rose JB. Drinking water treatment processes for removal of *Cryptosporidium* and *Giardia*. *Vet Parasitol.* 2004;126(1-2):219-34.

- Blanksby BA, Wearne FK, Elliott BC, Blitvich JD. Aetiology and occurrence of diving injuries. A review of diving safety. *Sports Med.* 1997 Apr;23(4):228-46.
- Blatchley E, Cheng M. Reaction mechanism for chlorination of urea. *Environ Sci Technol.* 2010;44(22):8529-8534.
- Blatchley ER, Margetas D, Ravikrishna D. Copper catalysis in chloroform formation during water chlorination. *Water Res* 2003;37:4385-4394.
- Blitvich JD, McElroy GK, Blanksby BA, Clothier PJ, Pearson CT. Dive depth and water depth in competitive swim starts. *J Swimming Res.* 2000;14:33-39.
- Bonneau J, Brown J. Physical ability, fitness and police work. *J Clin Forensic Med.* 1995;2(3):157-64.
- Borgmann-Strahsen, R. Comparative assessment of different biocides in swimming pool water, *International Biodeterioration and Biodegradation* 2003;51:291-297.
- Borius PY, Gouader I, Bousquet P, Draper L, Roux FE. Cervical spine injuries resulting from diving accidents in swimming pools: outcome of 34 patients. *Eur Spine J.* 2010 Apr;19(4):552-7.
- Bowen AB, Kile JC, Otto C, Kazerouni N, Austin C, Blount BC, Wong HN, Beach MJ, Fry AM. Outbreaks of short-incubation ocular and respiratory illness following exposure to indoor swimming pools. *Environ Health Perspect.* 2007 Feb;115(2):267-71.
- Brescia CC, Griffin SM, Ware MW, Varughese EA, Egorov AI, and Villegas EN. (2009) *Cryptosporidium* propidium monoazide-PCR, a molecular biology-based technique for genotyping of viable *Cryptosporidium* oocysts. *Applied and Environmental Microbiology*, 75:6856-6863.
- Broadbent C. (1996) *Guidance on water quality for heated spas*. Rundle Mall, South Australia: Public and Environmental Health Service.
- Brown JR, McLean DM, and Nixon MC. Bromine disinfection of a large swimming pool. *Can J Public Health.* 1964 Jun;55:251-6.
- Browne ML, Lewis-Michl EL, Stark AD. Unintentional drownings among New York State residents, 1988-1994. *Public Health Rep.* 2003 Sep-Oct;118(5):448-58.
- 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.
- Buss BF, Safranek TJ, Magri JM, Török TJ, Beach MJ, Foley BP. Association between swimming pool operator certification and reduced pool chemistry violations — Nebraska, 2005–2006. *J Environ Health.* 2009;71(8):36–40.
- Cammann K, Hubner K. Trihalomethane concentrations in swimmers' and bath attendants' blood and urine after swimming or working in indoor swimming pools. *Archives of Environmental Health* (1995); 50(1): 61-65.
- Camper AK, LeChevallier MW, Broadway SC, and McFeters GA. (1985) Growth and persistence of pathogens on granular activated carbon filters. *Journal of Applied Environmental Microbiology*, 50:1378–82.
- Cantor KP. Carcinogens in drinking water: the epidemiologic evidence. *Rev Environ Health.* 2010;25(1):9-16.
- Cary WH. Administration of swimming pool standards in Detroit. *Am. J. Public Health.* 1929;20(7):727-733.
- Cassan D, Mercier B, Castex F, Rambaud A. Effects of medium-pressure UV lamps radiation on water quality in a chlorinated indoor swimming pool. *Chemosphere* 2006;62(9):1507-13.
- 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.
- 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.
- Causser L, Handzel T, Welch P, Carr M, Culp M, Lucht R, Mudahar K, Robinson D, Neavear E, Fenton S, Rose C, Craig L, Ealey J, Arrowood M, Wahlquist S, Priest J, Xiao L, Lee Y-M, Mirel L, Levy D, Beach MJ, Poquette G, Dworkin M. An outbreak of *Cryptosporidium hominis* infection at an Illinois recreational waterpark. *Epidemiol Infect.* 2006 February; 134(1): 147–156.

- 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: <https://www.thefreelibrary.com/Chemical+off-gassing+from+indoor+swimming+pools.-a0217848230>.
- Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Web-based Injury Statistics Query and Reporting System (WISQARS). Available at <http://www.cdc.gov/injury/wisqars>. Accessed on April 25, 2018.
- Centers for Disease Control, National Institute for Occupational Safety and Health. UV radiation. Available from <http://www.cdc.gov/niosh/topics/uvradiation/>. Accessed April 24, 2018.
- Centers for Disease Control and Prevention. Acute illness and injury from swimming pool disinfectants and other chemicals --- United States, 2002—2008. MMWR Morb Mortal Wkly Rep. 2011;60(39):1343-1347.
- Centers for Disease Control and Prevention. An outbreak of *Pseudomonas folliculitis* associated with a waterslide – Utah. MMWR Morb Mortal Wkly Rep. 1983;32(32):425-7.
- Centers for Disease Control and Prevention. Chlorine disinfection timetable. Last modified May 04, 2016. Accessed July 6, 2016. <http://www.cdc.gov/healthywater/swimming/pools/chlorine-disinfection-timetable.html>.
- Centers for Disease Control and Prevention. Communitywide cryptosporidiosis outbreak--Utah, 2007. MMWR Morb Mortal Wkly Rep. 2008 Sep 12;57(36):989-93.
- Centers for Disease Control and Prevention. Cryptosporidiosis surveillance -- United States, 2011-2012. MMWR Suppl. 2015 May 1;64(3):1-14.
- Centers for Disease Control and Prevention. Drowning – United States, 2005-2009. MMWR Morb Mortal Wkly Rep. 2012;61(19):344-347.
- Centers for Disease Control and Prevention. Guidelines for environmental infection control in health-care facilities: recommendations of CDC and the healthcare infection control practices advisory committee (HICPAC). MMWR (2003);52: No.RR-10.
- Centers for Disease Control and Prevention. Immediate closures and violations identified during routine inspections of public aquatic facilities - network for aquatic facility inspection surveillance, five states, 2013. MMWR Surveill Summ. 2016 May 20;65(5):1-26.
- Centers for Disease Control and Prevention. Microbes in pool filter backwash as evidence of the need for improved swimmer hygiene - metro-Atlanta, Georgia, 2012. MMWR Morb Mortal Wkly Rep. 2013 May 17;62(19):385-8.
- Centers for Disease Control and Prevention. Ocular and respiratory illness associated with an indoor swimming pool--Nebraska, 2006. MMWR Morb Mortal Wkly Rep. 2007 Sep 14;56(36):929-32.
- Centers for Disease Control and Prevention. Outbreak of gastroenteritis associated with an interactive water fountain at a beachside park--Florida, 1999. MMWR Morb Mortal Wkly Rep. 2000 Jun 30;49(25):565-8.
- Centers for Disease Control and Prevention. Pool chemical-associated health events in public and residential settings — United States, 1983-2007. MMWR Morb Mortal Wkly Rep. 2009;58(18):489-93. Accessed 02/27/2011 at <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5818a1.htm>.
- Centers for Disease Control and Prevention. Prevalence of parasites in fecal material from chlorinated swimming pools — United States, 1999. MMWR Morb Mortal Wkly Rep. 2001;50(20):410–2.
- Centers for Disease Control and Prevention. *Pseudomonas* dermatitis/folliculitis associated with pools and hot tubs--Colorado and Maine, 1999-2000. MMWR Morb Mortal Wkly Rep. 2000 Dec 8;49(48):1087-91.
- Centers for Disease Control and Prevention. Respiratory and ocular symptoms among employees of a hotel indoor waterpark resort — Ohio, 2007. MMWR Morb Mortal Wkly Rep. 2009; 58(4):81-85.
- Centers for Disease Control and Prevention. Recommendations for preventing pool chemical-associated injuries. Accessed at <http://www.cdc.gov/healthywater/swimming/pools/preventing-pool-chemical-injuries.html>. Accessed April 25, 2018.
- Centers for Disease Control and Prevention. Surveillance data from public spa inspections — United States, May–September 2002. MMWR Morb Mortal Wkly Rep. 2004;53(25):553–555. Accessed 02/27/2011 at <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5325a2.htm>.

- Centers for Disease Control and Prevention. 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 Sep 12;57(9):1-29.
- Centers for Disease Control and Prevention. Ten leading causes of injury deaths by age group highlighting unintentional injury deaths, United States – 2016. Available online at https://www.cdc.gov/injury/images/lc-charts/leading_causes_of_death_highlighting_unintentional_2016_1040w800h.gif. Accessed on April 16, 2018.
- Centers for Disease Control and Prevention. Violations identified from routine swimming pool inspections – selected states and counties, United States, 2008. *MMWR Morb Mortal Wkly Rep.* 2010;59(19):582-587. Accessed 02/27/2011 at <http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5919a2.htm>.
- Centerwall BS, Armstrong CW, Funkhouser LS, Elzay RP. Erosion of dental enamel among competitive swimmers at a gas-chlorinated swimming pool. *Am J Epidemiol.* 1986;123(4):641-7.
- Chambers CD. Risks of hyperthermia associated with hot tub or spa use by pregnant women. *Birth Defects Res A Clin Mol Teratol.* 2006 Aug;76(8):569-73.
- Chappell CL, Okhuysen PC, Sterling CR, DuPont HL. *Cryptosporidium parvum*: intensity of infection and oocyst excretion patterns in healthy volunteers. *J Infect Dis.* 1996 Jan;173(1):232-6.
- Chen L, Dang B, Mueller C, Dunn K, Almaguer D, Enst J, Otto C. Health hazard evaluation report: investigation of employee symptoms at an indoor waterpark. Cincinnati, OH: US Department of Health and Human Services, CDC, National Institute for Occupational Safety and Health: 2008. Report no. HETA2007-0163-3062. Available at <http://www.cdc.gov/niosh/hhe/reports/pdfs/2007-0163-3062.pdf>.
- Chevrefils G, Caron E, Wright H, Sakamoto G. UV dose required to achieve incremental log inactivation of bacteria, protozoa and viruses. *IUVA News.* 2006 Mar:38-45.
- Cho M, Kim J, Kim JY, Yoon J, Kim JH. Mechanisms of *Escherichia coli* inactivation by several disinfectants. *Water Res.* 2010 Jun;44(11):3410-8.
- Chowdhury S, Alhooshani K, Karanfil T. Disinfection byproducts in swimming pool: occurrences, implications and future needs. *Water Res.* 2014 Apr 15;53:68-109.
- Cleasby JL and Logsdon GS. Chapter 8: Granular bed and precoat filtration. In *Water Quality and Treatment, 5th Ed.* McGraw Hill, Inc. NY:1999. ISBN: 0070016593.
- Clements W. (Ed.) (2000) ASHRAE guideline: Minimizing the risk of legionellosis associated with building water systems. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc.
- Coblentz A, Mollard R, Cabon P. (2001). Lifeguard vigilance bibliographic study, Executive summary. Paris: Applied Anthropology. Accessed April 21, 2018 at [http://www.sutcliffe.ca/joel/research/vigilanceStudy\(2001\).pdf](http://www.sutcliffe.ca/joel/research/vigilanceStudy(2001).pdf).
- Code of Federal Registry. 21 CFR Parts 201 and 310, Labeling and effectiveness testing; Sunscreen Drug Products for Over-the-Counter Human Use.
- Conference for Food Protection. Standards for Accreditation of food protection manager certification programs as amended by the 2018 biennial Conference for Food Protection. Accessed 07/05/2018 at <http://www.foodprotect.org/media/managercert/cfp-food-protection-manager-certification-standards.pdf>.
- Cornett AC, White JC, Wright BV, Willmott AP, Stager JM. Racing start safety: Head depth and head speed during competitive starts into a water depth of 1.22m. *Int J Aquatic Res Ed.* 2010;4:365-378.
- Cornett AC, White JC, Wright BV, Willmott AP, Stager JM. Racing start safety: Head depth and head speed during competitive starts into a water depth of 2.29m. *Int J Aquatic Res Ed.* 2011;5:14-31.
- Cornett AC, White JC, Wright BV, Willmott AP, Stager JM. Start depth modification by adolescent competitive swimmers. *Int J Aquatic Res Educ.* 2012;6:68-79.
- Cornett AC, White JC, Wright BV, Stager JM. Teaching competitive racing starts: Practices and opinions of professional swim coaches. *Int J Aquatic Res Educ.* 2012;6:156-170.
- Corona-Vasquez B, Samuelson A, Rennecker JL, Marinas BJ. Inactivation of *Cryptosporidium parvum* oocysts with ozone and free chlorine. *Water Res.* 2002;36(16):4053-63.
- Costerton JW. (2007) The biofilm primer. Germany: Springer-Verlag. 1-97.
- Council Directive 98/83/EC on the quality of water intended for human consumption, 1998 O.J. L 330/32.

- Cox GR, Broad EM, Riley MD, Burke LM. Body mass changes and voluntary fluid intakes of elite level water polo players and swimmers. *J Sci Med Sport*. 2002;5(3):183-193.
- Craik SA, Weldon D, Finch GR, Bolton JR, Belosevic M. Inactivation of *Cryptosporidium parvum* oocysts using medium- and low-pressure ultraviolet radiation. *Water Res*. 2001;35(6):1387-98.
- Crandell CC, Smaldino JJ, Flexer C. SoundField FM amplification: Theory and practical applications. San Diego: Singular Publishing Group, Inc; 1995.
- Croft T, Hartwell FP, Summers, WI. American electricians' handbook, Ed.16 (2013).
- Croll BT, Hayer CR, and Moss S. Simulated *Cryptosporidium* removal under swimming pool filtration conditions. *Water and Environment Journal*. 2007;21:149-156.
- Cummings P, Quan L. Trends in unintentional drowning: The role of alcohol and medical care. *JAMA*, 1999;281(23):2198-2202.
- Cusimano MD, Mascarenhas AM, Manoranjan B. Spinal cord injuries due to diving: A framework and call for prevention. *J Trauma*. 2008;65(5):1180-5.
- Dafoe WA. Appendix: Table of energy requirements for activities of daily living, household tasks, recreational activities, and vocational activities. In: Pashkow FJ, Dafoe WA, editors. *Clinical cardiac rehabilitation: a cardiologist's guide*. Baltimore, MD: Williams and Wilkins, 1993; 359-376.
- Dalton B, Behm D. Effects of noise and music on human and task performance: A systematic review. *Occupational Ergonomics* 7(2007): 143152.
- 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.
- Dawes C, Boroditsky CL. Rapid and severe tooth erosion from swimming in an improperly chlorinated pool: case report. *J Can Dent Assoc*. 2008;74(4):359-61.
- Davis TL, Standridge JH, Degnan AJ. Bacteriological analysis of indoor and outdoor water parks in Wisconsin. *J Water Health* 2009;7(3):452-463.
- Decker WJ, Koch HF. Chlorine poisoning at the swimming pool: an overlooked hazard. *Clinical Toxicology* (1978); 13(3): 377-381.
- Declerck P. (2010) Biofilms: the environmental playground of *Legionella pneumophila*. *Environmental Microbiology*, 12(3), 557-566.
- De Laat J, Feng W, Freyfer D, Dossier-Berne F. Concentration levels of urea in swimming pool water and reactivity of chlorine with urea. *Water Res*. 2011; 45(3):1139-1146.
- Dharmarajah AH and Cleasby JL. Predicting the expansion behavior of filter media. *Journ. AWWA*. 1986;78(12):66-76.
- Dick EC, Shull IF, and Armstrong AS. Surface-subsurface distribution of bacteria in swimming pools – field studies. *Am. J. Pub. Health*. 1960;50:5:689-695.
- DIN. Treatment and disinfection of water used in bathing facilities, part 1: general requirements. 1997. Ref. No. 19643-1.
- DeVivo MJ. Epidemiology of traumatic spinal cord injury: trends and future implications. *Spinal Cord*. 2012 May;50(5):365-72.
- DeVivo MJ, Sekar P. Prevention of spinal cord injuries that occur in swimming pools. *Spinal Cord*. 1997;35(8):509-15.
- Donlan RM and Costerton JW. (2002) Biofilms: survival mechanisms of clinically relevant microorganisms. *Clinical Microbiology Review*, 15, 167-93.
- Drobnic F, Freixa A, Casan P, Sanchis J, Guardino X. Assessment of chlorine exposure in swimmers during training. *Medicine and Science in Sports and Exercise* (1996); 28(2): 271-274.
- Dufour AP, Behymer TD, Cantú R, Magnuson M, Wymer LJ. Ingestion of swimming pool water by recreational swimmers. *J Water Health*. 2017 Jun;15(3):429-437.
- Dufour AP, Evans O, Behymer TD, Cantú R. Water ingestion during swimming activities in a pool: a pilot study. *J Water Health*. 2006 Dec;4(4):425-30.

- Duma SM, Bisplinghoff JA, Senge DM, McNally C, Alphonse VD. Eye injury risk from water stream impact: biomechanically based design parameters for water toy and park design. *Curr Eye Res.* 2012 Apr;37(4):279-85.
- Durston L. (2009) Design, construction, and testing of the commercial air barrier. Accessed on May 2, 2018 at <https://www.irinfo.org/05-01-2009-durston/>.
- Duong HT, Shahrukh Hashmi S, Ramadhani T, Canfield MA, Scheuerle A, Kim Waller D; National Birth Defects Prevention Study. Maternal use of hot tub and major structural birth defects. *Birth Defects Res A Clin Mol Teratol.* 2011 Sep;91(9):836-41.
- DuPont HL, Chappell CL, Sterling CR, Okhuysen PC, Rose JB, Jakubowski W. The infectivity of *Cryptosporidium parvum* in healthy volunteers. *N Engl J Med.* 1995 Mar 30;332(13):855-9.
- Egan MD. Architectural acoustics. New York: McGrawHill; 1988.
- Ehrlich PF, Young JG, Ulin S, Woolley C, Armstrong TJ, Galecki A, Chen S, Ashton-Miller JA. Maximum hand-rung coupling forces in children: the effects of handhold diameter. *Hum Factors.* 2013;55(3):545-56.
- EMS World Response Time Standards: <http://www.emsworld.com/article/10324786/ems-response-time-standards>
- Engel J P, Rubin AJ, Sproul OJ. Inactivation of *Naegleria gruberi* cysts by chlorinated cyanurates. *Appl Environ Microbiol.* 1983;46:1157–1162.
- Environmental Protection Agency. Disinfection profiling and benchmarking guidance manual. 1999. Available at <https://nepis.epa.gov/Exe/ZyPDF.cgi/20002249.PDF?Dockey=20002249.PDF>. Accessed on April 29, 2018.
- Erdinger L, Kirsch F, Sonntag HG. Chlorate as an inorganic disinfection by-product in swimming pools. *Zentralbl Hyg Umweltmed* (1999); 202: 61-75.
- Erdinger L, Kirsch F, Hoepfner A, Sonntag HG. Haloforms in spas. *Zentralbl Hyg Umweltmed* (1997);200: 309-317.
- Esterman A, Roder DM, Cameron AS, Robinson BS, Walters RP, Lake JA, and Christy PE. Determinants of the microbiological characteristics of South Australian swimming pools. *Appl Environ Microbiol.* 1984 February; 47(2): 325–328.
- Eykelbosh A, Beaudet S. Float tanks: Considerations for environmental public health. Vancouver, BC: National Collaborating Centre for Environmental Health; 2016 Jul. Available from http://www.nceeh.ca/sites/default/files/Float_Tanks_Considerations_EPH_July_2016.pdf. Accessed April 23, 2018.
- Falkinham JO 3rd. Mycobacterial aerosols and respiratory disease. *Emerg Infect Dis.* 2003;9(7):763-7.
- Favero, MS, Drake CH, and Randall GB. Use of staphylococci as indicators of swimming pool. *Public Health Rep.* 1964 Jan;79:61-70.
- 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.
- Fitzgerald DA, Wilkinson SM, Bhaggoe R, Beck MH, English JS. Spa pool dermatitis. *Contact Dermatitis.* 1995 Jul;33(1):53.
- Fitzgerald GP, DerVartanian ME. Factors influencing the effectiveness of swimming pool bactericides. *Appl Microbiol.* 1967 May;15(3):504-9.
- Fitzgerald GP, DerVartanian ME. *Pseudomonas aeruginosa* for the evaluation of swimming pool chlorination and algicides. *Appl Microbiol.* 1969 Mar;17(3):415-21.
- Font-Ribera L, Villanueva CM, Gràcia-Lavedan E, Borràs-Santos A, Kogevinas M, Zock JP. Indoor swimming pool attendance and respiratory and dermal health in schoolchildren--HITEA Catalonia. *Respir Med.* 2014 Jul;108(7):1056-9.
- 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(5):582-588.
- Fryar CD, Gu Q, Ogden CL, Flegal KM. Anthropometric reference data for children and adults: United States, 2011–2014. National Center for Health Statistics. *Vital Health Stat.* 2016;3(39):1-46. Available at https://www.cdc.gov/nchs/data/series/sr_03/sr03_039.pdf. Accessed on April 25, 2018.

- Fuchs J. Chlorination of pool water: urea degradation rate. *Chemiker Ztg. -Chem. Apparatur* (1962);86(3): 76-82.
- Gabrielsen MA, Spivey M. Diving injuries: The etiology of 486 case studies with recommendations for needed action. 1990. Nova University Press, Ft. Lauderdale, FL.
- Gage SD, Ferguson HF, Gillespie CG, Messer R, Tisdale ES, Hinman JJ, Green HW. Swimming pools and other public bathing places. *Am J Public Health (N Y)*. 1926 Dec;16(12):1186-201.
- 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.
- Galal-Gorchev H, Morris JC. Formation and stability of bromamide, bromimide, and nitrogen tribromide in aqueous solution. *Inorganic Chemistry*. 1965;4(6):899-905.
- Gerba CP. Assessment of enteric pathogen shedding by bathers during recreational activity and its impact on water quality. *Quant Microbiol* (2000); 2:55-68.
- German Standard DIN 19643, 2012. Treatment of water of swimming-pools and baths. Deutsches Institut Fur Normung E.V. (German National Standard).
- Geurtsen W. Rapid general dental erosion by gas-chlorinated swimming pool water. Review of the literature and case report. *Am J Dent*. 2000;13(6):291-3.
- Gilchrist J, Parker EM. Racial/ethnic disparities in fatal unintentional drowning among persons aged ≤ 29 Years — United States, 1999–2010. *J Safety Res*. 2014 Sep;50:139-42.
- Gipson K. Pool or spa submersion: estimated injuries and reported fatalities, 2011 Report. May 2011. Consumer Product Safety Commission. Available online at <http://www.cpsc.gov/LIBRARY/FOIA/FOIA11/os/poolsub2011.pdf>.
- 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.
- Glickman RD. Ultraviolet phototoxicity to the retina. *Eye Contact Lens*. 2011 Jul;37(4):196-205.
- Glickman RD. Phototoxicity to the retina: mechanisms of damage. *Int J Toxicol*. 2002 Nov-Dec;21(6):473-90.
- Goeres DM, Palys T, Sandel BB, and Geiger J. Evaluation of disinfectant efficacy against biofilm and suspended bacteria in a laboratory swimming pool model. *Water Research*. 2004;38(13):3103-3109.
- Golaszewski G, Seux R. The kinetics of the action of chloroisocyanurates on three bacteria: *Pseudomonas aeruginosa*, *Streptococcus faecalis*, and *Staphylococcus aureus*. *Water Research* 1994;28(1): 207-217.
- Goodgame RW, Genta RM, White AC, Chappell CL. Intensity of infection in AIDS-associated cryptosporidiosis. *J Infect Dis*. 1993 Mar;167(3):704-9.
- Goodman M, Hays S. Asthma and swimming: A meta-analysis. *Journal of Asthma* (2008); 45(8): 639-647.
- Goutziana G, Mouchtouri VA, Karanika M, Kavagias A, Stathakis NE, Gourgoulis 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.
- Grabow WO, Gauss-Müller V, Prozesky OW, Deinhardt F. Inactivation of hepatitis A virus and indicator organisms in water by free chlorine residuals. *Appl Environ Microbiol*. 1983 Sep;46(3):619-24.
- Gregory R. Bench-marking pool water treatment for coping with *Cryptosporidium*. *J Environ Hlth Res* . 2002;1(1):11-18.
- Grobe S, Wingender J, & Flemming H. (2001) Capability of mucoid *Pseudomonas aeruginosa* to survive in chlorinated water. *International Journal of Monitoring & Testing and Public Health*, 204, 139-142.
- Gunkel K, Jessen HJ. The urea problem in swimming pools. *Z. gesamte Hyg.* (1988); 34(4):248-50.
- Haas CN, Karra SB. Kinetics of wastewater chlorine demand exertion. *J Water Pollution Control Federation*. 1984;56:170-3.
- 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.
- Hanna JG, Siggia S. Determination of chloroform and bromoform. *Anal Chemistry* (1950); 22(4):569-570.

- Hendricks D. Water treatment unit processes, physical and chemical. 2006. CRC Press (Taylor & Francis Group), Boca Raton, FL. ISBN: 0824706951.
- 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, Gerber JM, Hubert G, Hecht G, Diebold F, Honnert B, Moulut JC. Exposure to metallic catalyst dust: manufacturing and handling of catalysts in the chemical industry. *Ann Occup Hyg*. 1994 Apr;38(2):119-35.
- 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.
- Heymann D. (Ed.) (2004) Control of communicable diseases manual. Washington, DC: American Public Health Association, pp. 138-141, 230-231, 383-385.
- Hlavsa MC, Cikesh BL, Roberts VA, Kahler AM, Vigar M, Hilborn ED, Wade TJ, Roellig DM, Murphy JL, Xiao L, Kunz JM, Cooley LA, Yates KM, Hill VE, Beach MJ, Fullerton KE, Yoder JS. Outbreaks associated with treated recreational water — United States, 2000–2014. *MMWR Morb Mortal Wkly Rep*. 2018;67(19):547-551.
- Hlavsa MC, Roberts VA, Anderson AR, Hill VR, Kahler AM, Orr M, Garrison LE, Hicks LA, Newton A, Hilborn ED, Wade TJ, Beach MJ, Yoder JS. Surveillance for waterborne disease outbreaks and other health events associated with recreational water use — United States, 2007–2008. *MMWR Surveill Summ* 2011;60:1-37.
- Hlavsa MC, Roberts VA, Kahler AM, Hilborn ED, Mecher TR, Beach, MJ, Wade TJ, Yoder JS. Outbreaks of illness associated with recreational water — United States, 2011–2012. *MMWR Morb Mortal Wkly Rep*. 2015;64(24):668-672.
- Hlavsa MC, Robinson TJ, Collier SA, Beach MJ. Pool chemical–associated health events in public and residential settings — United States, 2003–2012, and Minnesota, 2013. *MMWR Morb Mortal Wkly Rep*. 2014;63(19):427-30.
- Hodgson M, and Casey B. (1996) Prevalence of *Legionella* bacteria in building water systems. In *IAQ 96. Paths to Better Building Environments*. Conference of the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. Atlanta.
- Holzwarth G, Balmer RG, Soni L. The fate of chlorine and chloramines in cooling towers. *Water Res*. 1984;18:1421–1427.
- Howland J, Hingson R, Mangione TW, Bell N, Bak S. Why are most drowning victims men? Sex differences in aquatic skills and behaviors. *Am J Public Health* 1996;86:93--6.
- Hurst C, Crawford R, Knudsen G, McInerney M, and Stetzenbach L. (2002) Manual of environmental microbiology. Washington DC: American Public Health Association. 184, 186-188.
- IARC monographs on the evaluation of carcinogenic risks to humans. Solar and ultraviolet radiation. IARC Monogr Eval Carcinog Risks Hum. 1992;55:1-316.
- Ibarluzea, J, Moreno B, Zigorraga C, Castilla T, Martinez M, Santamaria J. Determinants of the microbiological water quality of indoor swimming pools in relation to disinfection. *Water Research*. 1998; 33(3): 865-871.
- International Standards Organization. ISO/IEC Guide 50:2014. Safety aspects--Guidelines for child safety in standards and other specifications. Available at <https://www.iso.org/standard/63937.html>. Access April 25, 2018.
- 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.
- Jetté M, Sidney K, Blümchen G. Metabolic equivalents (METs) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clin Cardiol*. 1990 Aug;13(8):555-65.
- Jerison HJ, Pickett RM. Vigilance: The importance of the elicited observing rate. *Science*. 1964;143(3609):970-1.
- Johnson JD, Overby R. Bromine and bromamine disinfection chemistry. *J of Sanitary Engineering Division Am Soc of Civil Eng*, 1971;97:617-628.
- Johnston K, Kinziger M. Certified operators: does certification provide significant results in real-world pool and spa chemistry? *Int J Aquatic Res Ed*. 2007;1(1):18–33.
- Jokinen E, Välimäki I, Antila K, Seppänen A, Tuominen J. Children in sauna: Cardiovascular adjustment. *Pediatrics*. 1990 Aug;86(2):282-8.

- Jones TF, Mcmillian MB, Scallan E, Frenzen PD, Cronquist AB, Thomas S, Angulo FJ. A population-based estimate of the substantial burden of diarrhoeal disease in the United States; FoodNet, 1996–2003. *Epidemiol Infect.* 2007;135:293–301.
- Jonsson K, Kjellgren A. Curing the sick and creating supermen – How relaxation in flotation tanks is advertised on the Internet. *Eur J Integrat Med.* 2014;6(5):601-9.
- Judd SJ, Black SH. Disinfection by-product formation in swimming pool waters: a simple mass balance. *Water Research* (2000); 34(5):1611-1619.
- Judd SJ, Bullock G. The fate of chlorine and organic materials in swimming pools. *Chemosphere* (2003); 51:869-879.
- Kaydos-Daniels SC, Beach MJ, Shwe T, Magri J, Bixler D. Health effects associated with indoor swimming pools: a suspected toxic chloramine exposure. *Public Health.* 2008 Feb;122(2):195-200.
- Kawamura, S. Integrated design and operation of water treatment facilities. 2000. John Wiley and Sons, Inc., NY.
- Kenttämies A, Karkola K. Death in sauna. *J Forensic Sci.* 2008 May;53(3):724-9.
- Kelsall HL, Sim MR. Skin irritation in users of brominated pools. *Int J Environ Health Res.* 2001 Mar;11(1):29-40.
- Keuten MG, Schets FM, Schijven JF, Verberk JQ, van Dijk JC. Definition and quantification of initial anthropogenic pollutant release in swimming pools. *Water Res.* 2012 Jul;46(11):3682-92.
- Kim H, Shim J, Lee S. Formation of disinfection by-products in chlorinated swimming pool water. *Chemosphere* (2002); 46:123-130.
- 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.
- Kott Y, Hershkovitz G, Shemtob A, Sless JB. Algicidal effect of bromine and chlorine on *Chlorella pyrenoidosa*. *Appl Microbiol.* 1966 Jan;14(1):8-11.
- Korich DG, Mead JR, Madore MS, Sinclair NA, Sterling CR. Effects of ozone, chlorine dioxide, chlorine, and monochloramine on *Cryptosporidium parvum* oocyst viability. *Appl Environ Microbiol* 1990;56:1423-1428.
- Kristensen GH, Klausen MM, Hansen VA, Lauritsen FR. On-line monitoring of the dynamics of trihalomethane concentrations in a warm public swimming pool using an unsupervised membrane inlet mass spectrometry system with off-site real-time surveillance. *Rapid Commun Mass Spectrom.* 2010 Jan;24(1):30-4. doi: 10.1002/rcm.4360.
- Krutmann J, Béhar-Cohen F, Baillet G, de Ayguavives T, Ortega Garcia P, Peña-García P, Remé C, Wolffsohn J. Towards standardization of UV eye protection: what can be learned from photodermatology? *Photodermatol Photoimmunol Photomed.* 2013 Nov 8.
- Kush BJ, Hoadley AW. A preliminary survey of the association of *Pseudomonas aeruginosa* with commercial whirlpool bath waters. *Am J Public Health.* 1980 Mar;70(3):279-81.
- Kyriacou DN, Arcinue EL, Peek C, Kraus JF. Effect of immediate resuscitation on children with submersion injury. *Pediatrics.* 1994;94 (2):137-142.
- Lagerkvist BJ, Bernard A, Blomberg A, Bergstrom E, Forsberg B, Holmstrom K, Karp K, Lundstrom NG, Segerstedt B, Svensson M, Nordberg G. Pulmonary epithelial integrity in children: Relationship to ambient ozone exposure and swimming pool attendance. *Environ Health Perspect* (2004);112:1768-1771.
- Lahl U, Batjer K, v Duzeln J, Gabel B, Stachel B, Thiemann W. Distribution and balance of volatile halogenated hydrocarbons in the water and air of covered swimming pools using chlorine for water disinfection. *Water Res.* 1981;15:803-814.
- 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.
- Lange KP, Bellamy WD, Hendricks DH, and Logsdon GS. Diatomaceous earth filtration of *Giardia* cysts and other substances. *Journal AWWA.* 1986;78(1):76-84.
- Layon AJ, Modell JH. Drowning: Update 2009. *Anesthesiology.* 2009 Jun;110(6):1390-401.
- Lazarov A, Nevo K, Pardo A, Froom P. Self-reported skin disease in hydrotherapists working in swimming pools. *Contact Dermatitis.* 2005 Dec;53(6):327-31.

- Lee J, Ha KT, Zoh KD. Characteristics of trihalomethane (THM) production and associated health risk assessment in swimming pool waters treated with different disinfection methods. *Sci Total Environ*. 2009 Mar 1;407(6):1990-7.
- Lee SH, Armstrong TJ. Field tool for on-site biomechanical analysis during ladder climbing. The Center for Construction Research and Training, CPWR Final Report, April 2014. Available at <https://www.cpwr.com/sites/default/files/publications/LeeFinalReport.pdf>. Accessed on April 29, 2018.
- Lee SH, Levy DA, Craun GF, Beach MJ, Calderon RL. Surveillance for waterborne-disease outbreaks--United States, 1999-2000. *MMWR Surveill Summ*. 2002 Nov 22;51(8):1-47.
- LEED version 4 for building design and construction. Updated April 6, 2018. Washington D.C.: U.S. Green Building Council; 2016. 161 p. Found at https://www.usgbc.org/sites/default/files/LEED%20v4%20BDC_04.6.18_current.pdf. Accessed April 21, 2018.
- Lenntech. Ozone decomposition. Delft, the Netherlands: Lenntech. n.d.; Available from <http://www.lenntech.com/library/ozone/decomposition/ozone-decomposition.htm>. Access April 23, 2018.
- Letterman RD. Water quality and treatment. 1999. 5th Ed. McGraw-Hill, NY.
- Leoni E, Legnani PP, Bucci Sabattini MA, Righi F. Prevalence of *Legionella* spp. in swimming pool environment. *Water Res*. 2001;35(15):3749-53.
- Leoni E, Legnani P, Mucci MT, and Pirani R. Prevalence of mycobacteria in a swimming pool environment. *J. Applied Microbiology*. 1999;87(5):683-688.
- 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.
- Lichstein KL, Riedel BW, Richman SL. The Mackworth clock test: a computerized version. *J Psychol*. 2000 Mar;134(2):153-61.
- Li DK, Janevic T, Odouli R, Liu L. Hot tub use during pregnancy and the risk of miscarriage. *Am J Epidemiol*. 2003 Nov 15;158(10):931-7.
- Li J, Blatchley ER, 3rd. UV photodegradation of inorganic chloramines. *Environ Sci Technol* 2009;43(1):60-5.
- 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.
- Lindstrom AB, Pleil JD, Berkoff DC. Alveolar breath sampling and analysis to assess trihalomethane exposures during competitive swimming training. *Environmental Health Perspectives* (1997); 105(6):636-642.
- Logsdon GS, Symons JM, Hoye RL, and Arozarena MM. Alternative filtration methods for removal of *Giardia* cysts and cyst models. *Journal AWWA*. 1981;73(2):111-118.
- Logsdon GS and Fox K. Getting your money's worth from filtration. *Journal AWWA*. 1982;74(5):249-256.
- Logsdon GS. Water filtration practices: including slow sand filters and precoat filtration. 2008. American Water Works Association, Denver, CO. ISBN: 9781583215951.
- Loughney E, Harrison J. Irritant contact dermatitis due to 1-bromo-3-chloro-5,5-dimethylhydantoin in a hydrotherapy pool. Risk assessments: the need for continuous evidence-based assessments. *Occup Med (Lond)*. 1998 Oct;48(7):461-3.
- Lyons TB and Kapur R. *Limax amoebae* in public swimming pools of Albany, Schenectady, and Rensselaer counties, New York: their concentration, correlations, and significance. *Applied and Environmental Microbiology*. 1977;33(3):551-555.
- Mackworth NH. Researches in the measurement of human performance. MRC Spec. Report 268 HMSO, 1950.
- Maffei L, Iannace G, Masullo M, Nataletti P. Noise exposure in school gymnasia and swimming pools. *Noise Control Engineering Journal* 57 (6). Institute of Noise Control Engineering. Nov-Dec 2009. 12 p.
- Malowitz R, Tortora GT, Lehmann CA. Effects of floating in a saturated Epsom-salt solution on the aerobic microbial flora of the skin. *Clin Lab Sci*. 1988;1(6):358-61.

- March JG, Gual M, Ramonell J. A kinetic model for chlorine consumption in grey water. *Desalination* (2005); 181:267-273.
- 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.
- McCarty CA, Taylor HR. A review of the epidemiologic evidence linking ultraviolet radiation and cataracts. *Dev Ophthalmol*. 2002;35:21-31.
- Mekjavic IB, Gaul CA, White MD, Mittleman KD. Cardiovascular responses during 70 degrees head-up tilt: the effect of elevated body temperature and high alcohol blood levels. *Physiologist*. 1987 Feb;30(1 Suppl):S56-7.
- 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.
- 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.
- Milunsky A, Ulcickas M, Rothman KJ, Willett W, Jick SS, Jick H. Maternal heat exposure and neural tube defects. *JAMA*. 1992 Aug 19;268(7):882-5.
- Modell JH. Prevention of needless deaths from drowning. *South Med J*. 2010 Jul;103(7):650-3.
- Moraga-McHaley SA, Landen M, Krapfl H, Sewell CM. Hypersensitivity pneumonitis with *Mycobacterium avium* complex among spa workers. *J Occup Environ Health*. 2013;19(1):55-61.
- Moretti ME, Bar-Oz B, Fried S, Koren G. Maternal hyperthermia and the risk for neural tube defects in offspring: systematic review and meta-analysis. *Epidemiology*. 2005 Mar;16(2):216-9.
- Moritz AR and Henriques FC. Studies of thermal injury: The relative importance of time and surface temperature in the causation of cutaneous burns. *Am J Pathol*. 1947 Sep;23(5):695-720.
- Muraca P, Stout J, & Yu V. (1987) Comparative assessment of chlorine, heat, ozone, and UV light for killing *Legionella pneumophila* within a model plumbing system. *Applied and Environmental Microbiology*, 53(2), Retrieved from <http://aem.asm.org/cgi/reprint/53/2/447>.
- Murphy JL, Arrowood MJ, Lu X, Hlavsa MC, Beach MJ, Hill VR. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol*. 2015;49(12):7348-55.
- Murphy JL, Haas CN, Arrowood MJ, Hlavsa MC, Beach MJ, Hill VR. Efficacy of chlorine dioxide tablets on inactivation of *Cryptosporidium* oocysts. *Environ Sci Technol*. 2014;48(10):5849-5856.
- Murphy JL, Hlavsa MC, Carter BC, Miller C, Jothikumar N, Gerth TR, Beach MJ, Hill VR. Pool water quality and prevalence of microbes in filter backwash from metro-Atlanta swimming pools. *J Water Health*. 2018 Feb;16(1):87-92.
- Mustchin CP, Pickering CA. Coughing water: bronchial hyper-reactivity induced by swimming in a chlorinated pool. *Thorax* (1979); 34(5): 682-683.
- Nadolny E, MacDougall C, Public Health Ontario. Evidence brief: Risk of infection in the use of floatation tanks. Toronto, ON: Ontario Agency for Health Protection and Promotion; 2016 Jun. Available from: http://www.publichealthontario.ca/en/eRepository/EB_Floatation_Tanks_Infection_Risk.pdf. Accessed April 23, 2018.
- Nemery B, Hoet PJM, Nowak D. Indoor swimming pools, water chlorination, and respiratory health. *Eur. Respir. J*. (2002); 19: 790-793.
- Neveu A, Pouliguen C, Tricard D, and Mallet A. Evaluation of operation and performance of swimming pool filtration plants. *Francaisd'Hydrologie*. 1988;19:2:203-213. (In French).
- Newbold J. (2006) *Management of spa pools: Controlling the risk of infection*. London, United Kingdom: Health Protection Agency.
- New South Wales Department of Health. Public swimming pool and spa pool code of practice. 2010. Available at: <http://www.health.nsw.gov.au/environment/publicpools/Pages/default.aspx>.
- Nichter MA, Everett PB. Profile of drowning victims in a coastal community. *J Fla Med Assoc*. 1989 Feb;76(2):253-6.

- Niquette P, Servais P, and Savoie R. Impacts of pipe materials on densities of fixed bacterial biomass in a drinking water distribution system. *Water Research*. 2000;34(6):1952-1956.
- Nordberg GF, Lundstrom NG, Forsberg B, Hagenbjork-Gustafsson A, Lagerkvist BJ, Nilsson J, Svensson M, Blomberg A, Nilsson L, Bernard A, Dumont X, Bertilsson H, Eriksson K. Lung function in volunteers before and after exposure to trichloramine in indoor pool environments and asthma in a cohort of pool workers. *BMJ Open*. 2012 Oct 8;2(5).
- NSF International. Component certification specification for floatation or sensory deprivation systems and related equipment, CCS-12804. Ann Arbor, MI: NSF International. 2013a. Available from <http://info.nsf.org/Certified/Pool/12804.pdf>. Accessed April 23, 2018.
- NSF International. Organism time kill in float lab water (J-00114729). Ann Arbor, MI: NSF International; November 2012. Available from <http://floatlab.com/wp-content/uploads/2012/01/Organism-Time-Kill-in-Float-Lab-Water5.pdf>.
- NSF International. Organism viability testing in Epsom salt and control solution: NSF International; 2015a Oct. Available from https://s3-us-west-2.amazonaws.com/floattanksolutions/NSF-Salt-Only-Tests_2015.pdf. Accessed April 23, 2018.
- NSF International. Qualification testing for float lab isolation floatation chamber (J-00119683). Ann Arbor, MI: NSF International; 2013b May.
- NSF International. Qualification testing for float lab isolation floatation chamber (J-00125267). Ann Arbor, MI: NSF International; 2013c May.
- NSF International. Recovery analysis of free and total chlorine measurement methods in high MgSO₄ solution. Ann Arbor, MI: NSF International; 2015b Feb.
- Ongerth JE and Hutton PE. Testing of diatomaceous earth filtration for removal of *Cryptosporidium* oocysts. *Journal AWWA*. 2001;93(12):54-63.
- Occupational Safety and Health Administration. 29 CFR Part 1910.95 App G, Monitoring noise levels non-mandatory informational appendix. Accessed April 21, 2018 at: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9742.
- Occupational Safety and Health Administration. 29 CFR Part 1910.95, Occupational noise exposure. Amended December 12, 2008. Accessed April 21, 2018 at: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735.
- Occupational Safety and Health Administration. Bloodborne pathogens and needlestick prevention. Available at: <http://www.osha.gov/SLTC/bloodbornepathogens>. Accessed: 5/1/2013.
- Occupational Safety and Health Administration. Bloodborne pathogens and needlestick prevention standards. Accessed on 4/25/2016 at: <http://www.osha.gov/SLTC/bloodbornepathogens/standards.html>.
- Occupational Safety and Health Administration. Coverage of lifeguards under 29 CFR 1910.1030. July 9, 1993. Corrected 08/16/2007. Accessed July 6, 2016 at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=21197.
- Occupational Safety and Health Administration. Fact sheet: OSHA's bloodborne pathogen standards. Accessed on 4/25/2016 at: <http://www.osha.gov/OshDoc/data/BloodborneFacts/bbfact01.pdf>.
- Occupational Safety and Health Administration. Personal protective equipment standard 1910.132. Accessed March 1, 2014 at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9777. Accessed April 24, 2018.
- Occupational Safety and Health Administration. Toxic and hazardous substances – blood borne pathogens 29 CFR 1910.1030. Available at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10051. Accessed April 24, 2018.
- Painter JE, Gargano JW, Yoder JS, Collier SA, Hlavsa MC. Evolving epidemiology of reported cryptosporidiosis cases in the United States, 1995–2012. *Epidemiol Infect*. 2016;144:1792-802.
- 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.

- Paulson D. (Ed.) (2010) Applied biomedical microbiology: A biofilms approach. Chapter 8: Matias F, et. al., Disinfection and its influence on biofilm ecology . Chapter 9: Goerers D, Understanding the importance of biofilm growth in hot tubs. Boca Raton, Fl: CRC Press.
- Pelletier AR, Gilchrist J. Fatalities in swimming pools with lifeguards: USA, 2000-2008. *Inj Prev*. 2011 Aug;17(4):250-3.
- Pintar KD, Fazil A, Pollari F, Charron DF, Waltner-Toews D, McEwan SA. A risk assessment model to evaluate the role of fecal contamination in recreational water on the incidence of *Cryptosporidiosis* at the community level in Ontario. *Risk Analysis*. 2010;30(1):49-64.
- Pleasance ED, Cheetham RK, Stephens PJ, McBride DJ, Humphray SJ, Greenman CD, Varela I, Lin ML, Ordóñez GR, Bignell GR, Ye K, Alipaz J, Bauer MJ, Beare D, Butler A, Carter RJ, Chen L, Cox AJ, Edkins S, Kokko-Gonzales PI, Gormley NA, Grocock RJ, Haudenschild CD, Hims MM, James T, Jia M, Kingsbury Z, Leroy C, Marshall J, Menzies A, Mudie LJ, Ning Z, Royce T, Schulz-Trieglaff OB, Spiridou A, Stebbings LA, Szajkowski L, Teague J, Williamson D, Chin L, Ross MT, Campbell PJ, Bentley DR, Futreal PA, and Stratton MR. A comprehensive catalogue of somatic mutations from a human cancer genome. *Nature*. 2010;463:7278;191-6.
- Pool Water Treatment Advisory Group (PWTAG). Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- Press E. The health hazards of saunas and spas and how to minimize them. *Am J Public Health*. 1991 Aug;81(8):1034-7.
- Price D, Ahearn DG. Incidence and persistence of *Pseudomonas aeruginosa* in whirlpools. *J Clin Microbiol*. 1988 Sep;26(9):1650-4.
- Quan L, Gore EJ, Wentz K, Allen J, Novack AH. Ten-year study of pediatric drownings and near-drownings in King County, Washington: lessons in injury prevention. *Pediatrics*. 1989 Jun;83(6):1035-40.
- Reisen WK, Takahashi RM, Carroll BD, Quiring R. Delinquent mortgages, neglected swimming pools, and West Nile virus, California. *Emerg Infect Dis*. 2008 Nov;14(11):1747-9.
- Richardson SD, DeMarini DM, Kogevinas M, Fernandez P, Marco E, Lourencetti C, Ballesté C, Heederik D, Meliefste K, McKague AB, Marcos R, Font-Ribera L, Grimalt JO, Villanueva CM. What's in the pool? A comprehensive identification of disinfection by-products and assessment of mutagenicity of chlorinated and brominated swimming pool water. *Environmental Health Perspectives*. 2010 Nov;118(11):1523-30.
- Ritter G, Wolfe RA, Goldstein S, Landis JR, Vasu CM, Acheson A, Leighton R, Medendrop SV. The effect of bystander CPR on survival of out-of-hospital cardiac arrest victims. *Am Heart J*. 1985 Nov;110(5):932-7.
- Roberts JE. Ultraviolet radiation as a risk factor for cataract and macular degeneration. *Eye Contact Lens*. 2011 Jul;37(4):246-9.
- Roberts JE. Ocular phototoxicity. *J Photochem Photobiol B*. 2001 Nov 15;64(2-3):136-43.
- Robinton ED, Mood EW. An evaluation of the inhibitory influence of cyanuric acid upon swimming pool disinfection. *Am J Public Health*. 1967 Feb;57(2):301-10.
- Robson HL. Chloramines and bromamines. *Encyclopedia of Chemical Technology*, Kirk-Othmer, 4d ed, Interscience, New York.
- Rochelle PA, Upton SJ, Montelone BA, Woods K. The response of *Cryptosporidium parvum* to UV light. *Trends Parasitol*. 2005;21(2):81-7.
- Rodhe A, Eriksson A. Sauna deaths in Sweden, 1992-2003. *Am J Forensic Med Pathol*. 2008 Mar;29(1):27-31.
- 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.
- Rosenman KD, Millerick-May M, Reilly MJ, Flattery J, Weinberg J, Harrison R, Lumia M, Stephens AC, Borjan M. Swimming facilities and work-related asthma. *J Asthma*. 2015 Feb;52(1):52-8.
- Rowland T. Thermoregulation during exercise in the heat in children: old concepts revisited. *J Appl Physiol*. 2008 Aug;105(2):718-24.
- Rycroft RJ, Penny PT. Dermatoses associated with brominated swimming pools. *Br Med J (Clin Res Ed)*. 1983 Aug 13;287(6390):462.

- Saita K, Tachikawa M, Tezuka M, Sawamura R. Effects of isocyanuric acid on the polio virus inactivation with hypochlorous acid. *Jpn. J. Toxicol. Environ. Health* 1998;44:442–450.
- Saluja G, Brenner RA, Trumble AC, Smith GS, Schroeder T, Cox C. Swimming pool drownings among US residents aged 5-24 years: understanding racial/ethnic disparities. *Am J Public Health*. 2006 Apr;96(4):728-33.
- 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.
- Schets FM, Engels GB, Evers EG. *Cryptosporidium* and *Giardia* in swimming pools in the Netherlands. *J Water Health*. 2004 Sep;2(3):191-200.
- Schmalz C, Frimmel F, Zwiener C. Trichloramine in swimming pools – Formation and mass transfer. *Water Res*. 2011; 45(8): 2681-2690.
- Schoefer Y, Zutavern A, Brockow I, Schäfer T, Krämer U, Schaaf B, Herbarth O, von Berg A, Wichmann HE, Heinrich J, LISA study group. Health risks of early swimming pool attendance. *Int J Hyg Environ Health*. 2008;211(3-4):367-73.
- Seux R. The development of pollution caused by swimmers in swimming pool water in relation to the effect of free chlorine. Translation from *Journal Francais d'Hydrologie* (1988);19(2):151-168.
- Seys SF, Feyen L, Keirsbilck S, Adams E, Dupont LJ, Nemery B. An outbreak of swimming-pool related respiratory symptoms: An elusive source of trichloramine in a municipal indoor swimming pool. *Int J Hyg Environ Health*. 2015 Jun;218(4):386-91.
- Shaw JW. A retrospective comparison of the effectiveness of bromination and chlorination in controlling *Pseudomonas aeruginosa* in spas (whirlpools) in Alberta. *Can J Public Health*. 1984 Jan-Feb;75(1):61-8.
- Shields JM, Arrowood MJ, Hill VR, Beach MJ. The effect of cyanuric acid on the disinfection rate of *Cryptosporidium parvum* in 20-ppm free chlorine. *J Water Health*. 2009 Mar;7(1):109-14.
- Shields JM, Gleim ER, Beach MJ. Prevalence of *Cryptosporidium* spp. and *Giardia* intestinalis in Atlanta metropolitan area swimming pools. *Emerg Inf Dis* 2008;14:948-950.
- Shields JM, Hill VR, Arrowood MJ, Beach MJ. Inactivation of *Cryptosporidium parvum* under chlorinated recreational water conditions. *J Water Health* 2008;6:513-520.
- Shin GA and Sobsey MD. Inactivation of norovirus by chlorine disinfection of water. *Water Res*. 2008 Nov;42(17):4562-8.
- Shultz JJ, Mianulli MJ, Gisch TM, Coffeen PR, Haidet GC, Lurie KG. Comparison of exertion required to perform standard and active compression-decompression cardiopulmonary resuscitation. *Resuscitation*. 1995 Feb;29(1):23-31.
- 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.
- Smith H. Diagnostics. In: Fayer R, Xiao L, eds. *Cryptosporidium* and cryptosporidiosis. 2nd ed. Boca Raton, Florida: CRC Press, 2008:173–207.
- Solomon SL. Host factors in whirlpool-associated *Pseudomonas aeruginosa* skin disease. *Infect Control*. 1985 Oct;6(10):402-6.
- Sommerfeld MR, Adamson RP. Influence of stabilizer concentration on effectiveness of chlorine as an algicide. *Appl Environ Microbiol*. 1982 Feb;43(2):497-9.
- 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.
- Sound system equipment. Part 16: Objective rating of speech intelligibility by speech transmission index. BS EN 6026815:2011, British Standards Institution; 2012. 78 p. Found at <http://resource.isvr.soton.ac.uk/staff/pubs/PubPDFs/BS%20EN%2060268-16.pdf>. Accessed April 21, 2018.
- Spack L, Gedeit R, Splaingard M, Havens PL. Failure of aggressive therapy to alter outcomes in pediatric near-drowning. *Pediatric Emergency Care* 1997;13(2):98-102.
- Stepkin R, Mosely R, eds. Noise control: A guide for workers and employers. American Society of Safety Engineers; 1984. 133p.
- Strayer DL, Drews FA. Profiles in driver distraction: Effects of cell phone conversations on younger and older drivers. *Hum Factors*. 2004 Winter;46(4):640-9.

- Tadros A, Sharon M, Hoffman SM, Davis SM. Emergency department visits coded for swimming pool diving injuries. *Int J Inj Contr Saf Promot.* 2018;5:1-5.
- Taylor HR. Ultraviolet radiation and the eye: an epidemiologic study. *Trans Am Ophthalmol Soc.* 1989;87:802-53.
- Teo TL, Coleman HM, Khan SJ. Chemical contaminants in swimming pools: Occurrence, implications and control. *Environ Int.* 2015 Mar;76:16-31.
- 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.
- Thompson DC, Rivara FP. Pool fencing for preventing drowning in children. *Cochrane Database Syst Rev.* 2000;(2):CD001047.
- 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.
- Trottier A, Brown J. *Police health: A physician's guide for the assessment of police officers: 1994.* Ottawa, Canada: Canadian Communication Group, 1993.
- US Census Bureau. Statistical abstract of the United States: 2012. Arts, Recreation, and Travel: Participation in Selected Sports Activities 2009. Available at <http://www.census.gov/compendia/statab/2012/tables/12s1249.pdf>. Accessed on April 15, 2016.
- US Environmental Protection Agency. Drinking water contaminants. Available at: <http://water.epa.gov/drink/contaminants/index.cfm>. Accessed on: 05/01/2013.
- US Environmental Protection Agency. National primary drinking water regulations: Long term 2 enhanced surface water treatment rule (Proposed Rule). 40 CFR Parts 141 and 142. *Federal Register.* 2003;68(154).
- US Lifeguard Standards Coalition. United States lifeguard standards: An evidence-based review and report. *Int J Aquatic Res Edu.* 2011;5(1):61-129. A pdf copy of the final report can be found at http://www.lifeguardstandards.org/pdf/USLSC_FINAL_APPROVAL_1-31-11.pdf.
- 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.
- Villanueva CM, Cordier S, Font-Ribera L, Salas LA, Levallois P. Overview of disinfection by-products and associated health effects. *Curr Environ Health Rep.* 2015 Mar;2(1):107-15.
- Villanueva CM, Font-Ribera L. Health impact of disinfection by-products in swimming pools. *Ann Ist Super Sanita.* 2012;48(4):387-96.
- Warren IC, Ridgway J. Swimming pool disinfection. Investigations on behalf of the Department of the Environment into the practice of disinfection of swimming pools during 1972 to 1975. Water Research Centre, Henly-on-Thames, England, 35 pp., Oct 1978.
- Weaver WA, Li J, Wen Y, Johnston J, Blatchley MR, & Blatchley ER. (2009) Volatile disinfection by-product analysis from chlorinated indoor swimming pools. *Water Research,* 43(13):3308-3318.
- Webb JD, Bines RD. *Noise Control in Industry.* Holbrook: Sound Research Labs Limited; 1976. 421 p.
- Weisel CP, Richardson S D, Nemery B, Aggazzotti G, Baraldi E, Blatchley E R, Blount BC, Carlsen K, 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. *Environmental Health Perspectives* (2009); 117: 500-507.
- Weng S, Blatchley E. DBP dynamics in a chlorinated, indoor swimming pool under conditions of heavy use: National swimming competition. *Water Res.* 2011;45(16):5241-5248.
- Weng AS, Li J, Blatchley III E. Effects of UV254 irradiation on residual chlorine and DBPs in chlorination of model organic-N precursors in swimming pools. *Water Res.* 2012;46:2674-2682.
- Wiant C. A snapshot of swimmer hygiene behavior. *Int J Aquat Res Ed.* 2011;5(3):244-245.
- Wilken JA, DiMaggio M, Kaufmann M, O'Connor K, Smorodinsky S, Armatas C, Barreau T, Kreutzer R, Ancheta L. Inhalational chlorine injuries at public aquatic venues - California, 2008-2015. *MMWR Morb Mortal Wkly Rep.* 2017;66:498-501.

- Williams A, Schweltnus MP, Noakes T. Increased concentration of chlorine in swimming pool water causes exercise-induced bronchoconstriction (EIB). *Medicine and Science in Sports and Exercise* (2004); 36(5) Supplement abstract 2046.
- Wheeler C, Vugia DJ, Thomas G, Beach MJ, Carnes S, Maier T, Gorman J, Xiao L, Arrowood MJ, Gilliss D, Werner SB. Outbreak of cryptosporidiosis at a California waterpark: employee and patron roles and the long road towards prevention. *Epidemiol Infect.* 2007 Feb;135(2):302-10.
- White GC. Handbook of chlorination and alternative disinfectants, 4th edition. John Wiley and Sons, Inc. Hoboken New Jersey 1999.
- White JC, Cornett AC, Wright BV, Willmott AP, Stager JM. Competitive swimmers modify racing start depth upon request. *Int J Aquatic Res Educ.* 2011;5:187-198.
- Wickramanayake GB, Rubin AJ, Sproul OJ. Inactivation of *Giardia lamblia* cysts with ozone. *Appl Environ Microbiol.* 1984 Sep;48(3):671-2.
- Wong G, Suedfeld P. Ultraviolet light as a sterilization method in flotation tanks. *J Clin Eng.* 1986;11(1):69- 72.
- Woolf A, Shannon M. Reactive airways dysfunction and systemic complaints after mass exposure to bromine. *Environ Health Perspect.* 1999 Jun;107(6):507-9.
- World Health Organization. Chlorine in drinking water background document for development of WHO guidelines for drinking-water quality. WHO/SDE/WSH/03.04/45. 2003. Accessed at http://www.who.int/water_sanitation_health/dwq/chlorine.pdf.
- World Health Organization (2000). Environmental health criteria 216. Accessed: 5/20/13. Available at: http://whqlibdoc.who.int/ehc/WHO_EHC_216.pdf.
- World Health Organization. (1999). Guidelines for community noise. Accessed April 21, 2018 at <http://www.bvsde.paho.org/bvsci/i/fulltext/noise/noise.pdf>.
- World Health Organization. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/. Accessed on April 17, 2018.
- Wyss O, Stockton JR. The germicidal action of bromine. *Arch Biochem.* 1947 Feb;12(2):267-71.
- Xu J. Unintentional drowning deaths in the United States, 1999–2010. *NCHS Data Brief* 2014;149:1–8.
- Yahya MT, Landeen LK, Messina MC, Kutz SM, Schulze R, Gerba CP. Disinfection of bacteria in water systems by using electrolytically generated copper: Silver and reduced levels of free chlorine. *Can J Microbiol.* 1990 Feb;36(2):109-16.
- Yamashita T, Sakae K, Ishihara Y, Inoue H, Isomura S. Influence of cyanuric acid on virucidal effect of chlorine and the comparative study in actual swimming pool waters. *Kansenshogaku Zasshi.* 1988 Mar;62(3):200-5.
- Yamashita T, Sakae K, Ishihara Y, Isomura S, Inoue H. Virucidal effect of chlorinated water containing cyanuric acid. *Epidemiol Infect.* 1988 Dec;101(3):631-9.
- Yamashita T, Sakae K, Ishihara Y, Isomura S, Takeuchi K. Microbiological and chemical analyses of indoor swimming pools and virucidal effect of chlorine in these waters. *Nihon Kosshu Eisei Zasshi.* 1990 Dec;37(12):962-6.
- Yang T. Pool or spa submersion: Estimated nonfatal drowning injuries and reported drownings, 2017 Report. U.S. Consumer Product Safety Commission, May 2017. Available online at https://www.poolsafely.gov/wp-content/uploads/2017/05/Pool_Spa_Submersion_Estimated_nonfatal_drowning_injuries_and_reported_drowning_s_2017_report_2017H004.pdf. Accessed on April 16, 2018.
- YMCA. Aquatics safety & risk reduction document, Topic: Aquatic Safety Technology. 2009.
- Young JG, Woolley C, Armstrong TJ, Ashton-Miller JA. Hand-handhold coupling: Effect of handle shape, orientation, and friction on breakaway strength. *Hum Factors.* 2009;51(5):705-17.
- Young JG, Woolley CB, Ashton-Miller JA, Armstrong TJ. The effect of handhold orientation, size, and wearing gloves on hand-handhold breakaway strength. *Hum Factors.* 2012;54(3):316-33.
- Zalosh R. Dust explosion fundamentals, NFPA.
- Zhang Q. 2012–2016 Reported circulation/suction entrapment incidents associated with pools, spas, and whirlpool bathtubs, 2017 Report. U.S. Consumer Product Safety Commission, April 2017. Available online at

- https://www.cpsc.gov/s3fs-public/2012-2016_%20Circulation_Suction_%20Entrapment_Incidents_Associated_with_pools_spas_whirlpool_bathtubs_2017%20Report.pdf?RiESYQQ8J9qiLOWWFIZe2Pcjt2hW3oh1. Accessed on April 16, 2018.
- Zhao T, Doyle MP, Zhao P, Blake P, Wu FM. Chlorine inactivation of *Escherichia coli* O157:H7 in water. *J Food Prot.* 2001 Oct;64(10):1607-9.
- Zuma FN, Lin J, Jonnalagadda SB. Kinetics of inactivation of *Pseudomonas aeruginosa* in aqueous solutions by ozone aeration. *J Environ Sci Health A Tox Hazard Subst Environ Eng.* 2009 Aug;44(10):929-935.
- Zwiener C, Richardson SD, De Marini DM, Grummt T, Glauner T, and Frimmel FH. Drowning in disinfection byproducts? Assessing swimming pool water. *Environ. Sci. Technol.* 2007 Jan 15;41(2):363-72.

References by Endnote/Citation Number

NOTE: These references are organized by order they appear in the MAHC Annex. An alphabetic list of all references can be found above this listing.

- 1 US Census Bureau. Statistical Abstract of the United States: 2012. Arts, recreation, and travel: Participation in selected sports activities 2009. Available at <http://www.census.gov/compendia/statab/2012/tables/12s1249.pdf>. Accessed on April 15, 2016.
- 2 Hlavsa MC, et al. Outbreaks associated with treated recreational water — United States, 2000–2014. *MMWR Morb Mortal Wkly Rep.* 2018;67(19):547-551.
- 3 Gilchrist J, et al. Racial/ethnic disparities in fatal unintentional drowning among persons aged ≤29 Years — United States, 1999–2010. *J Safety Res.* 2014 Sep;50:139-42.
- 4 CDC. Drowning – United States, 2005–2009. *MMWR Morb Mortal Wkly Rep.* 2012;61(19):344-347.
- 5 Xu J. Unintentional drowning deaths in the United States, 1999–2010. *NCHS Data Brief* 2014;149:1–8.
- 6 CDC. Ten leading causes of injury deaths by age group highlighting unintentional injury deaths, United States – 2016. Available online at https://www.cdc.gov/injury/images/lc-charts/leading_causes_of_death_highlighting_unintentional_2016_1040w800h.gif. Accessed on April 16, 2018.
- 7 Yang T. Pool or spa submersion: Estimated nonfatal drowning injuries and reported drownings, 2017 Report. U.S. Consumer Product Safety Commission, May 2017. Available online at https://www.poolsafely.gov/wp-content/uploads/2017/05/Pool_Spa_Submersion_Estimated_nonfatal_drowning_injuries_and_reported_drowning_s_2017_report_2017H004.pdf. Accessed on April 16, 2018.
- 8 Zhang Q. 2012–2016 Reported circulation/suction entrapment incidents associated with pools, spas, and whirlpool bathtubs, 2017 Report. U.S. Consumer Product Safety Commission, April 2017. Available online at https://www.cpsc.gov/s3fs-public/2012-2016_%20Circulation_Suction_%20Entrapment_Incidents_Associated_with_pools_spas_whirlpool_bathtubs_2017%20Report.pdf?RiESYQQ8J9qiLOWWFIZe2Pcjt2hW3oh1. Accessed on April 16, 2018.
- 9 CDC. Pool chemical–associated health events in public and residential settings — United States, 1983–2007. *MMWR Morb Mortal Wkly Rep.* 2009;58(18):489-93.
- 10 CDC. Acute illness and injury from swimming pool disinfectants and other chemicals — United States, 2002–2008. *MMWR Morb Mortal Wkly Rep.* 2011;60(39):1343-1347.
- 11 Hlavsa MC, et al. Pool chemical–associated health events in public and residential settings — United States, 2003–2012, and Minnesota, 2013. *MMWR Morb Mortal Wkly Rep.* 2014;63(19):427-30.
- 12 Anderson AR, et al. The distribution and public health consequences of releases of chemicals intended for pool use in 17 states, 2001–2009. *J Environ Hlth* 2014;76(9):10-5.
- 13 Hlavsa MC, et al. Outbreaks associated with treated recreational water — United States, 2000–2014. *MMWR Morb Mortal Wkly Rep.* 2018;67(19):547-551.
- 14 Hlavsa MC, et al. Outbreaks associated with treated recreational water — United States, 2000–2014. *MMWR Morb Mortal Wkly Rep.* 2018;67(19):547-551.
- 15 CDC. Prevalence of parasites in fecal material from chlorinated swimming pools — United States, 1999. *MMWR* 2001;50(20):410–2.
- 16 Painter JE, et al. Evolving epidemiology of reported cryptosporidiosis cases in the United States, 1995–2012. *Epidemiol Infect.* 2016;144:1792-802.
- 17 Korich DG, et al. Effects of ozone, chlorine dioxide, chlorine, and monochloramine on *Cryptosporidium parvum* oocyst viability. *Appl Environ Microbiol* 1990;56:1423-1428.

- 18 Shields JM, et al. Inactivation of *Cryptosporidium parvum* under chlorinated recreational water conditions. J Water Health 2008;6:513-520.
- 19 Shields JM, et al. The effect of cyanuric acid on the disinfection rate of *Cryptosporidium parvum* in 20-ppm free chlorine. J Water Health. 2009 Mar;7(1):109-14. doi: 10.2166/wh.2009.008.
- 20 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. Environ Sci Technol. 2015;49:7348-55.
- 21 DuPont HL, et al. The infectivity of *Cryptosporidium parvum* in healthy volunteers. N Engl J Med. 1995 Mar 30;332(13):855-9.
- 22 Goodgame RW, et al. Intensity of infection in AIDS-associated cryptosporidiosis. J Infect Dis. 1993 Mar;167(3):704-9.
- 23 Chappell CL, et al. *Cryptosporidium parvum*: intensity of infection and oocyst excretion patterns in healthy volunteers. J Infect Dis. 1996 Jan;173(1):232-6.
- 24 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64(24):668-72.
- 25 Lee SH, et al. Surveillance for waterborne-disease outbreaks--United States, 1999-2000. MMWR Surveill Summ. 2002 Nov 22;51(8):1-47.
- 26 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2016;64(24):668-72.
- 27 CDC. Drowning – United States, 2005-2009. MMWR Morb Mortal Wkly Rep. 2012;61(19):344-347.
- 28 Gilchrist J, et al. Racial/ethnic disparities in fatal unintentional drowning among persons aged ≤ 29 Years — United States, 1999 – 2010. J Safety Res. 2014 Sep;50:139-42.
- 29 Yang T. Pool or spa submersion: Estimated nonfatal drowning injuries and reported drownings, 2017 Report. U.S. Consumer Product Safety Commission, May 2017. Available online at https://www.poolsafely.gov/wp-content/uploads/2017/05/Pool_Spa_Submersion_Estimated_nonfatal_drowning_injuries_and_reported_drowning_s_2017_report_2017H004.pdf. Accessed on April 16, 2018.
- 30 Anderson AR, et al. The distribution and public health consequences of releases of chemicals intended for pool use in 17 states, 2001-2009. J Environ Hlth 2014;76(9):10-5.
- 31 Hlavsa MC, et al. Pool chemical-associated health events in public and residential settings — United States, 2003–2012, and Minnesota, 2013. MMWR Morb Mortal Wkly Rep. 2014;63(19):427-30.
- 32 Judd SJ, et al. Disinfection by-product formation in swimming pool waters: a simple mass balance. Water Research (2000); 34(5):1611-1619.
- 33 Judd SJ, et al. The fate of chlorine and organic materials in swimming pools, Chemosphere (2003); 51:869-879.
- 34 Keuten MG, et al. Definition and quantification of initial anthropogenic pollutant release in swimming pools. Water Res. 2012 Jul;46(11):3682-92.
- 35 Seux R. The development of pollution caused by swimmers in swimming pool water in relation to the effect of free chlorine. Translation from J Francais d'Hydrologie (1988);19(2):151-168.
- 36 Seux R. The development of pollution caused by swimmers in swimming pool water in relation to the effect of free chlorine. Translation from J Francais d'Hydrologie (1988);19(2):151-168.
- 37 March JG, et al. A kinetic model for chlorine consumption in grey water. Desalination (2005); 181:267-273.
- 38 Haas CN, et al. Kinetics of wastewater chlorine demand exertion. J Water Pollution Control Federation. 1984;56:170-3.
- 39 Teo TL, et al. Chemical contaminants in swimming pools: Occurrence, implications and control. Environ Int. 2015 Mar;76:16-31.
- 40 Chowdhury S, et al. Disinfection byproducts in swimming pool: occurrences, implications and future needs. Water Res. 2014 Apr 15;53:68-109.
- 41 Richardson SD, et al. What's in the pool? A comprehensive identification of disinfection by-products and assessment of mutagenicity of chlorinated and brominated swimming pool water. Environmental Health Perspectives. 2010 Nov;118(11):1523-30.
- 42 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.
- 43 Zwiener C, et al. Drowning in disinfection byproducts? Assessing swimming pool water. Environ. Sci. Technol. 2007 Jan 15;41(2):363-72.
- 44 EPA. Drinking water contaminants. Available at: <http://water.epa.gov/drink/contaminants/index.cfm>. Accessed on April 17, 2018.

- 45 ATSDR. Toxicological profile for chlorine. Available at: <https://www.atsdr.cdc.gov/toxguides/toxguide-172.pdf>. Accessed on April 17, 2018.
- 46 Decker WJ, et al. Chlorine poisoning at the swimming pool: an overlooked hazard. *Clinical Toxicology* (1978); 13(3): 377-381.
- 47 Drobic F, et al. Assessment of chlorine exposure in swimmers during training. *Medicine and Science in Sports and Exercise* (1996); 28(2): 271-274.
- 48 Richardson SD, et al. What's in the pool? A comprehensive identification of disinfection by-products and assessment of mutagenicity of chlorinated and brominated swimming pool water. *Environmental Health Perspectives*. 2010 Nov;118(11):1523-30.
- 49 Weng AS, et al. Effects of UV254 irradiation on residual chlorine and DBPs in chlorination of model organic-N precursors in swimming pools. *Water Res.* 2012;46:2674-268.
- 50 Erdinger L, et al. Chlorate as an inorganic disinfection by-product in swimming pools. *Zentralbl Hyg Umweltmed* (1999); 202: 61-75.
- 51 Beech JA, et al. Nitrates, chlorates and trihalomethanes in swimming pool water. *American Journal of Public Health* (1980); 70(1): 79-82.
- 52 Robson HL. Chloramines and bromamines; *Encyclopedia of Chemical Technology*, Kirk-Othmer, 4d ed, Interscience, New York.
- 53 Aggazzotti G, et al. Blood and breath analyses as biological indicators of exposure to trihalomethanes in indoor swimming pools. *Science of the Total Environment* (1998);217:155-163.
- 54 Erdinger L, et al. Haloforms in spas. *Zentralbl Hyg Umweltmed* (1997);200: 309-317.
- 55 Hanna JG, et al. Determination of chloroform and bromoform. *Anal Chemistry*(1950);22(4):569-570.
- 56 Erdinger L, et al. Haloforms in spas. *Zentralbl Hyg Umweltmed* (1997);200: 309-317.
- 57 Council Directive 98/83/EC on the Quality of Water Intended for Human Consumption, 1998 O.J. L 330/32.
- 58 EPA. Drinking Water Contaminants. Available at: <https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#Byproducts>. Accessed on April 17, 2018.
- 59 German Standard DIN 19643, 2012. Treatment of Water of Swimming-Pools and Baths. Deutsches Institut Fur Normung E.V. (German National Standard).
- 60 Holzwarth G, et al. The fate of chlorine and chloramines in cooling towers. *Water Res.* 1984;18:1421–1427.
- 61 CDC. Ocular and respiratory illness associated with an indoor swimming pool--Nebraska, 2006. *MMWR Morb Mortal Wkly Rep.* 2007 Sep 14;56(36):929-32.
- 62 CDC. Respiratory and ocular symptoms among employees of a hotel indoor waterpark resort—Ohio, 2007. *MMWR Morb Mortal Wkly Rep* 2009;58:81–85.
- 63 Bowen AB, et al. Outbreaks of short-incubation ocular and respiratory illness following exposure to indoor swimming pools. *Environmental Health Perspectives* (2007); 115(2): 267-271.
- 64 Kaydos-Daniels SC, et al. Health effects associated with indoor swimming pools: a suspected toxic chloramine exposure. *Public Health.* 2008 Feb;122(2):195-200.
- 65 Seys SF, et al. An outbreak of swimming-pool related respiratory symptoms: An elusive source of trichloramine in a municipal indoor swimming pool. *Int J Hyg Environ Health.* 2015 Jun;218(4):386-91.
- 66 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.
- 67 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. *MMWR Morb Mortal Wkly Rep.* 2015;64(24):668-672.
- 68 Williams A, et al. Increased concentration of chlorine in swimming pool water causes exercise-induced bronchoconstriction (EIB). *Medicine and Science in Sports and Exercise* (2004); 36(5) Supplement abstract 2046.
- 69 Nemery B, et al. Indoor swimming pools, water chlorination, and respiratory health. *Eur. Respir. J.* (2002); 19: 790-793.
- 70 Nordberg GF, et al. Lung function in volunteers before and after exposure to trichloramine in indoor pool environments and asthma in a cohort of pool workers. *BMJ Open.* 2012 Oct 8;2(5).
- 71 Lagerkvist BJ, et al. Pulmonary epithelial integrity in children: relationship to ambient ozone exposure and swimming pool attendance. *Environ Health Perspect* (2004);112:1768-1771.
- 72 Bernard A, et al. Lung hyperpermeability and asthma prevalence in schoolchildren: unexpected associations with the attendance at indoor chlorinated swimming pools. *Occupational and Environmental Medicine* (2003); 60: 385-394.
- 73 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. *Eur. Respir. J.* (2002)19: 827-832.

- 74 Mustchin CP, et al. Coughing water: bronchial hyper-reactivity induced by swimming in a chlorinated pool. *Thorax* (1979); 34(5): 682-683.
- 75 Rosenman KD, et al. Swimming facilities and work-related asthma. *J Asthma*. 2015 Feb;52(1):52-8.
- 76 Font-Ribera L, et al. Indoor swimming pool attendance and respiratory and dermal health in schoolchildren--HITEA Catalonia. *Respir Med*. 2014 Jul;108(7):1056-9.
- 77 Andersson M, et al. Swimming pool attendance is related to asthma among atopic school children: a population-based study. *Environ Health*. 2015 Apr 15;14:37.
- 78 Font-Ribera L, et al. Swimming pool attendance, asthma, allergies, and lung function in the Avon Longitudinal Study of Parents and Children cohort. *Am J Respir Crit Care Med*. (2011 Mar 1);183(5):582-8.
- 79 Goodman M, et al. Asthma and swimming: A meta-analysis. *J of Asthma* (2008);45(8):639-647.
- 80 Weisel CP, et al. Childhood asthma and environmental exposures at swimming pools: State of the science and research recommendations. *Environ Health Perspect* (2009); 117: 500-507.
- 81 Villanueva CM, et al. Overview of disinfection by-products and associated health effects. *Curr Environ Health Rep*. 2015 Mar;2(1):107-15.
- 82 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.
- 83 Font-Ribera L, et al. Swimming pool attendance, asthma, allergies, and lung function in the Avon Longitudinal Study of Parents and Children cohort. *Am J Respir Crit Care Med*. 2011;183(5):582-8.
- 84 Villanueva CM, et al. Health impact of disinfection by-products in swimming pools. *Ann Ist Super Sanita*. 2012;48(4):387-96.
- 85 Font-Ribera L, Villanueva CM, Gràcia-Lavedan E, Borràs-Santos A, Kogevinas M, Zock JP. Indoor swimming pool attendance and respiratory and dermal health in schoolchildren--HITEA Catalonia. *Respir Med*. 2014 Jul;108(7):1056-9.
- 86 Villanueva CM, Cordier S, Font-Ribera L, Salas LA, Levallois P. Overview of disinfection by-products and associated health effects. *Curr Environ Health Rep*. 2015 Mar;2(1):107-15.
- 87 Font-Ribera L, et al. Swimming pool attendance, asthma, allergies, and lung function in the Avon Longitudinal Study of Parents and Children cohort. *Am J Respir Crit Care Med*. 2011;183(5):582-8.
- 88 Font-Ribera L, Villanueva CM, Gràcia-Lavedan E, Borràs-Santos A, Kogevinas M, Zock JP. Indoor swimming pool attendance and respiratory and dermal health in schoolchildren--HITEA Catalonia. *Respir Med*. 2014 Jul;108(7):1056-9.
- 89 Belgian Superior Health Council. Publication no. 8748: The issue of chlorine in swimming pools: Risk attendant on baby swimming and reflections on the different methods used to disinfect swimming pools.
- 90 Kim H, et al. Formation of disinfection by-products in chlorinated swimming pool water. *Chemosphere* (2002); 46:123-130.
- 91 Bessonneau V, et al. Determinants of chlorination by-products in indoor swimming pools. *Int Hyg Environ Health*. 2011;215:76-85.
- 92 Weng S, et al. DBP dynamics in a chlorinated, indoor swimming pool under conditions of heavy use: National swimming competition. *Water Res*. 2011;45(16):5241-5248.
- 93 Cammann K, et al. Trihalomethane concentrations in swimmers' and bath attendants' blood and urine after swimming or working in indoor swimming pools. *Archives of Environmental Health* (1995); 50(1): 61-65.
- 94 Lindstrom AB, et al. Alveolar breath sampling and analysis to assess trihalomethane exposures during competitive swimming training. *Environmental Health Perspectives* (1997); 105(6):636-642.
- 95 WHO (2000). Environmental health criteria 216 (including corrigenda from 11/30/2004). Available at http://whqlibdoc.who.int/ehc/WHO_EHC_216.pdf. Accessed on April 17, 2018.
- 96 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/. Accessed on April 17, 2018.
- 97 Blatchley E, et al. Reaction mechanism for chlorination of urea. *Environ Sci Technol*. 2010 Nov 15;44(22):8529-34.
- 98 De Laat J, et al. Concentration levels of urea in swimming pool water and reactivity of chlorine with urea. *Water Res*. 2011; 45(3) 1139-46.
- 99 Schmalz C, et al. Trichloramine in swimming pools – Formation and mass transfer. *Water Res*. 2011;45(8):2681-90.

- 100 Fuchs J. Chlorination of pool water: urea degradation rate. *Chemiker Ztg. -Chem. Apparatur* (1962);86(3): 76-82.
- 101 Gunkel K, et al. The urea problem in swimming pools. *Z. gesamte Hyg.* (1988); 34(4):248-50.
- 102 ASHRAE. 2013 ASHRAE Handbook—Fundamentals. Available or can be purchased at <https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ASHRAE-handbook--fundamentals>. Accessed on April 18, 2018.
- 103 Cusimano MD, et al. Spinal cord injuries due to diving: a framework and call for prevention. *J Trauma*. 2008;65(5):1180-5.
- 104 DeVivo MJ. Epidemiology of traumatic spinal cord injury: trends and future implications. *Spinal Cord*. 2012 May;50(5):365-72.
- 105 Blanksby BA, et al. Aetiology and occurrence of diving injuries. A review of diving safety. *Sports Med*. 1997;23(4):228-46.
- 106 Borius PY, et al. Cervical spine injuries resulting from diving accidents in swimming pools: outcome of 34 patients. *Eur Spine J*. 2010 Apr;19(4):552-7.
- 107 Barss P, et al. Risk factors and prevention for spinal cord injury from diving in swimming pools and natural sites in Quebec, Canada: a 44-year study. *Accid Anal Prev*. 2008;40(2):787-97.
- 108 DeVivo MJ, et al. Prevention of spinal cord injuries that occur in swimming pools. *Spinal Cord*. 1997;35(8):509-15.
- 109 Gabrielsen MA, et al. Diving injuries: The etiology of 486 case studies with recommendations for needed action. 1990. Nova University Press, Ft. Lauderdale, FL.
- 110 DeVivo MJ. Epidemiology of traumatic spinal cord injury: trends and future implications. *Spinal Cord*. 2012 May;50(5):365-72.
- 111 Tadros A, et al. Emergency department visits coded for swimming pool diving injuries. *Int J Inj Contr Saf Promot*. 2018;5:1-5.
- 112 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.
- 113 Zwiener C, et al. Drowning in disinfection byproducts? Assessing swimming pool water. *Environ Sci Technol*. 2007;41(2):363-72.
- 114 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.
- 115 Villanueva CM, et al. Overview of disinfection by-products and associated health effects. *Curr Environ Health Rep*. 2015 Mar;2(1):107-15.
- 116 Goodman M, et al. Asthma and swimming: A meta-analysis. *J Asthma* (2008);45(8):639-647.
- 117 Villanueva CM, et al. Disinfection byproducts and bladder cancer: A pooled analysis. *Epidemiology*. 2004;15(3):357-67.
- 118 Cantor KP. Carcinogens in drinking water: the epidemiologic evidence. *Rev Environ Health*. 2010;25(1):9-16.
- 119 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.
- 120 Sanderson W, et al. Case reports: epidemic eye and upper respiratory irritation in poultry processing plants. *Appl Occup Environ Hyg* 1995;10:43-49.
- 121 Hery M, et al. Exposure to chloramines in a green salad processing plant. *Ann Occup Hyg* 1998;42:437-451.
- 122 Seys SF, et al. An outbreak of swimming-pool related respiratory symptoms: An elusive source of trichloramine in a municipal indoor swimming pool. *Int J Hyg Environ Health*. 2015 Jun;218(4):386-91.
- 123 CDC. Ocular and respiratory illness associated with an indoor swimming pool — Nebraska, 2006. *MMWR Morb Mortal Wkly Rep* 2007;56:929-932.
- 124 Kaydos-Daniels SC, et al. Health effects associated with indoor swimming pools: a suspected toxic chloramine exposure. *Public Health* 2008;122:195-200.
- 125 Bowen A, et al. Outbreaks of short-incubation illness following exposure to indoor swimming pools. *Environ Health Perspect* 2007;115:267-271.
- 126 CDC. Respiratory and ocular symptoms among employees of a hotel indoor waterpark resort --- Ohio, 2007. *MMWR Morb Mortal Wkly Rep* 2009;58:81-85
- 127 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.

- 128 Fields BS, et al. *Legionella* and legionnaires' disease: 25 years of investigation. *Clin Microbiol Rev.* 2002;15(3):506-26.
- 129 Falkinham JO 3rd. Mycobacterial aerosols and respiratory disease. *Emerg Infect Dis.* 2003;9(7):763-7.
- 130 Hanak V, et al. Causes and presenting features in 85 consecutive patients with hypersensitivity pneumonitis. *Mayo Clin Proc.* 2007;82(7):812-6.
- 131 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.
- 132 Rose CS, et al. "Lifeguard lung": endemic granulomatous pneumonitis in an indoor swimming pool. *American J Public Health.* 1998;88(12):1795-800.
- 133 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.
- 134 Tossa P, et al. Pontiac fever: an operational definition for epidemiological studies. *BMC Public Health.* 2006;6:112.
- 135 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. *Eur Respir J.* 2002;19(5):827-32.
- 136 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.
- 137 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.
- 138 Hery M, et al. Exposure to chloramines in the atmosphere of indoor swimming pools. *Ann Occup Hyg* 1995;39(4):427-439.
- 139 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.
- 140 Jacobs JH, et al. Exposure to trichloramine and respiratory symptoms in indoor swimming pool workers. *Eur Respir J.* 2007;29(4):690-8.
- 141 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. *Eur Respir J.* 2002;19(5):827-32.
- 142 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.
- 143 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.
- 144 Hery M, et al. Exposure to chloramines in the atmosphere of indoor swimming pools. *Ann Occup Hyg* 1995;39(4):427-439.
- 145 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.
- 146 Jacobs JH, et al. Exposure to trichloramine and respiratory symptoms in indoor swimming pool workers. *Eur Respir J.* 2007;29(4):690-8.
- 147 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. *Eur Respir J.* 2002;19(5):827-32.
- 148 Croft T, et al. *American electricians' handbook*, ed.16 (2013).
- 149 Durston L. (2009) Design, construction, and testing of the commercial air barrier. Accessed on May 2, 2018 at <https://www.irinfo.org/05-01-2009-durston/>.
- 150 Croft T, et al. *American electricians' handbook*, ed. 16, 2013 Sec. 9-340(b).
- 151 Durston L. (2009) Design, construction, and testing of the commercial air barrier. Accessed on May 2, 2018 at <https://www.irinfo.org/05-01-2009-durston/>.
- 152 Croft T, et al. *American electricians' handbook*, ed. 16, 2013 Sec. 9-340(b).
- 153 Croft T, et al. *American electricians' handbook*, ed. 16, 2013 Sec. 9-340(b).
- 154 Zalosh R. *Dust explosion fundamentals*, NFPA.
- 155 ASHRAE. 2013 ASHRAE Handbook—Fundamentals. Available at <https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ashrae-handbook--fundamentals>. Accessed on April 18, 2018.
- 156 ASHRAE. 2013 ASHRAE Handbook—Fundamentals. Available at <https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ashrae-handbook--fundamentals>. Accessed on April 18, 2018.
- 157 ASHRAE. 2013 ASHRAE Handbook—Fundamentals. Available at <https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ashrae-handbook--fundamentals>. Accessed on April 18, 2018.

- 158 Moritz AR, et al. Studies of thermal injury: The relative importance of time and surface temperature in the causation of cutaneous burns. *Am J Pathol.* 1947 Sep;23(5):695-720.
- 159 ASTM International. 2014 annual book of ASTM standards: section four: construction volume 04.06: thermal insulation; building and environmental acoustics. West Conshohocken, PA. ASTM Standard C6342013, Standard Terminology Relating to Building and Environmental Acoustics.
- 160 ASTM International. 2014 annual book of ASTM standards: section four: construction volume 04.06: thermal insulation; building and environmental acoustics. West Conshohocken, PA. ASTM Standard C6342013, Standard Terminology Relating to Building and Environmental Acoustics.
- 161 WHO. (1999). Guidelines for community noise. Accessed April 21, 2018 at <http://www.bvsde.paho.org/bvsci/i/fulltext/noise/noise.pdf>.
- 162 ANSI S12.60:2002. American national standard acoustical performance criteria, design requirements, and guidelines for schools. Acoustical Society of America, Melville, New York 11747.
- 163 Australian NSW EPA. Noise guide for local government. Accessed April 21, 2018 at <http://www.epa.nsw.gov.au/your-environment/noise/regulating-noise/noise-guide-local-government>
- 164 Dalton B, et al. Effects of noise and music on human and task performance: A systematic review. *Occupational Ergonomics* 7(2007): 143152.
- 165 Coblenz A, et al. (2001). Lifeguard vigilance bibliographic study, Executive summary. Paris: Applied Anthropology. Accessed April 21, 2018 at [http://www.sutcliffe.ca/joel/research/vigilanceStudy\(2001\).pdf](http://www.sutcliffe.ca/joel/research/vigilanceStudy(2001).pdf).
- 166 Maffei L, et al. Noise exposure in school gymnasias and swimming pools. *Noise Control Engineering Journal* 57 (6). Institute of Noise Control Engineering. Nov-Dec 2009. 12 p.
- 167 OSHA. 29 CFR Part 1910.95 App G, Monitoring noise levels non-mandatory informational appendix. Accessed April 21, 2018 at: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9742.
- 168 OSHA. 29 CFR Part 1910.95, Occupational noise exposure. Amended December 12, 2008. Accessed April 21, 2018 at: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735.
- 169 Berger EH, et al. *The Noise Manual*. 5th ed. Fairfax: American Industrial Hygiene Association; 2000. 796 p.
- 170 Stepkin R, Mosely R, eds. *Noise control: A guide for workers and employers*. American Society of Safety Engineers; 1984. 133p.
- 171 Webb JD, et al. *Noise Control in Industry*. Holbrook: Sound Research Labs Limited; 1976. 421 p.
- 172 ASTM International. 2014 annual book of ASTM standards: section four: construction volume 04.06: thermal insulation; building and environmental acoustics. West Conshohocken, PA. ASTM Standard C6342013, Standard Terminology Relating to Building and Environmental Acoustics.
- 173 Webb JD, et al. *Noise Control in Industry*. Holbrook: Sound Research Labs Limited; 1976. 421 p.
- 174 Sound system equipment. Part 16: Objective rating of speech intelligibility by speech transmission index. BS EN 6026815:2011, British Standards Institution; 2012. 78 p. Found at <http://resource.isvr.soton.ac.uk/staff/pubs/PubPDFs/BS%20EN%2060268-16.pdf>. Accessed April 21, 2018.
- 175 ANSI S12.602010 American national standard acoustical performance criteria, design requirements, and guidelines for schools: Part 1: Permanent schools, Melville, New York: Acoustical Society of America; 2010.
- 176 ANSI S12.602010 American national standard acoustical performance criteria, design requirements, and guidelines for schools: Part 1: Permanent schools, Melville, New York: Acoustical Society of America; 2010.
- 177 LEED version 4 for building design and construction. Updated April 6, 2018. Washington D.C.: U.S. Green Building Council; 2016. 161 p. Found at https://www.usgbc.org/sites/default/files/LEED%20v4%20BDC_04.6.18_current.pdf. Accessed April 21, 2018.
- 178 Beranek L. *Noise and vibration control*, rev. ed. Washington, DC: The Institute of Noise Control Engineering; 1988. 672 p.
- 179 ASTM International. 2014 annual book of ASTM standards: section four: construction volume 04.06: thermal insulation; building and environmental acoustics. West Conshohocken, PA. ASTM Standard C6342013, Standard Terminology Relating to Building and Environmental Acoustics.
- 180 Crandell CC, et al. *SoundField FM amplification: Theory and practical applications*. San Diego: Singular Publishing Group, Inc; 1995.
- 181 Crandell CC, et al. *SoundField FM amplification: Theory and practical applications*. San Diego: Singular Publishing Group, Inc; 1995.
- 182 Egan MD. *Architectural acoustics*. New York: McGrawHill; 1988.
- 183 ASHRAE. 2015 ASHRAE handbook: Heating, ventilating and air-conditioning applications. Atlanta: 2015. *Noise and Vibration Control*.

- 184 ASHRAE. 2015 ASHRAE handbook: Heating, ventilating and air-conditioning applications. Atlanta: 2015. Noise and Vibration Control..
- 185 Egan MD. Architectural acoustics. New York: McGrawHill; 1988.
- 186 Egan MD. Architectural acoustics. New York: McGrawHill; 1988.
- 187 Chappell CL, et al. *Cryptosporidium parvum*: intensity of infection and oocyst excretion patterns in healthy volunteers. J Infect Dis. 1996 Jan;173(1):232-6.
- 188 Goodgame RW, et al. Intensity of infection in AIDS-associated cryptosporidiosis. J Infect Dis. 1993 Mar;167(3):704-9.
- 189 Niquette P, et al. Impacts of pipe materials on densities of fixed bacterial biomass in a drinking water distribution system. Water Research. 2000;34(6):1952-1956.
- 190 Goeres DM, et al. Evaluation of disinfectant efficacy against biofilm and suspended bacteria in a laboratory swimming pool model. Water Research. 2004;38(13):3103-3109.
- 191 Goeres DM, et al. Evaluation of disinfectant efficacy against biofilm and suspended bacteria in a laboratory swimming pool model. Water Research. 2004;38(13):3103-3109.
- 192 Leoni E, et al. Prevalence of mycobacteria in a swimming pool. Environment. J. Applied Microbiology. 1999;87(5):683-688.
- 193 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas, 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 194 Keuten MG, et al. Definition and quantification of initial anthropogenic pollutant release in swimming pools. Water Res. 2012 Jul;46(11):3682-92.
- 195 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 196 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/. Accessed on April 20, 2018.
- 197 NSW Department of Health. Public Swimming Pool and Spa Pool Code of Practice. 2010. Available at: <http://www.health.nsw.gov.au/environment/publicpools/Pages/default.aspx>. Accessed on April 20, 2018.
- 198 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 199 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 20, 2018.
- 200 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 20, 2018.
- 201 CDC. Cryptosporidiosis surveillance -- United States, 2011-2012. MMWR Suppl. 2015 May 1;64(3):1-14.
- 202 Hlavsa MC, et al. Outbreaks associated with treated recreational water — United States, 2000–2014. MMWR Morb Mortal Wkly Rep. 2018;67(19):547-551.
- 203 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 21, 2018.
- 204 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 205 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 21, 2018.
- 206 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 21, 2018.

- 207 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. *MMWR Morb Mortal Wkly Rep.* 2015;64(24):668-72.
- 208 Painter JE, et al. Evolving epidemiology of reported cryptosporidiosis cases in the United States, 1995–2012. *Epidemiol Infect* 2016;144:1792-802.
- 209 CDC. Cryptosporidiosis surveillance -- United States, 2011-2012. *MMWR Suppl.* 2015 May 1;64(3):1-14.
- 210 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. *MMWR Morb Mortal Wkly Rep.* 2015;64(24):668-72.
- 211 CDC. Cryptosporidiosis surveillance -- United States, 2011-2012. *MMWR Suppl.* 2015 May 1;64(3):1-14.
- 212 Murphy, JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol* 2015;49:7348–55.
- 213 Shields JM, et al. Inactivation of *Cryptosporidium parvum* under chlorinated recreational water conditions. *J Water Health.* 2008;6(4):513-520.
- 214 Amburgey JE, et al. Removal of *Cryptosporidium* and polystyrene microspheres from swimming pool water with sand, cartridge, and precoat filters. *J Water Health.* 2012;10(1):31-42.
- 215 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. *MMWR Morb Mortal Wkly Rep.* 2015;64:668-72.
- 216 Shields JM, et al. Prevalence of *Cryptosporidium* spp. and *Giardia intestinalis* in swimming pools, Atlanta, Georgia. *Emerging Infectious Diseases.* 2008;14(6):948-950.
- 217 CDC. Microbes in pool filter backwash as evidence of the need for improved swimmer hygiene - metro-Atlanta, Georgia, 2012. *MMWR Morb Mortal Wkly Rep.* 2013 May 17;62(19):385-8.
- 218 Murphy JL, et al. Pool water quality and prevalence of microbes in filter backwash from metro-Atlanta swimming pools. *J Water Health.* 2018 Feb;16(1):87-92.
- 219 CDC. Cryptosporidiosis surveillance -- United States, 2011-2012. *MMWR Suppl.* 2015 May 1;64(3):1-14.
- 220 Amburgey JE, et al. Removal of *Cryptosporidium* and polystyrene microspheres from swimming pool water with sand, cartridge, and precoat filters. *J Water Health.* 2012;10(1):31-42.
- 221 Pintar KD, et al. A risk assessment model to evaluate the role of fecal contamination in recreational water on the incidence of cryptosporidiosis at the community level in Ontario. *Risk Analysis.* 2010;30:1:49-64.
- 222 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 223 Croll BT, et al. Simulated *Cryptosporidium* removal under swimming pool filtration conditions. *Water Environment Journal.* 2007;21:149-156.
- 224 Letterman RD. *Water Quality and Treatment.* 1999. 5th Ed. McGraw-Hill, NY.
- 225 AWWA. Operational control of coagulation and filtration processes: AWWA Manual. 2010;M37, 3rd ed. American Water Works Association, Denver, CO. ISBN: 978-1-58321-801-3.
- 226 Logsdon GS, et al. Alternative filtration methods for removal of *Giardia* cysts and cyst models. *Journal AWWA.* 1981;73(2):111-118.
- 227 Logsdon GS, et al. Getting your money's worth from filtration. *Journal AWWA.* 1982;74(5):249-256.
- 228 EPA. National primary drinking water regulations: Long term 2 enhanced surface water treatment rule (Proposed Rule). 40 CFR Parts 141 and 142. *Federal Register.* 2003;68(154).
- 229 AWWA. Operational control of coagulation and filtration processes: AWWA Manual. 2010;M37, 3rd ed. American Water Works Association, Denver, CO. ISBN: 978-1-58321-801-3
- 230 Croll BT, et al. Simulated *Cryptosporidium* removal under swimming pool filtration conditions. *Water and Environment Journal.* 2007;21:149-156.
- 231 Cary WH. Administration of swimming pool standards in Detroit. *Am. J. Public Health* 1929;20(7):727-733.
- 232 Gage SD, et al. Swimming pools and other public bathing places. *Am J Public Health (N Y).* 1926 Dec;16(12):1186-201.
- 233 Amburgey JE, et al. Removal of *Cryptosporidium* and polystyrene microspheres from swimming pool water with sand, cartridge, and precoat filters. *J Water Health.* 2012;10(1):31-42.
- 234 Croll BT, et al. Simulated *Cryptosporidium* removal under swimming pool filtration conditions. *Water Environ J.* 2007;21:149-156.
- 235 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland.
Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 21, 2018.

- 236 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 237 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 21, 2018.
- 238 Neveu A, et al. Evaluation of Operation and performance of Swimming Pool filtration Plants. *Francaisd'Hydrologie*. 1988;19:2:203-213.
- 239 Hendricks D. Water treatment unit processes, physical and chemical. 2006. CRC Press (Taylor & Francis Group), Boca Raton, FL. ISBN: 0824706951.
- 240 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 241 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 242 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 243 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 21, 2018.
- 244 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 245 Gregory R. Bench-marking pool water treatment for coping with *Cryptosporidium*. *J Environ Hlth Res*. 2002;1(1):11-18.
- 246 Logsdon GS, et al. Alternative filtration methods for removal of Giardia cysts and cyst models. *Journal AWWA*. 1981;73(2):111-118.
- 247 Logsdon GS, et al. Getting your money's worth from filtration. *Journal AWWA*. 1982;74(5):249-256.
- 248 Logsdon GS, et al. Getting your money's worth from filtration. *Journal AWWA*. 1982;74(5):249-256.
- 249 Cleasby JL, et al. Chapter 8: Granular bed and precoat filtration. In *Water Quality and Treatment, 5th Ed*. McGraw Hill, Inc. ISBN: 0070016593.
- 250 Lyons TB, et al. Limax amoebae in public swimming pools of Albany, Schenectady, and Rensselaer counties, New York: their concentration, correlations, and significance. *Applied and Environmental Microbiology*. 1977;33(3):551-555.
- 251 Shields JM, et al. Prevalence of *Cryptosporidium* spp. and *Giardia* intestinalis in Atlanta metropolitan area swimming pools. *Emerg Inf Dis* 2008;14:948-950.
- 252 Murphy JL, et al. Pool water quality and prevalence of microbes in filter backwash from metro-Atlanta swimming pools. *J Water Health*. 2018 Feb;16(1):87-92.
- 253 Cleasby JL, et al. Chapter 8: Granular bed and precoat filtration. In *Water Quality and Treatment, 5th Ed*. McGraw Hill, Inc. NY:1999. ISBN: 0070016593.
- 254 Kawamura, S. Integrated design and operation of water treatment facilities. 2000. John Wiley and Sons, Inc., NY.
- 255 Cleasby JL, et al. Chapter 8: Granular bed and precoat filtration. In *Water Quality and Treatment, 5th Ed*. McGraw Hill, Inc. NY:1999. ISBN: 0070016593.
- 256 Dharmarajah AH, et al. Predicting the expansion behavior of filter media. *Journ. AWWA*. 1986;78(12):66-76.
- 257 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 258 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 259 Letterman RD. *Water Quality and Treatment*. 1999. 5th Ed. McGraw-Hill, NY.
- 260 AWWA. Operational control of coagulation and filtration processes: *AWWA Manual*. 2010;M37, 3rd ed. American Water Works Association, Denver, CO. ISBN: 978-1-58321-801-3.
- 261 Logsdon GS, et al. Getting your money's worth from filtration. *Journal AWWA*. 1982;74(5):249-256.
- 262 EPA. National primary drinking water regulations: Long term 2 enhanced surface water treatment rule (Proposed Rule). 40 CFR Parts 141 and 142. *Federal Register*. 2003;68(154).

- 263 Logsdon GS. Water filtration practices: including slow sand filters and precoat filtration. 2008. American Water Works Association, Denver, CO. ISBN: 9781583215951.
- 264 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 265 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland.
Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en . Accessed on April 21, 2018.
- 266 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 267 Hendricks D. Water treatment unit processes, physical and chemical. 2006. CRC Press (Taylor & Francis Group), Boca Raton, FL. ISBN: 0824706951.
- 268 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 269 Logsdon GS, et al. Alternative filtration methods for removal of *Giardia* cysts and cyst models. Journal AWWA. 1981;73(2):111-118.
- 270 Logsdon GS, et al. Getting your money's worth from filtration. Journal AWWA. 1982;74(5):249-256.
- 271 DIN. Treatment and disinfection of water used in bathing facilities, part 1: general requirements. 1997. Ref. No. 19643-1.
- 272 Logsdon GS. Water filtration practices: including slow sand filters and precoat filtration. 2008. American Water Works Association, Denver, CO. ISBN: 9781583215951.
- 273 Lange KP, et al. Diatomaceous earth filtration of *Giardia* cysts and other substances. Journal AWWA. 1986;78(1):76-84.
- 274 Ongerth JE, et al. Testing of diatomaceous earth filtration for removal of *Cryptosporidium* oocysts. Journal AWWA. 2001;93(12):54-63.
- 275 Cleasby JL et al. Chapter 8: Granular bed and precoat filtration. In Water Quality and Treatment, 5th Ed. McGraw Hill, Inc. NY:1999. ISBN: 0070016593.
- 276 Moraga-McHaley SA, et al. Hypersensitivity pneumonitis with *Mycobacterium avium* complex among spa workers. J Occup Environ Health. 2013;19(1):55-61.
- 277 Chen L, et al. Health hazard evaluation report: investigation of employee symptoms at an indoor waterpark. Cincinnati, OH: US Department of Health and Human Services, CDC, National Institute for Occupational Safety and Health: 2008. Report no. HETA2007-0163-3062. Available at <http://www.cdc.gov/niosh/hhe/reports/pdfs/2007-0163-3062.pdf>. Accessed on April 21, 2018.
- 278 Bowen AB, et al. Outbreaks of short-incubation ocular and respiratory illness following exposure to indoor swimming pools. Environ Health Perspect. 2007 Feb;115(2):267-71.
- 279 Kaydos-Daniels SC, et al. Health effects associated with indoor swimming pools: a suspected toxic chloramine exposure. Public Health. 2008 Feb;122(2):195-200.
- 280 CDC. Ocular and respiratory illness associated with an indoor swimming pool--Nebraska, 2006. MMWR Morb Mortal Wkly Rep. 2007 Sep 14;56(36):929-32.
- 281 Hery M, et al. Exposure to metallic catalyst dust: manufacturing and handling of catalysts in the chemical industry. Ann Occup Hyg. 1994 Apr;38(2):119-35.
- 282 Massin N, et al. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. Occup Environ Med. 1998 Apr;55(4):258-63.
- 283 Anipsitakis GP, et al. Chemical and microbial decontamination of pool water using activated potassium peroxydisulfate. Water Res. 2008 Jun;42(12):2899-2910.
- 284 Chen L, et al. Health hazard evaluation report: investigation of employee symptoms at an indoor waterpark. Cincinnati, OH: US Department of Health and Human Services, CDC, National Institute for Occupational Safety and Health: 2008. Report no. HETA2007-0163-3062. Available at <http://www.cdc.gov/niosh/hhe/reports/pdfs/2007-0163-3062.pdf>. Accessed on April 21, 2018.
- 285 Hlavsa MC, et al. Surveillance for waterborne disease outbreaks and other health events associated with recreational water use — United States, 2007–2008. MMWR Surveill Summ. 2011;60:1-37.
- 286 Wilken JA, et al. Inhalational chlorine injuries at public aquatic venues - California, 2008–2015. MMWR Morb Mortal Wkly Rep. 2017 May 19;66(19):498-501.
- 287 CDC. Cryptosporidiosis surveillance -- United States, 2011–2012. MMWR Suppl. 2015 May 1;64(3):1-14.

- 288 Causer L, et al. An outbreak of *Cryptosporidium hominis* infection at an Illinois recreational waterpark. *Epidemiol Infect.* 2006 February; 134(1): 147–156.
- 289 Wheeler C, et al. Outbreak of cryptosporidiosis at a California waterpark: employee and patron roles and the long road towards prevention. *Epidemiol Infect.* 2007 Feb;135(2):302-10.
- 290 CDC. Communitywide cryptosporidiosis outbreak--Utah, 2007. *MMWR Morb Mortal Wkly Rep.* 2008 Sep 12;57(36):989-93.
- 291 Chappell CL, et al. *Cryptosporidium parvum*: intensity of infection and oocyst excretion patterns in healthy volunteers. *J Infect Dis.* 1996 Jan;173(1):232-6.
- 292 Goodgame RW, et al. Intensity of infection in AIDS-associated cryptosporidiosis. *J Infect Dis.* 1993 Mar;167(3):704-9.
- 293 Dufour AP, et al. Water ingestion during swimming activities in a pool: a pilot study. *J Water Health.* 2006 Dec;4(4):425-30.
- 294 Allen LM, et al. Absorption and excretion of cyanuric acid in long-distance swimmers. *Drug Metab Rev.* 1982;13(3):499-516.
- 295 Dufour AP, et al. Ingestion of swimming pool water by recreational swimmers. *J Water Health.* 2017 Jun;15(3):429-437.
- 296 Korich DG, et al. Effects of ozone, chlorine dioxide, chlorine, and monochloramine on *Cryptosporidium parvum* oocyst viability. *Appl Environ Microbiol.* 1990 May;56(5):1423-8.
- 297 Wickramanayake GB, et al. Inactivation of *Giardia lamblia* cysts with ozone. *Appl Environ Microbiol.* 1984 Sep;48(3):671-2.
- 298 Cho M, et al. Mechanisms of *Escherichia coli* inactivation by several disinfectants. *Water Res.* 2010 Jun;44(11):3410-8.
- 299 Zuma FN, et al. Kinetics of inactivation of *Pseudomonas aeruginosa* in aqueous solutions by ozone aeration. *J Environ Sci Health A Tox Hazard Subst Environ Eng.* 2009 Aug;44(10):929-935.
- 300 Yahya MT, et al. Disinfection of bacteria in water systems by using electrolytically generated copper: Silver and reduced levels of free chlorine. *Can J Microbiol.* 1990 Feb;36(2):109-16.
- 301 Beer CW, et al. Swimming pool disinfection: efficacy of copper/silver ions with reduced chlorine levels. *J Environmental Health,* 61(9): 9-12.
- 302 APHA, et al. (2017) (2017) Standard methods for the examination of water and wastewater, 22nd ed. E.W. Rice, R.B. Baird, A.D. Eaton, and L.S. Clesceri (eds). New York: American Public Health Association.
- 303 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 21, 2018.
- 304 Broadbent C. (1996) Guidance on water quality for heated spas. Rundle Mall, South Australia: Public and Environmental Health Service.
- 305 Newbold J. (2006) Management of spa pools: controlling the risk of infection. London, United Kingdom: Health Protection Agency.
- 306 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en. Accessed on April 21, 2018.
- 307 Camper AK, et al. (1985) Growth and persistence of pathogens on granular activated carbon filters. *Journal of Applied Environmental Microbiology,* 50:1378–82.
- 308 Goeres DM, et al. Evaluation of disinfectant efficacy against biofilm and suspended bacteria in a laboratory swimming pool model. *Water Research.* 2004;38(13):3103-3109.
- 309 Declerck P. (2010) Biofilms: the environmental playground of *Legionella pneumophila*. *Environmental Microbiology,* 12(3), 557-566.
- 310 Clements W. (Ed) (2000) ASHRAE guideline: Minimizing the risk of legionellosis associated with building water systems. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc.
- 311 Donlan RM, et al. Biofilms: survival mechanisms of clinically relevant microorganisms. *Clinical Microbiol Rev.* 2002;15:167-93.
- 312 Paulson D. (Ed.) (2010) Applied biomedical microbiology: A biofilms approach. Chapter 8: Matias F, et. al., Disinfection and its influence on biofilm ecology . Chapter 9: Goeres D, Understanding the importance of biofilm growth in hot tubs. Boca Raton, Fl: CRC Press.

- 313 Hurst C, et al. (2002) Manual of environmental microbiology. Washington DC: American Public Health Association. 184, 186-188.
- 314 Heymann D. (Ed.) (2004) Control of communicable diseases manual. Washington, DC: American Public Health Association, pp. 138-141, 230-231, 383-385.
- 315 APHA, et al. (2017) (2017) Standard methods for the examination of water and wastewater, 22nd ed. E.W. Rice, R.B. Baird, A.D. Eaton, and L.S. Clesceri (eds). New York: American Public Health Association.
- 316 Hodgson M, et al. (1996) Prevalence of *Legionella* bacteria in building water systems. In IAQ 96. Paths to Better Building Environments. Conference of the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. Atlanta.
- 317 Paulson D. (Ed.) (2010) Applied biomedical microbiology: A biofilms approach. Chapter 8: Matias F, et.al., Disinfection and its influence on biofilm ecology . Chapter 9: Goeres D, Understanding the importance of biofilm growth in hot tubs. Boca Raton, FL: CRC Press.
- 318 Donlan R, et al. (2002) Biofilms: survival mechanisms of clinically relevant microorganisms. Clinical Microbiology Review, 15, 167-93.
- 319 Costerton JW. (2007) The biofilm primer. Germany: Springer-Verlag. 1-97.
- 320 Grobe S, et al. (2001) Capability of mucoid *Pseudomonas aeruginosa* to survive in chlorinated water. International Journal of Monitoring & Testing and Public Health, 204, 139-142.
- 321 Price D, et al. Incidence and persistence of *Pseudomonas aeruginosa* in whirlpools. J Clin Microbiol. 1988 Sep;26(9):1650-4.
- 322 Muraca P, et al. (1987) Comparative assessment of chlorine, heat, ozone, and UV light for killing *Legionella pneumophila* within a model plumbing system. Appl Environ Microbiol. 1987;53(2):447-53.
- 323 Clements W. (Ed.) (2000) ASHRAE guideline: Minimizing the risk of legionellosis associated with building water systems. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc.
- 324 Brescia CC, et al. (2009) *Cryptosporidium* propidium monoazide-PCR, a molecular biology-based technique for genotyping of viable *Cryptosporidium* oocysts. Applied and Environmental Microbiology, 75:6856-6863.
- 325 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 326 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en Accessed on April 21, 2018.
- 327 Gregory R. Bench-marking pool water treatment for coping with *Cryptosporidium*. J Environ Health Res. 2002;1(1):11-18.
- 328 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 329 Ehrlich PF, et al. Maximum hand-rung coupling forces in children: the effects of handhold diameter. Hum Factors. 2013;55(3):545-56.
- 330 Young JG, et al. Hand-handhold coupling: Effect of handle shape, orientation, and friction on breakaway strength. Hum Factors. 2009;51(5):705-17.
- 331 Ehrlich PF, et al. Maximum hand-rung coupling forces in children: the effects of handhold diameter. Hum Factors. 2013;55(3):545-56.
- 332 Young JG, et al. Hand-handhold coupling: Effect of handle shape, orientation, and friction on breakaway strength. Hum Factors. 2009;51(5):705-17.
- 333 Young JG, et al. The effect of handhold orientation, size, and wearing gloves on hand-handhold breakaway strength. Hum Factors. 2012;54(3):316-33.
- 334 Armstrong TJ, et al. Development of design interventions for preventing falls from fixed ladders. The Center for Construction Research and Training, CPWR Small Study Final Report, April 2008. Available at <https://www.cpwr.com/sites/default/files/publications/Armstrong-Ladder-Study.pdf>. Accessed on April 29, 2018.
- 335 Lee SH, et al. Field tool for on-site biomechanical analysis during ladder climbing. The Center for Construction Research and Training, CPWR Final Report, April 2014. Available at <https://www.cpwr.com/sites/default/files/publications/LeeFinalReport.pdf>. Accessed on April 29, 2018.
- 336 DeVivo MJ. Epidemiology of traumatic spinal cord injury: trends and future implications. Spinal Cord. 2012 May;50(5):365-72.
- 337 Blanksby BA, et al. Aetiology and occurrence of diving injuries. A review of diving safety. Sports Med. 1997;23(4):228-46.

- 338 Blanksby BA, et al. Aetiology and occurrence of diving injuries. A review of diving safety. *Sports Med.* 1997;23(4):228-46.
- 339 Borius PY, et al. Cervical spine injuries resulting from diving accidents in swimming pools: outcome of 34 patients. *Eur Spine J.* 2010 Apr;19(4):552-7.
- 340 Tadros A, et al. Emergency department visits coded for swimming pool diving injuries. *Int J Inj Contr Saf Promot.* 2018;5:1-5.
- 341 Albrand OW, et al. Underwater deceleration curves in relation to injuries from diving. *Surg Neurol.* 1975;4(5):461-4.
- 342 Gabrielsen MA, et al. Diving injuries: The etiology of 486 case studies with recommendations for needed action. 1990. Nova University Press, Ft. Lauderdale, FL.
- 343 Blitvich JD, et al. Dive depth and water depth in competitive swim starts. *J Swimming Res.* 2000;14:33-39.
- 344 Cornett AC, et al. Start depth modification by adolescent competitive swimmers. *Int J Aquatic Res Educ.* 2012;6:68-79.
- 345 White JC, et al. Competitive swimmers modify racing start depth upon request. *Int J Aquatic Res Educ.* 2011;5:187-198.
- 346 Cornett AC, et al. Teaching competitive racing starts: Practices and opinions of professional swim coaches. *Int J Aquatic Res Educ.* 2012;6:156-170.
- 347 Cornett AC, et al. Racing start safety: Head depth and head speed during competitive starts into a water depth of 1.22m. *Int J Aquatic Res Ed.* 2010;4:365-378.
- 348 Cornett AC, et al. Racing start safety: Head depth and head speed during competitive starts into a water depth of 2.29m. *Int J Aquatic Res Ed.* 2011;5:14-31.
- 349 Fryar CD, et al. Anthropometric reference data for children and adults: United States, 2011–2014. National Center for Health Statistics. *Vital Health Stat.* 2016;3(39):1-46. Available at https://www.cdc.gov/nchs/data/series/sr_03/sr03_039.pdf. Accessed on April 25, 2018.
- 350 CDC. Acute illness and injury from swimming pool disinfectants and other chemicals --- United States, 2002—2008. *MMWR Morb Mortal Wkly Rep.* 2011;60(39):1343-1347.
- 351 CDC. Pool chemical—associated health events in public and residential settings---United States, 1983-2007. *MMWR Morb Mortal Wkly Rpt.* 2009;58(18):489-493.
- 352 Hlavsa MC, et al. Pool chemical—associated health events in public and residential settings — United States, 2003–2012, and Minnesota, 2013. *MMWR Morb Mortal Wkly Rep.* 2014;63(19):427-30.
- 353 Anderson AR, et al. The distribution and public health consequences of releases of chemicals intended for pool use in 17 states, 2001-2009. *J Environ Health.* 2014;76(9):10-5.
- 354 Hlavsa MC, et al. Surveillance for waterborne disease outbreaks and other health events associated with recreational water use — United States, 2007–2008. *MMWR Surveill Summ* 2011;60:1-37.
- 355 CDC. Recommendations for preventing pool chemical-associated injuries. Accessed at <http://www.cdc.gov/healthywater/swimming/pools/preventing-pool-chemical-injuries.html>. Accessed April 25, 2018.
- 356 Hlavsa MC et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. *MMWR Morb Mortal Wkly Rep.* 2015;64(24):668-72.
- 357 CDC. Communitywide cryptosporidiosis outbreak--Utah, 2007. *MMWR Morb Mortal Wkly Rep.* 2008;57(36):989-93.
- 358 Shields, et al. Inactivation of *Cryptosporidium parvum* under chlorinated recreational water conditions. *J Water Health* 2008;6(4):513–20.
- 359 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol* 2015;49:7348-55
- 360 Smith H. Diagnostics. In: Fayer R, Xiao L, eds. *Cryptosporidium* and cryptosporidiosis. 2nd ed. Boca Raton, Florida: CRC Press, 2008:173–207.
- 361 Betancourt WQ, et al. Drinking water treatment processes for removal of *Cryptosporidium* and *Giardia*. *Vet Parasitol.* 2004;126(1-2):219-34.
- 362 Craik SA, et al. Inactivation of *Cryptosporidium parvum* oocysts using medium- and low-pressure ultraviolet radiation. *Water Res.* 2001;35(6):1387-98.
- 363 Rochelle PA, et al. The response of *Cryptosporidium parvum* to UV light. *Trends Parasitol.* 2005;21(2):81-7.
- 364 Corona-Vasquez B, et al. Inactivation of *Cryptosporidium parvum* oocysts with ozone and free chlorine. *Water Res.* 2002;36(16):4053-63.

- 365 Korich DG, et al. Effects of ozone, chlorine dioxide, chlorine, and monochloramine on *Cryptosporidium parvum* oocyst viability. *Appl Environ Microbiol.* 1990;56(5):1423-8.
- 366 CDC. Respiratory and ocular symptoms among employees of a hotel indoor waterpark resort — Ohio, 2007. *MMWR* 2009; 58(4):81-85.
- 367 Wiant C. A snapshot of swimmer hygiene behavior. *Int J Aquat Res Ed.* 2011;5(3):244-245.
- 368 Cox, et al. Body mass changes and voluntary fluid intakes of elite level water polo players and swimmers. *J Sci Med Sport.* 5,3 (2002): 183-193.
- 369 Keuten MG, et al. Definition and quantification of initial anthropogenic pollutant release in swimming pools. *Water Res.* 2012 Jul;46(11):3682-92.
- 370 Cassan D, et al. Effects of medium-pressure UV lamps radiation on water quality in a chlorinated indoor swimming pool. *Chemosphere* 2006;62(9):1507-13.
- 371 Li J, et al. UV photodegradation of inorganic chloramines. *Environ Sci Technol* 2009;43(1):60-5.
- 372 Gerba CP. Assessment of enteric pathogen shedding by bathers during recreational activity and its impact on water quality. *Quant Micro.* 2000;2:55-68.
- 373 Shields JM, et al. The effect of cyanuric acid on the disinfection rate of *Cryptosporidium parvum* in 20-ppm free chlorine. *J Water Health.* 2009 Mar;7(1):109-14. doi: 10.2166/wh.2009.008.
- 374 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol* 2015;49:7348-55.
- 375 Keuten MG, et al. Definition and quantification of initial anthropogenic pollutant release in swimming pools. *Water Res.* 2012 Jul;46(11):3682-92.
- 376 Shields JM, et al. Prevalence of *Cryptosporidium* spp. and *Giardia intestinalis* in Atlanta metropolitan area swimming pools. *Emerg Inf Dis* 2008;14:948-950.
- 377 Schets FM, et al. *Cryptosporidium* and *Giardia* in swimming pools in the Netherlands. *J Water Health.* 2004 Sep;2(3):191-200.
- 378 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol* 2015;49:7348-55.
- 379 Duma SM, et al. Eye injury risk from water stream impact: biomechanically based design parameters for water toy and park design. *Curr Eye Res.* 2012 Apr;37(4):279-85.
- 380 Jonsson K, et al. Curing the sick and creating supermen – how relaxation in flotation tanks is advertised on the Internet. *Eur J Integrat Med.* 2014;6(5):601-9.
- 381 Beaudet S, et al. Float tanks: Review of current guidance and considerations for public health inspectors. Vancouver, BC: National Collaborating Centre for Environmental Health; July 2016. http://www.nccch.ca/sites/default/files/Float_Tanks_Review_Current_Guidance_July_2016.pdf. Accessed April 23, 2018.
- 382 Eykelbosh A, Beaudet S. Float tanks: Considerations for environmental public health. Vancouver, BC: National Collaborating Centre for Environmental Health; 2016 Jul. Available from http://www.nccch.ca/sites/default/files/Float_Tanks_Considerations_EPH_July_2016.pdf. Accessed April 23, 2018.
- 383 Nadolny E, MacDougall C, Public Health Ontario. Evidence brief: Risk of infection in the use of floatation tanks. Toronto, ON: Ontario Agency for Health Protection and Promotion; 2016 Jun. Available from: http://www.publichealthontario.ca/en/eRepository/EB_Floatation_Tanks_Infection_Risk.pdf. Accessed April 23, 2018.
- 384 NSF International. Component certification specification for floatation or sensory deprivation systems and related equipment, CCS-12804. Ann Arbor, MI: NSF International. 2013a. Available from <http://info.nsf.org/Certified/Pools/12804.pdf>. Accessed April 23, 2018.
- 385 Beaudet S, et al. Float tanks: Review of current guidance and considerations for public health inspectors. Vancouver, BC: National Collaborating Centre for Environmental Health; July 2016. http://www.nccch.ca/sites/default/files/Float_Tanks_Review_Current_Guidance_July_2016.pdf. Accessed April 23, 2018.
- 386 Eykelbosh A, et al. Float tanks: Considerations for environmental public health. Vancouver, BC: National Collaborating Centre for Environmental Health; July 2016. Available from http://www.nccch.ca/sites/default/files/Float_Tanks_Considerations_EPH_July_2016.pdf. Accessed April 23, 2018.

- 387 NSF International. Organism time kill in float lab water (J-00114729). Ann Arbor, MI: NSF International; November 2012. Available from <http://floatlab.com/wp-content/uploads/2012/01/Organism-Time-Kill-in-Float-Lab-Water5.pdf>.
- 388 NSF International. Organism viability testing in Epsom salt and control solution: NSF International; 2015a Oct. Available from https://s3-us-west-2.amazonaws.com/floattanksolutions/NSF-Salt-Only-Tests_2015.pdf. Accessed April 23, 2018.
- 389 Malowitz R, et al. Effects of floating in a saturated Epsom-salt solution on the aerobic microbial flora of the skin. Clin Lab Sci. 1988;1(6):358-61.
- 390 Wong G, et al. Ultraviolet light as a sterilization method in flotation tanks. J Clin Eng. 1986;11(1):69-72.
- 391 NSF International. Qualification testing for float lab isolation floatation chamber (J-00119683). Ann Arbor, MI: NSF International; 2013b May.
- 392 NSF International. Qualification testing for float lab isolation floatation chamber (J-00125267). Ann Arbor, MI: NSF International; 2013c May.
- 393 Beaudet S, et al. Float tanks: Review of current guidance and considerations for public health inspectors. Vancouver, BC: National Collaborating Centre for Environmental Health; July 2016. http://www.nccch.ca/sites/default/files/Float_Tanks_Review_Current_Guidance_July_2016.pdf. Accessed April 23, 2018.
- 394 Eykelbosh A, et al. Float tanks: Considerations for environmental public health. Vancouver, BC: National Collaborating Centre for Environmental Health; July 2016. Available from: http://www.nccch.ca/sites/default/files/Float_Tanks_Considerations_EPH_July_2016.pdf. Accessed April 23, 2018.
- 395 NSF International. Recovery analysis of free and total chlorine measurement methods in high MgSO₄ solution. Ann Arbor, MI: NSF International; 2015b Feb.
- 396 Chevrefils G, et al. UV dose required to achieve incremental log inactivation of bacteria, protozoa and viruses. IUVA News. 2006 Mar:38-45.
- 397 Lenntech. Ozone decomposition. Delft, the Netherlands: Lenntech. n.d.; Available from <http://www.lenntech.com/library/ozone/decomposition/ozone-decomposition.htm>. Access April 23, 2018.
- 398 Reisen WK, et al. Delinquent mortgages, neglected swimming pools, and West Nile virus, California. Emerg Infect Dis. 2008;14(11):1747-9.
- 399 Anderson AR, et al. The distribution and public health consequences of releases of chemicals intended for pool use in 17 states, 2001-2009. J. Environ Hlth 2014;76:10-15.
- 400 White GC. Handbook of Chlorination and Alternative Disinfectants 4th edition. John Wiley and Sons, Inc. Hoboken New Jersey 1999.
- 401 CDC. An outbreak of *Pseudomonas* folliculitis associated with a waterslide – Utah. MMWR Morb Mortal Wkly Rep. 1983;32(32):425-7.
- 402 Dick EC, et al. Surface-subsurface distribution of bacteria in swimming pools – field studies. Am. J. Pub. Health. 1960;50:5:689-695.
- 403 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 404 Dick EC, et al. Surface-subsurface distribution of bacteria in swimming pools – field studies. Am. J. Pub. Health. 1960;50:5:689-695.
- 405 Hlavsa MC, et al. Surveillance for waterborne disease outbreaks and other health events associated with recreational water use — United States, 2007–2008. MMWR Surveill Summ. 2011;60:1-37.
- 406 Wilken JA, et al. Inhalational chlorine injuries at public aquatic venues - California, 2008-2015. MMWR Morb Mortal Wkly Rep. 2017 May 19;66(19):498-501.
- 407 Cleasby JL, et al. Chapter 8: Granular bed and precoat filtration. In Water Quality and Treatment, 5th Ed. McGraw Hill, Inc. NY:1999.
- 408 Logsdon GS, et al. Alternative filtration methods for removal of *Giardia* cysts and cyst models. Journal AWWA. 1981;73(2):111-118.
- 409 Letterman RD. Water Quality and Treatment. 1999. 5th Ed. McGraw-Hill, NY.
- 410 Croll BT, et al. Simulated *Cryptosporidium* removal under swimming pool filtration conditions. Water Environment Journal. 2007;21:149-156.
- 411 Letterman RD. Water Quality and Treatment. 1999. 5th Ed. McGraw-Hill, NY.
- 412 Cleasby JL, et al. Chapter 8: Granular bed and precoat filtration. In Water Quality and Treatment, 5th Ed. McGraw Hill, Inc. NY:1999. ISBN: 0070016593.

- 413 Cleasby JL, et al. Chapter 8: Granular bed and precoat filtration. In *Water Quality and Treatment*, 5th Ed. McGraw Hill, Inc. NY:1999. ISBN: 0070016593.
- 414 Croll BT, et al. Simulated *Cryptosporidium* removal under swimming pool filtration conditions. *Water Environment Journal*. 2007;21:149-156.
- 415 Logsdon GS, et al. Alternative filtration methods for removal of *Giardia* cysts and cyst models. *Journal AWWA*. 1981;73(2):111-118.
- 416 Lange KP, et al. Diatomaceous earth filtration of *Giardia* cysts and other substances. *Journal AWWA*. 1986;78(1):76-84.
- 417 Logsdon GS. *Water filtration practices: including slow sand filters and precoat filtration*. 2008. American Water Works Association, Denver, CO. ISBN: 9781583215951.
- 418 Moraga-McHaley SA, et al. Hypersensitivity pneumonitis with *Mycobacterium avium* complex among spa workers. *J Occup Environ Health*. 2013; Jan-Mar;19(1):55-61.
- 419 Moraga-McHaley SA, et al. Hypersensitivity pneumonitis with *Mycobacterium avium* complex among spa workers. *J Occup Environ Health*. 2013; Jan-Mar;19(1):55-61.
- 420 CDC. Chlorine disinfection timetable. Last modified May 04, 2016. Available from <http://www.cdc.gov/healthywater/swimming/pools/chlorine-disinfection-timetable.html>. Accessed April 2018.
- 421 Zhao T, et al. Chlorine inactivation of *Escherichia coli* O157:H7 in water. *J Food Prot*. 2001 Oct;64(10):1607-9.
- 422 Grabow WO, et al. Inactivation of hepatitis A virus and indicator organisms in water by free chlorine residuals. *Appl Environ Microbiol*. 1983 Sep;46(3):619-24.
- 423 EPA. Disinfection profiling and benchmarking guidance manual. 1999. Available at <https://nepis.epa.gov/Exe/ZyPDF.cgi/20002249.PDF?Dockey=20002249.PDF>. Accessed on April 29, 2018.
- 424 Shields JM, et al. Inactivation of *Cryptosporidium parvum* under chlorinated recreational water conditions. *J Water Health* 2008;6(4):513–20.
- 425 Murphy JL, Arrowood MJ, Lu X, Hlavsa MC, Beach MJ, Hill VR. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol*. 2015;49(12):7348-55.
- 426 Esterman A, et al. Determinants of the microbiological characteristics of South Australian swimming pools. *Appl Environ Microbiol*. 1984 February; 47(2): 325–328.
- 427 Ibarluzea J, et al. Determinants of the microbiological water quality of indoor swimming pools in relation to disinfection. *Water Research*. 1998; 33(3): 865-871.
- 428 Price D, et al. Incidence and persistence of *Pseudomonas aeruginosa* in whirlpools. *J Clin Microbiol*. 1988 Sep;26(9):1650-4.
- 429 Anderson JR. A study of the influence of cyanuric acid on the bactericidal effectiveness of chlorine. *Am J Public Health Nations Health*. 1965 Oct;55(10):1629-37.
- 430 Fitzgerald GP, et al. Factors influencing the effectiveness of swimming pool bactericides. *Appl Microbiol*. 1967 May;15(3):504-9.
- 431 Golaszewski G, et al. The kinetics of the action of chloroisocyanurates on three bacteria: *Pseudomonas aeruginosa*, *Streptococcus faecalis*, and *Staphylococcus aureus*. *Water Research* 1994;28(1): 207-217.
- 432 Fitzgerald GP, et al. *Pseudomonas aeruginosa* for the evaluation of swimming pool chlorination and algicides. *Appl Microbiol*. 1969 Mar;17(3):415-21.
- 433 WHO. (2003). Chlorine in drinking water background document for development of WHO guidelines for drinking-water quality. WHO/SDE/WSH/03.04/45. World Health Organization, Geneva. Available from http://www.who.int/water_sanitation_health/dwq/chlorine.pdf. Accessed April 23, 2018.
- 434 White GC. 1999. *Handbook of chlorination and alternative disinfectants*. 4th ed.: John Wiley and Sons, Inc. New York.
- 435 Esterman A, et al. Determinants of the microbiological characteristics of South Australian swimming pools. *Appl Environ Microbiol*. 1984 February; 47(2): 325–328.
- 436 Brown JR, et al. Bromine disinfection of a large swimming pool. *Can J Public Health*. 1964 Jun;55:251-6.
- 437 Shaw JW. A retrospective comparison of the effectiveness of bromination and chlorination in controlling *Pseudomonas aeruginosa* in spas (whirlpools) in Alberta. *Can J Public Health*. 1984 Jan-Feb;75(1):61-8.
- 438 Galal-Gorchev H, et al. Formation and stability of bromamide, bromimide, and nitrogen tribromide in aqueous solution. *Inorganic Chemistry*. 1965;4(6):899-905.
- 439 Galal-Gorchev H, et al. Formation and stability of bromamide, bromimide, and nitrogen tribromide in aqueous solution. *Inorganic Chemistry*. 1965;4(6):899-905.
- 440 Wyss O, et al. The germicidal action of bromine. *Arch Biochem*. 1947 Feb;12(2):267-71.

- 441 Kush BJ, et al. A preliminary survey of the association of *Pseudomonas aeruginosa* with commercial whirlpool bath waters. *Am J Public Health*. 1980 Mar;70(3):279-81.
- 442 Johnson JD, et al. Bromine and bromamine disinfection chemistry. *J of Sanitary Engineering Division Am Soc of Civil Eng*, 1971;97:617-628.
- 443 Rycroft RJ, et al. Dermatoses associated with brominated swimming pools. *Br Med J (Clin Res Ed)*. 1983 Aug 13;287(6390):462.
- 444 Fitzgerald DA, et al. Spa pool dermatitis. *Contact Dermatitis*. 1995 Jul;33(1):53.
- 445 Loughney E, et al. Irritant contact dermatitis due to 1-bromo-3-chloro-5,5-dimethylhydantoin in a hydrotherapy pool. Risk assessments: the need for continuous evidence-based assessments. *Occup Med (Lond)*. 1998 Oct;48(7):461-3.
- 446 Lazarov A, et al. Self-reported skin disease in hydrotherapists working in swimming pools. *Contact Dermatitis*. 2005 Dec;53(6):327-31.
- 447 Kelsall HL, et al. Skin irritation in users of brominated pools. *Int J Environ Health Res*. 2001 Mar;11(1):29-40.
- 448 Woolf A, et al. Reactive airways dysfunction and systemic complaints after mass exposure to bromine. *Environ Health Perspect*. 1999 Jun;107(6):507-9.
- 449 Robinton ED, et al. An evaluation of the inhibitory influence of cyanuric acid upon swimming pool disinfection. *Am J Public Health*. 1967 Feb;57(2):301-10.
- 450 Warren IC, et al. Swimming pool disinfection. Investigations on behalf of the Department of the Environment into the practice of disinfection of swimming pools during 1972 to 1975. Water Research Centre, Henly-on-Thames, England, 35 pp., Oct 1978.
- 451 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/. Accessed on April 23, 2018.
- 452 Shields JM, et al. The effect of cyanuric acid on the disinfection rate of *Cryptosporidium parvum* in 20-ppm free chlorine. *J Water Health*. 2009 Mar;7(1):109-14.
- 453 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol*. 2015;49(12):7348-55.
- 454 Fitzgerald GP, et al. *Pseudomonas aeruginosa* for the evaluation of swimming pool chlorination and algicides. *Appl Microbiol*. 1969 Mar;17(3):415-21.
- 455 CDC. *Pseudomonas* dermatitis/folliculitis associated with pools and hot tubs--Colorado and Maine, 1999-2000. *MMWR Morb Mortal Wkly Rep*. 2000 Dec 8;49(48):1087-91.
- 456 Shields JM, et al. The effect of cyanuric acid on the disinfection rate of *Cryptosporidium parvum* in 20-ppm free chlorine. *J Water Health*. 2009 Mar;7(1):109-14.
- 457 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol*. 2015;49(12):7348-55.
- 458 Yamashita T, et al. Influence of cyanuric acid on virucidal effect of chlorine and the comparative study in actual swimming pool waters. *Kansenshogaku Zasshi*. 1988 Mar;62(3):200-5.
- 459 Yamashita T, et al. Virucidal effect of chlorinated water containing cyanuric acid. *Epidemiol Infect*. 1988 Dec;101(3):631-9.
- 460 Yamashita T, et al. Microbiological and chemical analyses of indoor swimming pools and virucidal effect of chlorine in these waters. *Nihon Koshu Eisei Zasshi*. 1990 Dec;37(12):962-6.
- 461 Saita K, et al. Effects of isocyanuric acid on the polio virus inactivation with hypochlorous acid. *Jpn. J. Toxicol. Environ. Health* 1998;44:442-450.
- 462 Sommerfeld MR, et al. Influence of stabilizer concentration on effectiveness of chlorine as an algicide. *Appl Environ Microbiol*. 1982 Feb;43(2):497-9.
- 463 Engel J P, et al. Inactivation of *Naegleria gruberi* cysts by chlorinated cyanurates. *Appl Environ Microbiol*. 1983;46:1157-1162.
- 464 Shields JM, et al. The effect of cyanuric acid on the disinfection rate of *Cryptosporidium parvum* in 20-ppm free chlorine. *J Water Health*. 2009 Mar;7(1):109-14.
- 465 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol*. 2015;49(12):7348-55.
- 466 Woolf A, et al. Reactive airways dysfunction and systemic complaints after mass exposure to bromine. *Environ Health Perspect*. 1999 Jun;107(6):507-9.

- 467 Favero MS, et al. Use of staphylococci as indicators of swimming pool. Public Health Rep. 1964 Jan;79:61-70.
- 468 Fitzgerald GP, et al. *Pseudomonas aeruginosa* for the evaluation of swimming pool chlorination and algicides. Appl Microbiol. 1969 Mar;17(3):415-21.
- 469 Shields JM, et al. Inactivation of *Cryptosporidium parvum* under chlorinated recreational water conditions. J Water Health 2008;6:513-520.
- 470 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. Environ Sci Technol. 2015;49(12):7348-55.
- 471 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. Environ Sci Technol. 2015;49(12):7348-55.
- 472 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. Environ Sci Technol. 2015;49(12):7348-55.
- 473 Kristensen GH, et al. On-line monitoring of the dynamics of trihalomethane concentrations in a warm public swimming pool using an unsupervised membrane inlet mass spectrometry system with off-site real-time surveillance. Rapid Commun Mass Spectrom. 2010 Jan;24(1):30-4.
- 474 Lee J, et al. Characteristics of trihalomethane (THM) production and associated health risk assessment in swimming pool waters treated with different disinfection methods. Sci Total Environ. 2009 Mar 1;407(6):1990-7.
- 475 Zwiener C, et al. Drowning in disinfection byproducts? Assessing swimming pool water. Environ Sci Technol. 2007 Jan 15;41(2):363-72.
- 476 CDC. Immediate closures and violations identified during routine inspections of public aquatic facilities - network for aquatic facility inspection surveillance, five states, 2013. MMWR Surveill Summ. 2016 May 20;65(5):1-26.
- 477 CDC. Outbreak of gastroenteritis associated with an interactive water fountain at a beachside park--Florida, 1999. MMWR Morb Mortal Wkly Rep 2000;49:565-8.
- 478 CDC. 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;57:1-29.
- 479 Blatchley ER, et al. Copper catalysis in chloroform formation during water chlorination. Wat Res 2003;37:4385-4394.
- 480 Borgmann-Strahsen, R. Comparative assessment of different biocides in swimming pool water, International Biodeterioration and Biodegradation 2003;51:291-297.
- 481 Murphy JL et al. Efficacy of chlorine dioxide tablets on inactivation of *Cryptosporidium* oocysts. Environ Sci Technol. 2014;48(10):5849-5856.
- 482 Wilken JA, et al. Inhalational chlorine injuries at public aquatic venues - California, 2008-2015. MMWR Morb Mortal Wkly Rep. 2017;66:498-501.
- 483 De Laat J, et al. Concentration levels of urea in swimming pool water and reactivity of chlorine with urea. Water Research, 2011, 45(3) 1139-1146.
- 484 Weaver, et al. (2009) Volatile disinfection by-product analysis from chlorinated indoor swimming pools. Water Research, 43(13):3308-3318.
- 485 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/. Accessed on April 23, 2018.
- 486 Weaver, et al. (2009) Volatile disinfection by-product analysis from chlorinated indoor swimming pools. Water Research, 43(13):3308-3318.
- 487 Lahl U, et al. Distribution and balance of volatile halogenated hydrocarbons in the water and air of covered swimming pools using chlorine for water disinfection. Water Res. 1981;15:803-814.
- 488 Lévesque B, et al. The determinants of prevalence of health complaints among young competitive swimmers. Int Arch Occup Environ Health. 2006 Oct;80(1):32-9.
- 489 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64(24):668-72.
- 490 CDC. Ocular and respiratory illness associated with an indoor swimming pool--Nebraska, 2006. MMWR Morb Mortal Wkly Rep. 2007 Sep 14;56(36):929-32.
- 491 Massin N, et al. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. Occup Environ Med. 1998 Apr;55(4):258-63.
- 492 Goodman M ,et al. Asthma and swimming: a meta-analysis. J Asthma. 2008 Oct;45(8):639-47.

- 493 Schoefer Y, et al. Health risks of early swimming pool attendance. *Int J Hyg Environ Health*. 2008;211(3-4):367-73.
- 494 Weisel CP, et al. Childhood asthma and environmental exposures at swimming pools: State of the science and research recommendations. *Environ Health Perspect*. 2009 Apr;117(4):500-7.
- 495 Font-Ribera L, et al. Swimming pool attendance, asthma, allergies, and lung function in the Avon Longitudinal Study of Parents and Children cohort. *Am J Respir Crit Care Med*. 2011;183(5):582-8.
- 496 Villanueva CM, et al. Health impact of disinfection by-products in swimming pools. *Ann Ist Super Sanita*. 2012;48(4):387-96.
- 497 Schoefer Y, et al. Health risks of early swimming pool attendance. *Int J Hyg Environ Health*. 2008;211(3-4):367-73.
- 498 Fitzgerald DA, et al. Spa pool dermatitis. *Contact Dermatitis*. 1995 Jul;33(1):53.
- 499 Rycroft RJ, et al. Dermatoses associated with brominated swimming pools. *Br Med J (Clin Res Ed)*. 1983 Aug 13;287(6390):462.
- 500 Kott Y, et al. Algicidal effect of bromine and chlorine on *Chlorella pyrenoidosa*. *Appl Microbiol*. 1966 Jan;14(1):8-11.
- 501 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/. Accessed on April 23, 2018.
- 502 Press E. The health hazards of saunas and spas and how to minimize them. *Am J Public Health*. 1991 Aug;81(8):1034-7.
- 503 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/. Accessed on April 23, 2018.
- 504 Howland J, et al. Why are most drowning victims men? Sex differences in aquatic skills and behaviors. *Am J Public Health* 1996;86:93--6.
- 505 Allison TG, et al. Thermoregulatory, cardiovascular, and psychophysical response to alcohol in men in 40 degrees C water. *J Appl Physiol*. 1992 Jun;72(6):2099-107.
- 506 Mekjavic IB, et al. Cardiovascular responses during 70 degrees head-up tilt: the effect of elevated body temperature and high alcohol blood levels. *Physiologist*. 1987 Feb;30(1 Suppl):S56-7.
- 507 Alhadj M, et al. Hot tub, whirlpool, and spa-related injuries in the U.S., 1990-2007. *Am J Prev Med*. 2009 Dec;37(6):531-6.
- 508 Rodhe A, et al. Sauna deaths in Sweden, 1992-2003. *Am J Forensic Med Pathol*. 2008 Mar;29(1):27-31.
- 509 Kenttämies A, et al. Death in sauna. *J Forensic Sci*. 2008 May;53(3):724-9.
- 510 Moretti ME, et al. Maternal hyperthermia and the risk for neural tube defects in offspring: systematic review and meta-analysis. *Epidemiology*. 2005 Mar;16(2):216-9.
- 511 Milunsky A, et al. Maternal heat exposure and neural tube defects. *JAMA*. 1992 Aug 19;268(7):882-5.
- 512 Duong HT, et al; National Birth Defects Prevention Study. Maternal use of hot tub and major structural birth defects. *Birth Defects Res A Clin Mol Teratol*. 2011 Sep;91(9):836-41.
- 513 Chambers CD. Risks of hyperthermia associated with hot tub or spa use by pregnant women. *Birth Defects Res A Clin Mol Teratol*. 2006 Aug;76(8):569-73.
- 514 Li DK, et al. Hot tub use during pregnancy and the risk of miscarriage. *Am J Epidemiol*. 2003 Nov 15;158(10):931-7.
- 515 Rowland T. Thermoregulation during exercise in the heat in children: old concepts revisited. *J Appl Physiol*. 2008 Aug;105(2):718-24.
- 516 Jokinen E, et al. Children in sauna: Cardiovascular adjustment. *Pediatrics*. 1990 Aug;86(2):282-8.
- 517 EMS World Response Time Standards. Available at <http://www.emsworld.com/article/10324786/ems-response-time-standards>. Accessed April 24, 2018.
- 518 OSHA. Coverage of Lifeguards under 29 CFR 1910.1030. July 9, 1993. Corrected 08/16/2007. Available at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=21197. Accessed April 24, 2018.
- 519 Pleasance ED, et al. A comprehensive catalogue of somatic mutations from a human cancer genome. *Nature*. 2010;463;7278;191-6.

- 520 21 CFR Parts 201 and 310, Labeling and effectiveness testing; Sunscreen Drug Products for Over-the-Counter Human Use.
- 521 CDC/NIOSH. UV radiation. Available from <http://www.cdc.gov/niosh/topics/uvradiation/>. Accessed April 24, 2018.
- 522 IARC monographs on the evaluation of carcinogenic risks to humans. Solar and ultraviolet radiation. IARC Monogr Eval Carcinog Risks Hum. 1992;55:1-316. PMID:1345607.
- 523 OSHA. Personal protective equipment standard 29 CFR 1910.132. Available at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9777. Accessed April 24, 2018.
- 524 Krutmann J, et al. Towards standardization of UV eye protection: what can be learned from photodermatology? *Photodermatol Photoimmunol Photomed*. 2013 Nov 8.
- 525 Glickman RD. Ultraviolet phototoxicity to the retina. *Eye Contact Lens*. 2011 Jul;37(4):196-205.
- 526 Roberts JE. Ultraviolet radiation as a risk factor for cataract and macular degeneration. *Eye Contact Lens*. 2011 Jul;37(4):246-9.
- 527 Glickman RD. Phototoxicity to the retina: mechanisms of damage. *Int J Toxicol*. 2002 Nov-Dec;21(6):473-90.
- 528 McCarty CA, et al. A review of the epidemiologic evidence linking ultraviolet radiation and cataracts. *Dev Ophthalmol*. 2002;35:21-31.
- 529 Roberts JE. Ocular phototoxicity. *J Photochem Photobiol B*. 2001 Nov 15;64(2-3):136-43.
- 530 Taylor HR. Ultraviolet radiation and the eye: an epidemiologic study. *Trans Am Ophthalmol Soc*. 1989;87:802-53.
- 531 OSHA. Personal protective equipment standard 29 CFR 1910.132 Available at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9777. Accessed April 24, 2018.
- 532 OSHA. Toxic and hazardous substances – blood borne pathogens 29 CFR 1910.1030. Available at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10051. Accessed April 24, 2018.
- 533 Kyriacou DN, et al. Effect of immediate resuscitation on children with submersion injury. *Pediatrics*. 1994;94(2):137-142.
- 534 Anderson AR, et al. The distribution and public health consequences of releases of chemicals intended for pool use in 17 states, 2001-2009. *J Environ Health* 2014;76:10-15.
- 535 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 536 Davis TL, et al. Bacteriological analysis of indoor and outdoor water parks in Wisconsin. *J Water Health* 2009;7(3):452-463.
- 537 Davis TL, et al. Bacteriological analysis of indoor and outdoor water parks in Wisconsin. *J Water Health* 2009;7(3):452-463.
- 538 PWTAG. Swimming pool water: Treatment and quality standards for pools and spas. 3rd Ed. 2017. Micropress Printers, Ltd. ISBN: 978-1-5272-1666-2.
- 539 Solomon SL. Host factors in whirlpool-associated *Pseudomonas aeruginosa* skin disease. *Infect Control*. 1985 Oct;6(10):402-6.
- 540 Price D, et al. Incidence and persistence of *Pseudomonas aeruginosa* in whirlpools. *J Clin Microbiol*. 1988 Sep;26(9):1650-4.
- 541 CDC. Violations identified from routine swimming pool inspections – selected states and counties, United States, 2008. *MMWR Morb Mortal Wkly Rep*. 2010;59(19):582-587.
- 542 CDC. Surveillance data from public spa inspections — United States, May–September 2002. *MMWR Morb Mortal Wkly Rep*. 2004;53(25):553–555.
- 543 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. *MMWR Morb Mortal Wkly Rep*. 2016;64(24):668-72
- 544 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. *MMWR Morb Mortal Wkly Rep*. 2016;64(24):668-72.
- 545 CDC. Pool chemical-associated health events in public and residential settings — United States, 1983-2007. *MMWR Morb Mortal Wkly Rep*. 2009;58(18):489-493.
- 546 Buss BF, et al. Association between swimming pool operator certification and reduced pool chemistry violations — Nebraska, 2005–2006. *J Environ Health*. 2009;71(8):36–40.

- 547 Johnston K, et al. Certified operators: Does certification provide significant results in real-world pool and spa chemistry? *Int J Aquat Res Educ* 2007;1:18–33
- 548 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. *MMWR Morb Mortal Wkly Rep.* 2016;64(24):668-72.
- 549 Anderson AR, et al. The distribution and public health consequences of releases of chemicals intended for pool use in 17 states, 2001-2009. *J Environ Hlth* 2014;76:10-15.
- 550 CDC. Healthy Swimming website. Recommendations for preventing pool chemical-associated injuries. Available at <http://www.cdc.gov/healthywater/swimming/pools/preventing-pool-chemical-injuries.html>. Accessed April 25, 2018.
- 551 CDC. Pool chemical–associated health events in public and residential settings — United States, 1983-2007. *MMWR Morb Mortal Wkly Rep.* 2009;58(18):489-93.
- 552 Zhang Q. 2012–2016 Reported circulation/suction entrapment incidents associated with pools, spas, and whirlpool bathtubs, 2017 Report. U.S. Consumer Product Safety Commission, April 2017. Available online at https://www.cpsc.gov/s3fs-public/2012-2016_%20Circulation_Suction_%20Entrapment_Incidents_Associated_with_pools_spas_whirlpool_bathtubs_2017%20Report.pdf?RiESYQQ8J9qiLOWWFIZe2Pcj2hW3oh1. Accessed on April 16, 2018.
- 553 CFP. Standards for Accreditation of food protection manager certification programs as amended by the 2016 Meeting of the Conference for Food Protection Available at <http://www.foodprotect.org/media/managercert/cfp-2016-standards-adopted.pdf>. Accessed April 25, 2018.
- 554 CFP. Standards for Accreditation of food protection manager certification programs as amended by the 2016 Meeting of the Conference for Food Protection Available at <http://www.foodprotect.org/media/managercert/cfp-2016-standards-adopted.pdf>. Accessed April 25, 2018.
- 555 CFP. Standards for Accreditation of food protection manager certification programs as amended by the 2016 Meeting of the Conference for Food Protection Available at <http://www.foodprotect.org/media/managercert/cfp-2016-standards-adopted.pdf>. Accessed April 25, 2018.
- 556 Trottier A, et al. Police health: a physician's guide for the assessment of police officers: 1994. Ottawa, Canada: Canadian Communication Group, 1993.
- 557 Bonneau J, et al. Physical ability, fitness and police work. *J Clin Forensic Med.* 1995;2(3):157-64.
- 558 Modell JH. Prevention of needless deaths from drowning. *South Med J.* 2010 Jul;103(7):650-3.
- 559 Pelletier AR, et al. Fatalities in swimming pools with lifeguards: USA, 2000-2008. *Inj Prev.* 2011 Aug;17(4):250-3.
- 560 Quan L, et al. Ten-year study of pediatric drownings and near-drownings in King County, Washington: lessons in injury prevention. *Pediatrics.* 1989 Jun;83(6):1035-40.
- 561 Layon AJ, et al. Drowning: Update 2009. *Anesthesiology.* 2009 Jun;110(6):1390-401.
- 562 Browne ML, et al. Unintentional drownings among New York State residents, 1988-1994. *Public Health Rep.* 2003 Sep-Oct;118(5):448-58.
- 563 Saluja G, et al. Swimming pool drownings among US residents aged 5-24 years: understanding racial/ethnic disparities. *Am J Public Health.* 2006 Apr;96(4):728-33.
- 564 Thompson DC, et al. Pool fencing for preventing drowning in children. *Cochrane Database Syst Rev.* 2000;(2):CD001047.
- 565 Nichter MA, et al. Profile of drowning victims in a coastal community. *J Fla Med Assoc.* 1989 Feb;76(2):253-6.
- 566 CDC. Drowning – United States, 2005-2009. *MMWR Morb Mortal Wkly Rep.* 2012;61(19):344-347.
- 567 CDC, National Center for Injury Prevention and Control. Web-based Injury Statistics Query and Reporting System (WISQARS). Available at <http://www.cdc.gov/injury/wisqars>. Accessed on April 25, 2018.
- 568 CDC. Drowning – United States, 2005-2009. *MMWR Morb Mortal Wkly Rep.* 2012;61(19):344-347.
- 569 CDC. Drowning – United States, 2005-2009. *MMWR Morb Mortal Wkly Rep.* 2012;61(19):344-347.
- 570 CDC, National Center for Injury Prevention and Control. Web-based Injury Statistics Query and Reporting System (WISQARS). Available at <http://www.cdc.gov/injury/wisqars>. Accessed on April 25, 2018.
- 571 Cummings P, et al. Trends in unintentional drowning: The role of alcohol and medical care. *JAMA.* 1999;281(23):2198-2202.
- 572 Spack L, et al. Failure of aggressive therapy to alter outcomes in pediatric near-drowning. *Pediatric Emergency Care* 1997;13(2):98-102.

- 573 American Heart Association Guidelines available at http://www.heart.org/HEARTORG/CPRAndECC/Science/Guidelines_UCM_303151_SubHomePage.jsp/. Accessed on April 25, 2018.
- 574 United States Lifeguard Standards Coalition. United States lifeguard standards: An evidence-based review and report. *Int J Aquatic Res Edu*. 2011;5(1):61-129.
- 575 American Red Cross. ACFASP Scientific Review. CPR Skill Retention review. Accessed at <http://www.instructorscorner.org/media/resources/SAC/Reviews/CPR%20Skill%20Retention.pdf>.
- 576 American Red Cross. ACFASP Scientific Review. CPR Skill Retention review. Accessed at <http://www.instructorscorner.org/media/resources/SAC/Reviews/CPR%20Skill%20Retention.pdf>.
- 577 CFP. Standards for Accreditation of food protection manager certification programs as amended by the 2016 Meeting of the Conference for Food Protection Available at <http://www.foodprotect.org/media/managercert/cfp-2016-standards-adopted.pdf>. Accessed April 25, 2018.
- 578 Fryar CD, et al. Anthropometric reference data for children and adults: United States, 2011–2014. National Center for Health Statistics. *Vital Health Stat*. 2016;3(39):1-46. Available at https://www.cdc.gov/nchs/data/series/sr_03/sr03_039.pdf. Accessed on April 25, 2018.
- 579 International Standards Organization. ISO/IEC Guide 50:2014. Safety aspects--Guidelines for child safety in standards and other specifications. Available at <https://www.iso.org/standard/63937.html>. Accessed April 25, 2018.
- 580 Fryar CD, et al. Anthropometric reference data for children and adults: United States, 2011–2014. National Center for Health Statistics. *Vital Health Stat*. 2016;3(39):1-46. Available at https://www.cdc.gov/nchs/data/series/sr_03/sr03_039.pdf. Accessed on April 25, 2018.
- 581 Jerison HJ, et al. Vigilance: The Importance of the elicited observing rate. *Science*. 1964;143(3609):970-1.
- 582 Mackworth NH. Researches in the measurement of human performance. MRC spec. Report 268 HMSO, 1950.
- 583 Lichstein KL, et al. The Mackworth Clock Test: a computerized version. *J Psychol*. 2000 Mar;134(2):153-61.
- 584 Ritter G, et al. The effect of bystander CPR on survival of out-of-hospital cardiac arrest victims. *Am Heart J*. 1985 Nov;110(5):932-7.
- 585 United States Lifeguard Standards Coalition. United States lifeguard standards: An evidence-based review and report. *Int J Aquatic Res Edu*. 2011;5(1):61-129.
- 586 American Red Cross. CPR Skill Retention review. Accessed at <http://www.instructorscorner.org/media/resources/SAC/Reviews/CPR%20Skill%20Retention.pdf>.
- 587 Shultz JJ, et al. Comparison of exertion required to perform standard and active compression-decompression cardiopulmonary resuscitation. *Resuscitation*. 1995 Feb;29(1):23-31.
- 588 Ainsworth BE, et al. 2011 Compendium of Physical Activities: A second update of codes and MET values. *Med Sci Sports Exerc*. 2011 Aug;43(8):1575-81.
- 589 Dafoe WA. Appendix: table of energy requirements for activities of daily living, household tasks, recreational activities, and vocational activities. In: Pashkow FJ, Dafoe WA, editors. *Clinical cardiac rehabilitation: a cardiologist's guide*. Baltimore, MD: Williams and Wilkins, 1993; 359-376.
- 590 Jetté M, et al. Metabolic equivalents (METs) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clin Cardiol*. 1990 Aug;13(8):555-65.
- 591 Strayer DL, et al. Profiles in driver distraction: Effects of cell phone conversations on younger and older drivers. *Hum Factors*. 2004 Winter;46(4):640-9.
- 592 Beede KE, et al. Engrossed in conversation: The impact of cell phones on simulated driving performance. *Accid Anal Prev*. 2006 Mar;38(2):415-21.
- 593 YMCA. Aquatics safety & risk reduction document, Topic: Aquatic Safety Technology. 2009.
- 594 Hlavsa MC, et al. Outbreaks associated with treated recreational water — United States, 2000–2014. *MMWR Morb Mortal Wkly Rep*. 2018;67(19):547-551.
- 595 CDC. Immediate closures and violations identified during routine inspections of public aquatic facilities - network for aquatic facility inspection surveillance, five states, 2013. *MMWR Surveill Summ*. 2016 May 20;65(5):1-26.
- 596 CDC. Pool chemical-associated health events in public and residential settings — United States, 1983-2007. *MMWR Morb Mortal Wkly Rep*. 2009;58(18):489-493.
- 597 Centerwall BS, et al. Erosion of dental enamel among competitive swimmers at a gas-chlorinated swimming pool. *Am J Epidemiol*. 1986;123(4):641-7.

- 598 Dawes C, et al. Rapid and severe tooth erosion from swimming in an improperly chlorinated pool: case report. *J Can Dent Assoc.* 2008;74(4):359-61.
- 599 Geurtsen W. Rapid general dental erosion by gas-chlorinated swimming pool water. Review of the literature and case report. *Am J Dent.* 2000;13(6):291-3.
- 600 American Academy of Pediatrics. Committee on injury, violence, and poison prevention. Prevention of Drowning. *Icon Pediatrics.* 2010;126(1):178-85.
- 601 American Academy Of Pediatrics, et al. (2002). Caring for our children: National health and safety performance standards; Guidelines for Out-of-Home Child Care Programs, 2nd edition. Elk Grove Village, IL: American Academy of Pediatrics and Washington, DC: American Public Health Association. Available at <http://nrckids.org>.
- 602 Hlavsa MC, Cikesh BL, Roberts VA, Kahler AM, Vigar M, Hilborn ED, Wade TJ, Roellig DM, Murphy JL, Xiao L, Kunz JM, Cooley LA, Yates KM, Hill VE, Beach MJ, Fullerton KE, Yoder JS. Outbreaks associated with treated recreational water — United States, 2000–2014. *MMWR Morb Mortal Wkly Rep.* 2018;67(19):547-551.
- 603 Jones TF, et al. A population-based estimate of the substantial burden of diarrhoeal disease in the United States; FoodNet, 1996–2003. *Epidemiol Infect* (2007); 135:293–301.
- 604 Gerba CP. Assessment of enteric pathogen shedding by bathers during recreational activity and its impact on water quality. *Quant Microbiol* (2000); 2:55-68.
- 605 CDC. Prevalence of parasites in fecal material from chlorinated swimming pools — United States, 1999. *MMWR* 2001;50(20):410–2.
- 606 OSHA. Bloodborne pathogens and needlestick prevention standards. Available at <http://www.osha.gov/SLTC/bloodbornepathogens/standards.html>. Accessed April 29, 2018.
- 607 OSHA. Bloodborne pathogens and needlestick prevention. Available at <http://www.osha.gov/SLTC/bloodbornepathogens>. Accessed April 29, 2018.
- 608 OSHA. Fact sheet: OSHA’s bloodborne pathogen standards. Available at http://www.osha.gov/OshDoc/data_BloodborneFacts/bbfact01.pdf. Accessed April 29, 2018.
- 609 EPA. Disinfection profiling and benchmarking guidance manual. 1999. Available at <https://nepis.epa.gov/Exe/ZyPDF.cgi/20002249.PDF?Dockey=20002249.PDF>. Accessed on April 29, 2018.
- 610 Shields JM, et al. The effect of cyanuric acid on the disinfection rate of *Cryptosporidium parvum* in 20-ppm free chlorine. *J Water Health.* 2009 Mar;7(1):109-14.
- 611 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol.* 2015;49(12):7348-55.
- 612 Chappell CL, et al. *Cryptosporidium parvum*: intensity of infection and oocyst excretion patterns in healthy volunteers. *J Infect Dis.* 1996 Jan;173(1):232-6.
- 613 Goodgame RW, et al. Intensity of infection in AIDS-associated cryptosporidiosis. *J Infect Dis.* 1993 Mar;167(3):704-9.
- 614 Shields JM, et al. The effect of cyanuric acid on the disinfection rate of *Cryptosporidium parvum* in 20-ppm free chlorine. *J Water Health.* 2009 Mar;7(1):109-14.
- 615 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol.* 2015;49(12):7348-55.
- 616 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. *Environ Sci Technol.* 2015;49(12):7348-55.
- 617 Shin GA, et al. Inactivation of norovirus by chlorine disinfection of water. *Water Res.* 2008 Nov;42(17):4562-8.
- 618 EPA. Disinfection profiling and benchmarking guidance manual. 1999. Available at <https://nepis.epa.gov/Exe/ZyPDF.cgi/20002249.PDF?Dockey=20002249.PDF>. Accessed on April 29, 2018.
- 619 CDC. Guidelines for environmental infection control in health-care facilities: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). *MMWR* (2003);52 (No.RR-10.)
- 620 Centerwall BS, et al. Erosion of dental enamel among competitive swimmers at a gas-chlorinated swimming pool. *Am J Epidemiol.* 1986;123(4):641-7.
- 621 Dawes C, et al. Rapid and severe tooth erosion from swimming in an improperly chlorinated pool: case report. *J Can Dent Assoc.* 2008;74(4):359-61.
- 622 Geurtsen W. Rapid general dental erosion by gas-chlorinated swimming pool water. Review of the literature and case report. *Am J Dent.* 2000;13(6):291-3.
- 623 Barbee SJ, et al. Acute inhalation toxicology of nitrogen trichloride. *Am Ind Hyg Assoc J.* 1983;44(2):145-6.

- 624 Hery M, et al. Exposure to chloramines in the atmosphere of indoor swimming pools. *Ann Occup Hyg* 1995;39(4):427-439.
- 625 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.
- 626 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.
- 627 Hery M, et al. Exposure to chloramines in the atmosphere of indoor swimming pools. *Ann Occup Hyg* 1995;39(4):427-439.
- 628 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.
- 629 Jacobs JH, et al. Exposure to trichloramine and respiratory symptoms in indoor swimming pool workers. *Eur Respir J.* 2007;29(4):690-8.
- 630 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. *Eur Respir J.* 2002;19(5):827-32.
- 631 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. *Eur Respir J.* 2002;19(5):827-32.
- 632 WHO. Guidelines for safe recreational water environments: Vol. 2- swimming pools and similar environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/. Accessed on April 23, 2018.
- 633 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.
- 634 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.
- 635 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.
- 636 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.
- 637 Li J, et al. Volatile disinfection byproduct formation resulting from chlorination of organic-nitrogen precursors in swimming pools. *Environ Sci Technol.* 2007;41(19):6732-9.
- 638 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.
- 639 Angenent LT, et al. Molecular identification of potential pathogens in water and air of a hospital therapy pool. *PNAS* 2005;102(13):4860-5.
- 640 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.
- 641 Leoni E, et al. Prevalence of Legionella spp. in swimming pool environment. *Water Res.* 2001;35(15):3749-53.
- 642 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.
- 643 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.
- 644 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.
- 645 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.
- 646 Milton DK, et al. Endotoxin exposure-response in a fiberglass manufacturing facility. *Am J Ind Med.* 1996;29(1):3-13.
- 647 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.
- 648 Rose CS, et al. "Lifeguard lung": endemic granulomatous pneumonitis in an indoor swimming pool. *Am J Public Health.* 1998;88(12):1795-800.
- 649 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.

-
- 650 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.
- 651 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.
- 652 Cavestri, RC, et al. 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>.
- 653 Alberta. Pool standards, 2006 for the swimming pool, wading pool, and water spray park regulation. (Last accessed July 6, 2016 at <https://open.alberta.ca/dataset/f2e84a9a-2e3c-43b4-8542-5762624c499a/resource/ef958320-f00b-43df-881d-0ecf6e67236e/download/Standards-Pools.pdf>).