

**Model Aquatic Health Code
Disinfection and Water Quality Module ANNEX Draft Sections
for the First 60-day Review**

**Posted for Public Comment on 02/27/2012
Currently Open for Public Comment that Closes on 04/27/2012**

In an attempt to speed the review process along, the MAHC steering committee has decided to release MAHC draft modules prior to their being fully complete and formatted. These drafts will continue to be edited and revised while being posted for public comment. The complete versions of the drafts will also be available for public comment again when all MAHC modules are posted for final public comment. The MAHC committees appreciate your patience with the review process and commitment to this endeavor as we all seek to produce the best aquatic health code possible.

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MAHC Disinfection & Water Quality Module Abstract

Disinfection and water quality are critical components in maintaining bather health and comfort. Health issues related to inadequate disinfection and poor water quality are increasingly being documented. Outbreak investigations have often determined that disinfectant levels and other water quality parameters were not maintained appropriately thereby allowing disinfectant-sensitive pathogens to be associated with pool use. The emergence of chlorine-tolerant microbes also necessitates changing accepted standards for pool treatment to protect the health of bathers in the future. The Disinfection and Water Quality Module takes the first steps in addressing these recurring and emerging aquatic health issues. The Disinfection and Water Quality Module contains requirements for new or modified construction that include:

- 1) Primary disinfectant levels set.
- 2) Secondary disinfection required for “increased risk” aquatic venues such as Interactive features, spray pads, wading pools, and other venues designed primarily for diaper-aged children as well as therapy pools
- 3) Combined chlorine maximum levels set
- 4) Prohibition of cyanuric acid in Indoor facilities and “increased risk” aquatic venues

MAHC Disinfection and Water Quality Module Review Guidance

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

Review Reminders:

- Please download and use the [MAHC Comment Form](http://www.cdc.gov/healthywater/swimming/pools/mahc/structure-content/) (<http://www.cdc.gov/healthywater/swimming/pools/mahc/structure-content/>) to submit your detailed, succinct comments and suggested edits. Return your review form by 04/27/2012, as an email attachment to MAHC@cdc.gov.
- If part of a larger group or organization, please consolidate comments to speed the MAHC response time to public comments.
- To provide context for this module review, please consult the [MAHC Strawman Outline](http://www.cdc.gov/healthywater/pdf/swimming/pools/mahc/structure-content/mahc-strawman.pdf) (<http://www.cdc.gov/healthywater/pdf/swimming/pools/mahc/structure-content/mahc-strawman.pdf>). Section headers of related content have been

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included in this draft module to assist reviewers to see where each section fits into the overall MAHC structure. Additional MAHC draft modules that contain this content will be or already have been posted for your review.

- The complete draft MAHC, with all of the individual module review comments addressed will be posted again for a final review and comment before MAHC publication. This will enable reviewers to review modules in the context of other modules and sections that may not have been possible during the initial individual module review.
- The published MAHC will be regularly updated through a collaborative all-stakeholder process.

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

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

Douglas C. Sackett, Director
MAHC Steering Committee

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

Reviewer Note on Module Section Numbering:

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

Reviewer Note on the MAHC Annex

Rationale

The annex is provided to:

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

Content

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

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

Appendices

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

Acronyms in this Module: See the Disinfection and Water Quality Module, Code Section

Glossary Terms in this Module: See the Disinfection and Water Quality Module, Code Section

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

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Model Aquatic Health Code Disinfection and Water Quality Module Annex 4.0 Design Standards and Construction

Keyword	Section	Annex
	4.0	Design Standards and Construction
	4.1	Plan Submittal
	4.2	Materials
	4.3	Equipment Standards
	4.4	Pool Operation and Facility Maintenance
	4.5	Pool Structure
	4.6	Indoor/Outdoor Environment
	4.7	Recirculation and Water Treatment
	4.7.1	
	4.7.2	
	4.7.3	Disinfection and Indoor Air Quality

*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 variables. Proper ventilation and humidity control are important in removing excess heat, moisture, noxious odors, and harmful DISINFECTION by-products.¹

In addition, proper usage of chemicals can also affect the quality of the indoor air environment.^{2,3,4}

High levels of chloramines and other volatile compounds in air can increase the possibility of adverse health effects such as upper respiratory illnesses and irritation of the mucous membranes.^{5,6}

¹ 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>.

² 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.

³ 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.

⁴ Centers for Disease Control and Prevention (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.

⁵ 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.

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Furthermore, these contaminants can also cause detrimental effects to metal structures and equipment.

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. Some research has been done that shows that non-CHLORINE shock oxidizers reduce the propensity to develop chloramines. However, this research has not been peer-reviewed to date. The EPA final guidelines state that manufacturers of “shock oxidizers” may advertise that their “shock oxidizer” products “remove,” “reduce,” or “eliminate” organic contaminants (***EPA Final Guidelines re “Shock Oxidizer” Products***, <http://apsp.org/APSPWeekllye-ad/Aug20-08/Shock%20Oxidizer.html>). Shock dosing with CHLORINE can destroy inorganic chloramines that are formed. SECONDARY DISINFECTION SYSTEMS such as ozone and ultraviolet light may effectively destroy inorganic as well as some organic chloramines.

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.⁷

These steps can reduce the chemical impact on indoor air quality, helping to maintain an environment

⁶ 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.

⁷ 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>.

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		that minimizes detrimental effects on BATHER comfort and health, as well as facilities and equipment.
	4.7.3.1	<i>Primary Disinfectants</i>
	4.7.3.2	<i>Stabilizers</i>
Secondary Disinfection Systems	4.7.3.3	<i>Secondary Disinfection Systems</i>
		<p>Due to the risk of outbreaks of recreational water illnesses (RWIs) associated with the disinfectant tolerant pathogen <i>Cryptosporidium</i>, it is strongly recommended that aquatic facilities include SECONDARY DISINFECTION SYSTEMS to minimize the risk to the public associated with these outbreaks.</p> <p>However, there are some facilities where the risk of acquiring a RWI is elevated (INCREASED RISK AQUATIC VENUES) due to either the use of the facility, or the users of the facility. Therapy POOLS, for example, are often utilized by individuals with compromised immune systems and / or open wounds. The risk of acquiring a 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.⁸ Water features 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.</p> <p>The intent of requiring a SECONDARY DISINFECTION SYSTEM (SDS) is to limit the length of exposure to gastrointestinal pathogens, in particular <i>Cryptosporidium</i>, after a fecal accident in INCREASED RISK AQUATIC VENUES.</p>

⁸ Yoder JS et al; Centers for Disease Control and Prevention (CDC). Cryptosporidiosis surveillance - United States, 2006-2008. MMWR Surveill Summ. 2010 Jun 11;59(6):1-14.

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		<p>These facilities include therapy POOLS, and wading POOLS, water activity POOLS, interactive water features, spray pads, and other AQUATIC VENUES designed primarily for young children including diaper-aged children. In these facilities the potential of gastrointestinal illness is elevated due to the population mix of the patrons and the design of the facility. The pathogens of concern in such facilities are <i>Cryptosporidium</i>, <i>Giardia</i>, <i>Shigella</i>, <i>E. coli</i> O157:H7, and norovirus. Because of the seriousness of illness caused by these pathogens, particularly CHLORINE tolerant <i>Cryptosporidium</i>, a SECONDARY DISINFECTION SYSTEM is required for all new construction of these types of facilities after the adoption of this CODE. When older facilities are renovated they must retrofit to meet this treatment requirement.</p>

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.^{9,10,11} In order to design a treatment system that can reduce the duration of exposure to a single day the Technical Committee made the following assumptions:

- The target of concern is *Cryptosporidium*. Based on known CT values, all other pathogens will be inactivated within an hour if the facility is maintaining at least 1ppm of free

⁹ Causer L et al. An outbreak of *Cryptosporidium hominis* infection at an Illinois recreational waterpark. *Epidemiol Infect.* 2006 February; 134(1): 147–156.

¹⁰ 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.

¹¹ Centers for Disease Control and Prevention (CDC). Communitywide cryptosporidiosis outbreak--Utah, 2007. *MMWR Morb Mortal Wkly Rep.* 2008 Sep 12;57(36):989-93.

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		<p>CHLORINE.</p> <ul style="list-style-type: none"> • At a concentration of 1 ppm free CHLORINE any <i>Cryptosporidium</i> 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 ~100ml could introduce 10⁸ <i>Cryptosporidium</i> OOCYSTS into the water.^{12,13} • Reducing the amount of <i>Cryptosporidium</i> below the level at which there is one infectious OOCYST per average volume swallowed by swimmers (16-128ml) would be a reasonable target for overnight remediation of the water to reduce the risk of transmission beyond the day of initial contamination.^{14,15} The concentration chosen was one OOCYST/100ml • The only effective means currently to reduce the concentration of OOCYST in an AQUATIC VENUE is by dilution. 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 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 10⁸ OOCYSTS introduced into a AQUATIC VENUE (i.e. a diarrheal event) to be reduced to a maximum

¹² 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.

¹³ Goodgame RW et al. Intensity of infection in AIDS-associated cryptosporidiosis. J Infect Dis. 1993 Mar;167(3):704-9.

¹⁴ Dufour AP et al. Water ingestion during swimming activities in a pool: a pilot study. J Water Health. 2006 Dec;4(4):425-30.

¹⁵ Allen LM et al. Absorption and excretion of cyanuric acid in long-distance swimmers. Drug Metab Rev. 1982;13(3):499-516.

Keyword	Section	Annex
		<p>concentration of 1 OOCYST per 100 ml.</p> <ul style="list-style-type: none"> • 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. • Any treatment system that demonstrates this reduction in <i>Cryptosporidium</i> 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.

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 flowrate. While this was recommended by the Technical Committee, ultimately this approach was rejected by the steering committee. 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 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.

In developing this approach the technical committee considered establishing maximum permissible concentrations of OOCYSTS, which would be monitored and verified, but rejected that approach as impractical since it would require actual lab testing.

Establishing a concentration based standard for the

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water cannot be 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 including the number of OOCYSTS released per accident, the number of accidents 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 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.

SECONDARY DISINFECTION SYSTEMS are located in the treatment loop (post filtration) and treat a portion (up to 100%) of the recirculation flow prior to return of the water to the POOL or AQUATIC FEATURE.

Examples of SECONDARY DISINFECTION SYSTEMS include but are not necessarily limited to: UV DISINFECTION and Ozone DISINFECTION.

Records of the correct calibration, maintenance and operation of SECONDARY DISINFECTION SYSTEMS should be maintained by the facility's management.

UV Disinfection

4.7.3.3.3 Ultraviolet Disinfection

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

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Validation	<p>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. Where possible, transmissivity tests should be obtained for existing facilities.</p>	<p>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.</p> <p>It is important to note that evidence of testing is not the same as validation.</p> <p>Validation must follow one of the approved validation systems, preferably the USEPA DGM 2006, MUST have been carried out by a genuine third party, and MUST include all the required validation factors and RED bias.</p> <p>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.</p>
Validation Factor	<p>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.</p>	
RED Bias	<p>The USEPA 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</p>	

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<i>Transmissivity (Transmission)</i>	delivery of validated performance. Depending on the quality of the water, this RED bias can be between 35% and 70%.	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 1cm, 4cm or 5cm cell. It is measured in a UV Spectrophotometer.
	In many water treatment applications, this value will vary very considerably but swimming POOLS are for the most part consistent, due to the bleaching effect of the CHLORINE used as a residual disinfectant.	
	Typically swimming POOLS will have a transmission of between 94% and 95% in a 1 cm cell, with splash pads and other interactive features 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 are with a UV unit installed and operational.	
	Design transmissions over 94% are not recommended, and exceptionally heavily loaded facilities 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.	
<i>Validation Range</i>	A validated system will have different performance levels at different water qualities and flows. The	

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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 500gpm is NOT validated for any flow over 500gpm

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 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 $60\text{mJ}/\text{cm}^2$ 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 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

Keyword	Section	Annex
Ozone Disinfection	4.7.3.3.4	Ozone Disinfection
		reduction in performance, and assure themselves that the equipment will still provide a beneficial level of performance.
		Ozone is a SECONDARY DISINFECTION SYSTEM and must meet the minimum requirements of all SECONDARY DISINFECTION SYSTEMS as defined in section 4.7.3.3.
		Ozone is an antimicrobial oxidizer. Its use as a SECONDARY DISINFECTION SYSTEM in commercial swimming POOLS in the U.S. dates back to the 1930's. Ozone is proven to kill <i>Cryptosporidium parvum</i> ¹⁶ , <i>Giardia</i> ¹⁷ , <i>E. coli</i> ¹⁸ , and <i>Pseudomonas aeruginosa</i> ¹⁹ , along with any other microorganism potentially found in swimming POOLS, 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 the Occupational Safety and Health Administration (OSHA) has identified a time weighted average (TWA) of 0.1 PPM (0.2 mg/m ³) as the permissible exposure limit for ozone.

¹⁶ 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.

¹⁷ Wickramanayake GB et al. Inactivation of *Giardia lamblia* cysts with ozone. Appl Environ Microbiol. 1984 Sep;48(3):671-2.

¹⁸ Cho M et al. Mechanisms of *Escherichia coli* inactivation by several disinfectants. Water Res. 2010 Jun;44(11):3410-8.

¹⁹ 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.

Keyword
Material Selection

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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.

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)

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		<ul style="list-style-type: none">• PVDF (Polyvinylidene Fluoride), Kynar® (Pennwalt patent)
	3. Gaskets and O-rings	<ul style="list-style-type: none">• 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	<p>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.</p>

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.

There currently is no recognized national standard for validation of ozone equipment for inactivation of cryptosporidium. To be considered acceptable as a national standard, the standard must be ANSI approved or developed by a Federal Agency following a development process consistent with ANSI criteria.

Supplemental Treatment Systems

4.7.3.4

Supplemental Treatment Systems

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Keyword	Section	Annex
		<p>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 <i>Cryptosporidium</i>, and may not remove chloramines as effectively as SECONDARY DISINFECTION SYSTEMS. However, if sized within supplementary treatment system requirements in Sections 4.7.3.4, a SUPPLEMENTAL TREATMENT SYSTEM may be of benefit in maintaining air quality at indoor facilities, reducing the <i>Cryptosporidium</i> burden over an extended period of time, and reducing the amount of disinfectant needed to maintain required disinfectant levels.</p> <p>Although SUPPLEMENTARY TREATMENT SYSTEMS are optional, it should be noted that this CODE, as written, represents best practice.</p>
UV Light	4.7.3.4.2	<p>Ultraviolet Light</p> <p>See information presented in Section 4.7.3.3.3 of this annex.</p>
Ozone	4.7.3.4.3	<p>Ozone</p> <p>See information presented in Section 4.7.3.3.4.</p>
Copper / Silver Ion	4.7.3.4.4	<p>Copper/Silver Ion</p> <p>The scientific data available on efficacy of these systems is predominantly for bacterial inactivation and always includes FREE AVAILABLE CHLORINE.^{20,21}</p> <p>There is insufficient scientific literature that documents the efficacy of these systems on viruses and parasites.</p>

²⁰ 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.

²¹ Beer CW et al. Swimming Pool Disinfection: Efficacy of copper/silver ions with reduced chlorine levels. J Environmental Health, 61(9): 9-12.

Keyword	Section	Annex
UV Light / Hydrogen Peroxide Systems	4.7.3.4.5	<p>Given the importance and frequency of recreational water illnesses associated with these other microorganisms (viruses and parasites), it is essential that DISINFECTION chemicals / systems are also effective against such microorganisms as well.</p> <p><i>Ultraviolet Light / Hydrogen Peroxide Systems</i></p> <p>UV-peroxide systems have not been registered by the US 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 POOL. Hydrogen peroxide is used as a hard surface disinfectant and has been granted registration for this purpose by the US 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 facility. Further, hydrogen peroxide is not registered by the US 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 the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).</p> <p>UV-peroxide system should not be used as a SUPPLEMENTAL DISINFECTING SYSTEM on CHLORINE treated POOLS. The addition of hydrogen peroxide to a CHLORINE-treated POOL will inactivate the hypochlorous acid. If sufficient hydrogen peroxide is added, the hypochlorous acid will be completely eliminated and no disinfectant for inactivation of pathogenic organisms will remain.</p>

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Model Aquatic Health Code Disinfection and Water Quality Module Annex 5.0 Operation and Maintenance

Keyword	Section	Annex
	5.0	Operation and Maintenance
	5.1	Plan Submittal
	5.2	Materials
	5.3	Equipment Standards
	5.4	Pool Operation and Facility Maintenance
	5.5	Pool Structure
	5.6	Indoor/Outdoor Environment
	5.7	Recirculation and Water Treatment
	5.7.1	Recirculation Systems and Equipment
	5.7.2	Filtration
	5.7.3	Disinfection
	5.7.3.1	Oxidants
	5.7.3.1.1	Chlorine

Minimum Free Available Chlorine (FAC)

5.7.3.1.1.3 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 cyanuric acid, higher FAC levels may be necessary for POOLS using cyanuric acid or stabilized CHLORINE.

The minimum FAC level of 1.0 PPM (MG/L) for swimming POOLS is well-supported by available data. CDC website data indicates that a 1.0 PPM (MG/L) FAC residual can provide effective DISINFECTION of most pathogens other than *Cryptosporidium*.²²

Germ	Time
<i>E. coli</i> O157:H7 Bacterium	Less than 1 minute
Hepatitis A Virus	About 16 minutes
<i>Giardia</i> Protozoan	About 45 minutes
<i>Cryptosporidium</i> Protozoan	About 15,300 minutes (10.6 days)

²² Centers for Disease Control and Prevention (CDC). Chlorine Disinfection Timetable. Last modified May 07, 2010. Accessed February 6, 2012. <http://www.cdc.gov/healthywater/swimming/pools/chlorine-disinfection-timetable.html>.

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Germ inactivation for chlorinated water*

* Laboratory testing results using CHLORINE demand free water with 1 PPM (MG/L) (1MG/L) CHLORINE at PH 7.5, 77° F (25° C) and in the absence of cyanuric acid

Swimming POOL survey data demonstrates that 1.0 PPM (MG/L) FAC provides acceptable bacteriological quality.^{23,24} (available at www.nspf.org/research.html).

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.”²⁵

A minimum FAC level (3.0 PPM (MG/L)) for INCREASED RISK AQUATIC VENUES addresses the higher BATHER load, higher temperatures and/or at-risk populations served by these venues. This minimum requirement is consistent with CDC *Final Recommendations to minimize transmission of Legionnaires disease from 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* were rapidly reestablished in whirlPOOLS (< 10³ cells per ml) when disinfectant concentrations decreased below recommended levels [CHLORINE, 3.0 PPM (MG/L), bromine 6.0 PPM (MG/L)].²⁶

In general, a range of 2-4 PPM (MG/L) FAC for POOLS (3-5

²³ Esterman A et al. Determinants of the microbiological characteristics of South Australian swimming pools. *Appl Environ Microbiol.* 1984 February; 47(2): 325–328.

²⁴ Leoni E et al. Risk of infection associated with microbiological quality of public swimming pools in Bologna, Italy. *Public Health.* 1999 Sep;113(5):227-32.

²⁵ 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.

²⁶ Price D, Ahearn DG. Incidence and persistence of *Pseudomonas aeruginosa* in whirlpools. *J Clin Microbiol.* 1988 Sep;26(9):1650-4.

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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 cyanuric acid, higher FAC levels may be necessary for POOLS using cyanuric acid or stabilized CHLORINE.^{27,28,29}
- **Algae control:** Algae is more difficult to control than most pathogens and may require FAC residuals >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.

Maximum FAC

Maximum FAC

FAC levels shall be consistent with label instructions of the disinfectant. All POOL and spa disinfectants must be

²⁷ 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.

²⁸ Fitzgerald GP, DerVartanian ME. Factors influencing the effectiveness of swimming pool bactericides. Appl Microbiol. 1967 May;15(3):504-9.

²⁹ 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.

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registered by the U.S. Environmental Protection Agency (EPA) under the Federal Insecticide, Fungicide and Rodenticide Act. MAHC Technical and Steering committees welcome input and supporting data for establishing upper limits.

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 of 4 PPM (MG/L) for drinking water.

No data was 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 CHLORINE.³⁰

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

³⁰ 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. Accessed at http://www.who.int/water_sanitation_health/dwq/chlorine.pdf

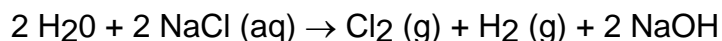
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hydroxide



The hydrogen gas is dissolved in the water and eventually vents to the atmosphere. The CHLORINE gas then dissociates into hypochlorous acid (HOCl), which provides a residual of FREE AVAILABLE CHLORINE (FAC).



Operators must still test the FAC residual of the water to ensure that the cell is producing adequate CHLORINE for the POOL. The cells are usually sized to treat the POOL effectively with run time of 50% to 60%. This allows the system to be “boosted” to run 100% of the time as a method of shocking 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.

The water exiting the cell has a relatively high PH in comparison to the recommended ranges for POOL operation. 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. They systems have sensors and cut-offs to prevent this damage, but operators must be sure to

<i>Keyword</i>	<i>Section</i>	<i>Annex</i>
<i>Bromine</i>	5.7.3.1.2	<i>Bromine</i> <p>monitor the unit to recognize when there is a problem.</p> <p>The US 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 USEPA under the Federal Insecticide Fungicide and Rodenticide Act (FIFRA). The efficacy data analyzed by the US EPA is company confidential and has not been reviewed as part of the development of the MAHC. MAHC Technical and Steering committees welcome input and supporting data for establishing upper limits.</p> <p>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.</p> <p>Commercially available test kits are not capable of distinguishing free bromine (Br_2, 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 ($\text{Br} = 79.90$ grams per mole and $\text{Cl} = 35.45$ grams per mole).</p> <p>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 hypobromous acid, whereas at the same pH, hypochlorous acid is 55% in chlorinated water. At pH of 8.0 bromine still</p>

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has 83% hypobromous acid, while in a chlorinated water, hypochlorous acid is 28%.³¹

Bromine is also not very common in outdoor POOLS because like CHLORINE, bromine is destroyed rapidly in sunlight. Cyanuric acid 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. 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 whirlPOOLS (<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 treatment.²⁴

The committee recommends a follow up study to evaluate the efficacy of bromine on *P. aeruginosa*, since it is so commonly found in spas, and because bromine is 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 reported reasonable bacterial control with 2.0 total bromine in an 118,000 gallon indoor POOL using BCDMH.³² Normal day time BATHER loading was around 0.21 persons per 500 gallons 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

³¹ White GC. 1999. Handbook of chlorination and alternative disinfectants. 4th ed.: John Wiley and Sons, Inc. New York.

³² Brown JR et al. Bromine disinfection of a large swimming pool. Can J Public Health. 1964 Jun;55:251-6.

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the low reported ammonia nitrogen and organic nitrogen. Shaw reports a retrospective analysis of brominated and chlorinated semi-public spas in Alberta.³³ 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 hypochlorous acid/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 US 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

Bromates

Ozone and bromide ions in water form hypobromous acid and bromate ions. Bromates have been classified by the International Agency for Research on Cancer (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 USEPA 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.

At present there is little information on the functionality of using DMH in this manner. Since there is not a convenient

³³Shaw 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.

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field test kit 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 don't 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.

Ozone should 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), the ozone readily converts residual bromide ion back to hypobromous acid. 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

DISINFECTION using bromine is more complex but less well documented than DISINFECTION using CHLORINE. Hypobromous acid is the putative biocidal chemical species at recreational water pH. Hypobromous acid reacts with inorganic ammonia and forms monobromamine, dibromamine, and nitrogen tribromide, depending on the pH and concentration of ammonia.³⁴ These inorganic bromamines are all considered more biocidal than their corresponding CHLORINE analogs. Hypobromous acid is converted to inert bromide ion upon biocidal action in a manner similar to that seen with hypochlorous acid. One key difference between bromine and CHLORINE DISINFECTION is that bromide is readily oxidized back to hypobromous acid and chloride is not. Further, hypobromous acid is a much weaker oxidizer than hypochlorous acid. As a consequence

³⁴ Galal-Gorchev H et al. Formation and stability of bromamide, bromimide, and nitrogen tribromide in aqueous solution. *Inorganic Chemistry*. 1965;4(6):899-905.

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of these two differences, exogenous OXIDATION of brominated waters (e.g. shocking with CHLORINE, or supplemental OXIDATION with either ozone or potassium monopersulfate) 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

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, hypobromous acid, monobromamine, dibromamine, and nitrogen tribromamide) depending in the PH and concentration of ammonia.³³ 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 reduced.³⁵ The levels of ammonia that result in loss of bromine of efficacy have been detected in spa water.³⁶ At these documented concentrations of bromine and ammonia the predominant bromamine is most likely dibromamine, which has an estimated half-life of 10 minutes.³⁷ The technical committee was not able to locate data on the efficacy of organic bromamines.

Future Research Needs

Future Research Needs

³⁵ Wyss O et al. The germicidal action of bromine. Arch Biochem. 1947 Feb;12(2):267-71.

³⁶ 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.

³⁷ Johnson JD et al. Bromine and bromamine disinfection chemistry. J of Sanitary Engineering Division Am Soc of Civil Eng, 1971;97:617-628.

Keyword

Cryptosporidium
Inactivation

Section

Annex
Cryptosporidium Inactivation

Methods to hyper-brominate recreational water in response to diarrheal fecal accidents have not been established. Inactivation of *Cryptosporidium* using hypobromous acid has been shown to be approximately three times higher than what is found with CHLORINE and therefore would require 22 hours for 30 PPM (MG/L) bromine at PH 7.5 for a 3 log reduction (unpublished CDC data). Whether all inorganic bromamines are equally as OOCYSTICIDAL as hypobromous acid is not known. A method to hyper-brominate to the 30 PPM (MG/L) hypobromous acid treatment would need to consider the oxidizer demand from organics which often accumulates in bromine systems as well as the oxidizer demand from the large bank of bromide ions that are known to accumulate with BCDMH and DBDMH systems. Research in this area is lacking.

Bromine
Associated
Rashes

Bromine Associated Rashes

Note to readers: These comments have been inserted to point future researchers toward an under-investigated area of public health, not meant to imply a negative bias towards 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 medical literature.^{38,39,40} 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

³⁸ Rycroft RJ et al. Dermatoses associated with brominated swimming pools. Br Med J (Clin Res Ed). 1983 Aug 13;287(6390):462.

³⁹ Fitzgerald DA et al. Spa pool dermatitis. Contact Dermatitis. 1995 Jul;33(1):53.

⁴⁰ 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.

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bromine treated water and is particularly prevalent among medical personnel provide aquatic physical therapy.⁴¹ The exact compounds inducing contact dermatitis have not been identified. One study strongly suggests that the use of bromine with supplemental OXIDATION minimizes contact dermatitis.⁴² 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 RWI⁴³). The typical incubation period for *Pseudomonas aeruginosa* folliculitis is several days but can be as short at 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 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 DISINFECTIONS. After reviewing the literature, the committee has concluded the following research is essential to understanding bromine DISINFECTION.

Further research needs to address, in priority order:

1. The efficacy of bromine to establish a minimum concentration for AQUATIC VENUES and warm water spas and therapy POOLS.
2. The maximum bromine concentration that should be allowed

⁴¹ Lazarov A et al. Self-reported skin disease in hydrotherapists working in swimming pools. Contact Dermatitis. 2005 Dec;53(6):327-31.

⁴² Kelsall HL et al. Skin irritation in users of brominated pools. Int J Environ Health Res. 2001 Mar;11(1):29-40.

⁴³ Woolf A et al. Reactive airways dysfunction and systemic complaints after mass exposure to bromine. Environ Health Perspect. 1999 Jun;107(6):507-9.

<i>Keyword</i>	<i>Section</i>	<i>Annex</i>
		3. The contribution of bromamines to DISINFECTION and BATHER rashes
		a. Methods to better control bromamines
		b. Creation of a test kit to differentiate free bromine from combined (as is currently practiced with CHLORINE) in the water
		4. Use of DMH in respect to bromate formation
		a. Establish a safe maximum level
		b. Creation of a test kit to establish levels in the water
		5. Fecal accident recommendations to control <i>Cryptosporidium</i> when using a bromine POOL.

Stabilizers **5.7.3.2** **Stabilizers**

Cyanuric Acid **5.7.3.2.1** **Cyanuric Acid (CYA)**

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 cyanuric acid. Trichlor is commonly found as tablets or sticks. Dichlor is a granular material, as is the isocyanuric acid.

Products containing or forming cyanuric acid (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 acid helps maintain free CHLORINE levels in outdoor POOLS.

CYA acid 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 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.

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Minimum
Disinfection

Minimum Disinfection

Minimum CHLORINE levels should be increased by a factor of at least two when using CYA. Robinton et al⁴⁴ found that “50 mg/L of cyanuric acid produced pronounced retardation of the bactericidal efficiencies of solutions of calcium hypochlorite, trichloroisocyanuric 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.”⁴⁵

Laboratory studies by Warren and Ridgway show that addition of 50 MG/L cyanuric acid to 0.5 - 1.0 MG/L available CHLORINE resulted in a significant increase in CT *Staphylococcus aureus*, in parallel with the increase in available CHLORINE stability in sunlight. However, higher concentrations of cyanuric acid resulted in little to modest further increases in CT over that for 50 MG/L cyanuric acid. For example, the data suggest that for 50, 100 and 200 MG/L of cyanuric acid, 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 respectively.⁴⁶

Indoor POOLS

Indoor POOLS

There is no operational or public health reason for indoor AQUATIC VENUES to use CYA. It is a stabilizer for degradation from direct sunlight and so has no benefits for indoor POOLS. However, since the addition of cyanuric acid in an indoor environment reduces the OXIDATION potential, the recommended maximum level is zero.

CDC does not recommend cyanuric acid use for indoor POOLS or hot tubs. The recommendation was underscored in

⁴⁴ 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.

⁴⁵ 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.

⁴⁶ 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.

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a 2000 MMWR after investigating a *Pseudomonas dermatitis/folliculitis* outbreak associated with indoor POOLS and hot tubs in Maine, noting that cyanuric acid was added to an indoor POOL which reduces the antimicrobial capacity of free CHLORINE.^{47,48}

Effects of CYA

Effects of Cyanuric Acid on Microbial Inactivation

There are a large number of references on the effect of CYA on kill times (CT values). In general, they show that the presence of CYA increase CT 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 cyanuric acid are required to maintain a swimming POOL in a biologically satisfactory state.

Studies examining the effect of cyanuric acid on the DISINFECTION capacity of CHLORINE show that using cyanuric acid or stabilized CHLORINE slows down the inactivation times on bacteria, algae, protozoa (*Naegleria gruberi* and *Cryptosporidium parvum*), and viruses.⁴² Yamashita et al concluded the addition of cyanuric acid increased the time needed for DISINFECTION of 12 virus types by a factor of 4.8-28.8 compared to free CHLORINE alone.⁴⁹

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

⁴⁷ Fitzgerald GP et al. . *Pseudomonas aeruginosa* for the evaluation of swimming pool chlorination and algicides. Appl Microbiol. 1969 Mar;17(3):415-21.

⁴⁸ Centers for Disease Control and Prevention (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.

⁴⁹ 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.

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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 al⁵⁰ 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 3 swimming POOLS using trichloroisocyanurates, poliovirus type 1 survived after 2 min contact while in 5 samples poliovirus type 1 survived after 5 min 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 poliovirus.⁵¹ Likewise, algacidal activity was reduced in the presence of cyanuric acid.⁵² There are few data regarding protozoa and the effect of CYA on inactivation though the DISINFECTION rate for *Naegleria gruberi* was reduced by cyanuric acid.⁵³

Shields et al⁵⁴ extended the previous findings by demonstrating that cyanuric acid significantly decreases the rate of inactivation for *Cryptosporidium parvum* OOCYSTS. In this study a three-log reduction of OOCYSTS was found to

⁵⁰ 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.

⁵¹ 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.

⁵² Sommerfeld MR, Adamson RP. Influence of stabilizer concentration on effectiveness of chlorine as an algicide. Appl Environ Microbiol. 1982 Feb;43(2):497-9.

⁵³ Engel J P et al. Inactivation of *Naegleria gruberi* cysts by chlorinated cyanurates. Appl Environ Microbiol. 1983;46:1157–1162.

⁵⁴ 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.

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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.

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 cyanuric acid was greater as the concentration of CHLORINE in the water decreased.⁴⁴

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*.⁵⁵

CYA and ORP
Controllers

CYA and ORP Controllers/ Interferences

Data show that when CYA is greater than 50 PPM (MG/L), it interferes with ORP controllers. These controllers measure the potential for OXIDATION in the water (regardless of the type of oxidizer present). The accuracy of the ORP measuring device is not compromised by the CYA; the actual strength of OXIDATION in the water is compromised; therefore the POOL water's lower ORP reading is an indication of lower OXIDATION potential in the water. This potential is further decreased as the CYA concentration in the water is increased, regardless of the PPM (MG/L) level of the CHLORINE in the water.

Cyanuric Acid has also been show to interfere with the Total Alkalinity test. See information in Total Alkalinity section of this Annex.

Meters for PH and TDS may also be compromised if the probes are coated by CYA. See information in PH and TDS section of this Annex.

⁵⁵ Favero, MS et al. Use of staphylococci as indicators of swimming pool. Public Health Rep. 1964 Jan;79:61-70.

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Fecal Accident
Response

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Fecal Accident Response

The use of stabilized CHLORINE is not recommended for hyperchlorination in RWI outbreaks, or in response to fecal accidents. Present MAHC requirements for hyperchlorination and POOL remediation are ineffective for POOLS using cyanurate-stabilized CHLORINE.

Toxicity

Toxicity

The maximum CYA concentration of 50 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 US EPA SWIMODEL, relying on somewhat lower exposure assumptions, would yield a higher acceptable level for CYA.

Research

Research

Though the data shows using CYA reduces the inactivation time of many pathogens, the committee would like to have a study done on specific pathogens and inactivation rates at differing CYA levels, up to 200 PPM (MG/L). Further research on the inhibitory effect of cyanuric acid on DISINFECTION should evaluate the level at which cyanuric acid 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 cyanuric acid 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 cannot read values lower than 30 PPM (MG/L) and higher than 100 PPM (MG/L). During RWI outbreaks, it is strongly recommended that the investigation team measure CYA levels.

Secondary
Disinfection
Systems

5.7.3.3

Secondary Disinfection Systems

Due to the risk of outbreaks of recreational water illnesses

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(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 POOL or water feature turnover rate and mixing/circulation within the POOL or water feature, 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 facilities presents a higher risk of recreational water illness (RWI) to users. These facilities include therapy POOLS, wading POOLS, swim schools, and aquatic play facilities / features (spray pads), and aquatic play facilities / features. Given that users of these types of facilities frequently have lesser-developed immune systems (children), and / or a higher prevalence of disease (children and older adults), and / or compromised immune systems, and / or open wounds, additional precautions against RWIs are warranted.

CDC swimming POOL surveillance reports shows that of the 21,500 inspections conducted between May and September of 2002, water chemistry violations were found at 38.7% of these facilities. Of this percentage, 14.3% of the violations

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were for inadequate DISINFECTION levels at therapy POOLS.⁵⁶

The use of interactive fountains 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 Florida.⁵⁷

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 sufficient to protect the patrons from this disease. In response, emergency legislation was passed, which required the installation of secondary DISINFECTION (e.g., ultraviolet radiation or ozonation) on water returning through the sprayers).⁵⁸

pH

5.7.3.5

pH

There are three reasons to maintain pH: 1) efficacy of the CHLORINE, 2) BATHER comfort, and 3) maintenance of balanced water, each of which are discussed briefly below. 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. 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

⁵⁶ Centers for Disease Control and Prevention (CDC). Surveillance data from swimming pool inspections--selected states and counties, United States, May--September 2002. MMWR Morb Mortal Wkly Rep. 2003 Jun 6;52(22):513-6.

⁵⁷ Centers for Disease Control and Prevention (CDC). 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.

⁵⁸ Yoder JS et al; Centers for Disease Control and Prevention (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 Sep 12;57(9):1-29.

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the internet as of July 2009. The discussion on efficacy and BATHER comfort is a summary of the 1972 edition discussion on pH.

Efficacy of Chlorine

Efficacy of Chlorine

CHLORINE used in POOLS refers to hypochlorous acid. Hypochlorous acid (HOCl) is a weak acid that readily dissociates to form hypochlorite (OCl⁻) and hydrogen ion (H⁺). The mid-point of the dissociation (the pK_a) is at PH 7.5. Functionally, this means that at PH of 7.5, 50% (fifty percent) of the free CHLORINE present will be in the form of hypochlorous acid and 50% (fifty percent) will be in the form of hypochlorite. As the PH decreases below 7.5, the proportion of hypochlorous acid increases and proportion of hypochlorite ion decreases. The opposite occurs as the PH increases above 7.5. Numerous investigators have reported that hypochlorous acid 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 hypochlorous acid portion of the free CHLORINE present in the water.

Bather Comfort

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 BATHER'S eyes to PH changes of 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.

Water Balance

Water 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,

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and temperature. The presently used water balance parameters are used to protect POOL 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 appendix.

Lowering pH

Potential for Lowering pH in the Future

During the review of the data the technical committee had a broad interest in lowering the minimum pH. This would increase the efficacy of the CHLORINE by increasing the proportion of hypochlorous acid (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 technical committee 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.

5.7.4 Water Quality

Clarifiers,
Flocculants,
and Defoamers

Clarifiers, Flocculants and Defoamers

POOLS and spas may benefit from the use of one or more of these types of products periodically. 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 US EPA or any other federal agency. The state of California does require submission of a detailed data package prior to registration.

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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, 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.

Total Alkalinity
Level

5.7.4.3.2

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 CODE, the ideal level is 80 – 120 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.

If total alkalinity is too low: PH changes rapidly when chemicals or impurities enter the water. PH may drop rapidly, causing etching and corrosion.

Raising total alkalinity - Total alkalinity can be raised by the addition of bicarbonate of soda (sodium bicarbonate, baking soda). 1.4 lbs. bicarbonate of soda per 10,000 gallons will raise total alkalinity ~10 PPM.

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. If the total alkalinity is too high, it can make PH adjustment difficult.

To lower total alkalinity, add acid - The acid reacts with bicarbonates in the water and reduces the total alkalinity.

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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 cyanuric acid will cause interference in the total alkalinity test. This interference is magnified at low levels of total alkalinity. To correct for cyanuric acid interference, measure the concentration of cyanuric acid, 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.

Pool Water
Chemical
Balance
Chloramines
(Combined
Chlorine)

5.7.4.3.3 Pool Water Chemical Balance

5.7.4.3.3.1 Combined CHLORINE compounds (chloramines) are formed when FREE AVAILABLE CHLORINE 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 as quick kill disinfectants than FREE AVAILABLE CHLORINE. If the local water treatment plant uses chloramination for drinking water DISINFECTION, inorganic chloramines (predominantly monochloramine) may be present in the fill water.

A high level of chloramines is undesirable in POOLS and spas. The maximum level for combined CHLORINE is 0.4 PPM (MG/L). Higher levels indicate that bathing loads or pollution from BATHERS may be too high, or that treatment is inadequate. Higher levels and may also pose a health concern to swimmers, employees and other POOL attendees.

The World Health Organization recommends that combined

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CHLORINE levels be “as low as possible, ideally below 0.2 MG/L”⁵⁹. However, this “ideal” level would be challenging to implement as a CODE requirement.

Published data are limited, but suggest that combined CHLORINE levels are commonly above 0.2 PPM (MG/L) in swimming POOL water.^{60, 61, 62}

Volatilization of chloramine compounds can lead to strong objectionable odors in POOL environments, as well as eye, mucous membrane and skin irritation for POOL users and attendants. Among the inorganic chloramines, NCl₃ has the greatest impact on air quality, owing to its relatively low affinity for water and its irritant properties. NCl₃ has been reported to be an irritant at concentrations in water as low as 0.02 PPM (MG/L).^{6, 63}

Odors are unlikely to be present from organic chloramines below the following concentrations⁶⁴:

- Monochloramine (NH₂Cl) 5.0 PPM (MG/L)
- Dichloramine (NHCl₂) 0.8 PPM (MG/L)
- Nitrogen trichloride (NCl₃) 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 NCl₃ concentration is dynamic and impacted by BATHER load, swimmer activity, liquid phase NCl₃

⁵⁹ World Health Organization. 2006. Guidelines for safe recreational water environments. Volume 2, Swimming pools and similar environments. World Health Organization, Geneva, p. 71. (http://www.who.int/water_sanitation_health/bathing/srwe2full.pdf)

⁶⁰ Weaver WA et al. Volatile disinfection by-product analysis from chlorinated indoor swimming POOLS. Water Res. 2009 Jul;43(13):3308-18.

⁶¹ 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.

⁶² 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.

⁶³ 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 (Great Britain), 35 pp., Oct 1978.

⁶⁴ White GC. 1999. Handbook of chlorination and alternative disinfectants. 4th ed.: John Wiley and Sons, Inc. New York.

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concentration. Reliable sampling and analytical methods affect the accuracy of the characterization of the POOL water and air.⁵⁷

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 swimming POOLS.⁶⁵ CDC has intervened and 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.^{66, 67}

For lifeguards at swimming POOLS, an exposure–response relationship has been identified between NCl_3 , measured as total chloramines, and irritant eye, nasal, and throat symptoms, although not chronic respiratory symptoms or bronchial hyper responsiveness.⁶

In addition to potential occupational exposures, there have been a number of studies investigating respiratory conditions, including asthma, related to swimming POOLS.

There appears to be no consistent association between swimming POOL attendance during childhood and the prevalence of asthma or atopic disease.^{68, 69, 70} 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

⁶⁵ World Health Organization. 2006. Guidelines for safe recreational water environments. Volume 2, Swimming pools and similar environments. World Health Organization, Geneva, p. 71.

⁶⁶ Dziuban EJ et al. Surveillance for waterborne disease and outbreaks associated with recreational water—United States, 2003–2004. MMWR Surveill Summ. 2006 Dec 22;55(12):1–30.

⁶⁷ Centers for Disease Control and Prevention (CDC). Ocular and respiratory illness associated with an indoor swimming pool --- Nebraska, 2006, MMWR Morbidity and Mortality Weekly Report. 2007;56(36):929–932.

⁶⁸ Goodman M et al. Asthma and swimming: a meta-analysis. J Asthma. 2008 Oct;45(8):639–47.

⁶⁹ Schoefer Y et al. Health risks of early swimming pool attendance. Int J Hyg Environ Health. 2008;211(3–4):367–73.

⁷⁰ 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.

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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 condition.⁷¹

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 CHLORINE alone (hand dosing), CHLORINE plus ozone (automatic dosing and control), and 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 rashes.⁴⁰ 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-therapists.³⁹ 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 (DISINFECTION by-products) is the cause. One conservative estimate places the number of halogenated DISINFECTION byproducts, 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).

After considerable discussion the technical committee decided to recommend a maximum concentration of 0.4 PPM (MG/L) for combined CHLORINE in all recreational waters. This recommendation is based on the desire to minimize the potential for both respiratory and dermal

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disease that is known to be associated with exposure to chloramines. The technical committee recognizes that this concentration is arbitrary and that it is has not been substantiated by adequate human clinical studies. In the absence of an adequate human study the technical committee 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.

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 USEPA has determined that manufacturers of “shock oxidizers” may advertise that their “shock oxidizer” products “remove,” “reduce,” or “eliminate” organic contaminants (http://www.epa.gov/oppad001/shock_ltr.htm).

SECONDARY DISINFECTION SYSTEMS such as ozone and ultraviolet 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:

Keyword	Section	Annex
		<ul style="list-style-type: none">▪ defining the fundamental chemistry of <u>DISINFECTION byproducts including, organic and non-organic</u> 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, <u>to include inhalation, ingestion and contact,</u>▪ documenting efficacy of water treatment technologies to reduce chloramine levels▪ improve testing for combined CHLORINE in air and water▪ testing for the components of combined CHLORINE

PHMB 5.7.4.3.3.2 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 US EPA accepted labels is “Poly (iminoimidocarbonyliminoimido-carbonyl iminohexamethylene) hydrochloride”. The US EPA REGISTERED PHMB for use in POOLS and spas as a “sanitizer”. The EPA accepted label directions require 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 in private residences but a limited number of public facilities have used PHMB.

Because of its limited use in public 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 US EPA found that manufacturer’s generated data demonstrated adequate efficacy under the EPA guideline DIS/TSS-12 to grant registration under the Federal Fungicide, Insecticide and Rodenticide Act (FIFRA) and without regard to whether the facility is public, semi-public or private. As part of their registration process the US EPA does not distinguish between public and private facilities.

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Keyword	Section	Annex
		<p>The efficacy data analyzed by the US EPA is company confidential and has not been reviewed as part of the development of the MAHC.</p> <p>There are no known published studies of the efficacy of PHMB against non-bacterial POOL and spa infectious agents (e.g. norovirus, hepatitis A, <i>Giardia sp.</i>, <i>Cryptosporidium spp.</i>), under 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.</p> <p>PHMB IS NOT compatible with CHLORINE or bromine. POOLS using PHMB have a serious treatment dilemma for control of <i>Cryptosporidium</i> after a suspected outbreak, or even a diarrheal fecal accident. The addition of a 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.</p> <p>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.</p>
Chlorine Dioxide	5.7.4.3.3.3	<p>CHLORINE dioxide is not presently registered by the US 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 the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). CHLORINE dioxide has granted registration by the US EPA as an antimicrobial for other applications, including drinking water. One product was previously registered as a slimicide for use in PHMB-sanitized recreational water but that registration has since been dropped. The US EPA Registration Eligibility Document (RED) on CHLORINE dioxide is available from the US EPA website at http://www.epa.gov/oppsrrd1/REDs/chlorine_dioxide_red.pdf</p>

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The US 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 US EPA stamped and accepted copy of the product use directions at this website.

Future Potential

Potential for Using Chlorine Dioxide in the Future

During the drafting of this section of the MAHC several members of the committee had interest in using CHLORINE dioxide as a remedial treatment for *Cryptosporidium* and *Legionella*. Recommendations for this were not pursued because of the status of CHLORINE dioxide under FIFRA. Published studies, including the EPA Alternate DISINFECTION Manual for drinking water show that CHLORINE dioxide may be a very rapid remedial treatment for these life-threatening pathogens. If the registration status of CHLORINE dioxide changes the writing committee suggests that CHLORINE dioxide use should be reconsidered.

Emergency Use

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 US 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.

Hydrogen Peroxide

5.7.4.3.3.4

Hydrogen peroxide is not registered by the US 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 the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Hydrogen peroxide has been

Keyword	Section	Annex
		<p>granted registration by the US EPA as a hard surface disinfectant and several other applications. The US EPA Registration Eligibility Document (RED) on hydrogen peroxide is available from the EPA website at www.epa.gov/oppsrrd1/REDs/old_reds/peroxy_compounds.pdf. The US 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 US EPA stamped and accepted copy of the product use directions at this website.</p> <p>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.⁷¹ Whether 150 PPM (MG/L) of hydrogen peroxide was used by itself or in combination with 24 ppb of silver nitrate it had negligible killing power against <i>Pseudomonas aeruginosa</i>, <i>E. coli</i>, <i>Staphylococcus aureus</i>, <i>Legionella pneumophila</i> or <i>Candida albicans</i>, even with a 30 minute contact period. In the same tests the sodium hypochlorite controls displayed typical kill patterns widely reported in 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.”</p>
Algaecides	5.7.4.3.5	<p>In practice most algaecides are reasonably effective when applied according their US EPA accepted label directions and the application is coupled with frequent and thorough brushing.</p> <p>CHLORINE and bromine can be registered and used as algaecides, but must be used in accordance with EPA label</p>

⁷¹ Borgmann-Strahsen, R. Comparative assessment of different biocides in swimming pool water, *International Biodeterioration and Biodegradation* 2003;51:291-297.

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directions.

Bromine and bromamine have been demonstrated to be algicidal.⁷²

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. 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.

In selecting a quat it is vital that the product has been registered by the US EPA for use in swimming POOLS. The vast majority, but not all, of the products on the market have current US EPA registrations. All products registered by the

⁷² Kott Y et al. Algicidal effect of bromine and chlorine on *Chlorella pyrenoidosa*. Appl Microbiol. 1966 Jan;14(1):8-11.

Keyword	Section	Annex
		<p>US EPA will have a registration number on the label (usually it will state "EPA Reg. No." followed a series of numbers). This registration number can be verified by using the EPA National Pesticide Information Retrieval System (http://ppis.ceris.purdue.edu/#) which is managed for the EPA by Perdue University. As part of their registration process the US EPA does not distinguish between public and private facilities.</p>
		<p>The US EPA registration process for algaecides is substantially different than the registration process used for disinfectants. As part of the development of the product, the US EPA requires companies to conduct efficacy studies on the product. The US 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 US EPA does not require companies to submit their efficacy package for an agency data review. Thus, in the registration process the US 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, but are not required to, have the California registration number on the label. Any local agency concerned about the efficacy 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.</p>
Calcium Hardness	5.7.4.3.3.6	<p>Calcium hardness is the amount of dissolved calcium (plus some other minerals like magnesium) in the water. High calcium is not healthy for swimming since it can cause burning of the mucous membranes, as well as skin irritation on sensitive people. 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. Too much calcium causes cloudiness and scale formation. It also reduces the effectiveness of disinfectants. Too little calcium, when combined with low pH or low Total Alkalinity can also lead to "aggressive water," which can dissolved metallic parts of the POOL (walls, floor, hand rails, ladders, light fixtures, and equipment), and also cause discolored</p>

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water or stains on the POOL walls and floor.

The maximum permissible concentration of 400 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 >400 PPM (MG/L) total hardness.

Minor deviations from the calcium hardness levels stated in the CODE do not in themselves present imminent health threats to the BATHERS. As such, minor 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.

Total Dissolved Solids

5.7.4.3.4

Total Dissolved Solids

Total dissolved solids (TDS) are a measure of the overall quantity of matter in the POOL that isn't 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 POOL 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 (> 5000 PPM (MG/L)) may require more drastic measures such as a complete POOL drain and refill, or additional water filtering, as a complete water drain may damage some POOLS.

It is also important to note that the salt required by saltwater chlorination systems will substantially increase the TDS level. Therefore, in saltwater POOLS, it is best to consider the TDS level after the required amount of salt has been added to a freshly filled POOL as the baseline level.

Source Water

5.7.4.3.5

Source (fill) Water

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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.

5.7.4.4 *Water Balance /Langelier Saturation Index*

Langelier
Saturation
Index

5.7.4.4.1

Water balance is an important part of proper POOL and spa operation and maintenance. As such, the Langelier Saturation Index (LSI) is a useful tool for monitoring the corrosive or scale-forming tendencies of POOL or spa water. Although there is little scientific literature on the LSI and POOL / spa 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 the chart below, look up the actual POOL or spa 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 chart 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 chart below, use the appropriate total alkalinity (TA) reading, in

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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

Langlier 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

A low Langelier Index (a value less than –0.5) can result in corrosion, BATHER irritation and discomfort.

A high Langelier Index (a value greater than +0.5) can lead to scale formation, cloudy water, filtration problems, heater

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problems, loss of CHLORINE efficiency and BATHER discomfort. 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 -0.5 to +0.5 range by:

- Adjusting the PH to 7.2 to 7.6, and
- Adjusting the total alkalinity to 80 to 120 PPM (MG/L), and
- Adjusting the calcium hardness to 150 to 200 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 POOL or spa is outdoors, and uses stabilized CHLORINE, in order to get a more accurate reading of the LSI, it is recommended that 30% of the cyanuric acid reading be deducted from the total alkalinity test result.

5.7.4.5 Water Clarity

Water Temperature

5.7.4.6 Water Temperature

There are no definitive temperatures that are applicable for all uses of an AQUATIC VENUE. The suggested POOL 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) than individuals

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participating in water fitness for arthritis (83° F minimum) (http://www.uswfa.com/suggested_pool_temps.asp). Water ranging in temperature from 79-86° F is comfortable for most swimmers throughout prolonged periods of moderate physical exertion.⁷³

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 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. High temperatures (above 104° F) in spas or hot tubs can cause drowsiness, which may lead to unconsciousness and, consequently, drowning.⁷⁴ The Consumer Product Safety Commission has received reports of several deaths from extremely hot water (approximately 109° F) in hot tubs. In addition, high temperatures can lead to heat stroke and death.⁷⁵

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 and are used in conjunction with saunas or steam baths. Adverse health outcomes that may

⁷³ World Health Organization. 2006. Guidelines for safe recreational water environments. Volume 2, Swimming pools and similar environments. World Health Organization, Geneva, p. 71. (http://www.who.int/water_sanitation_health/bathing/srwe2full.pdf)

⁷⁴ Press E. The health hazards of saunas and spas and how to minimize them. Am J Public Health. 1991 Aug;81(8):1034-7.

⁷⁵ CPSC. Spas, hot tubs, and whirlpools. Washington, DC, United States Consumer Product Safety Commission (CPSC Document #5112; <http://www.cpsc.gov/cpsc/pub/pubs/5112.html>, accessed 2 March 2010.

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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.⁷⁶

⁷⁶ World Health Organization. 2006. Guidelines for safe recreational water environments. Volume 2, Swimming pools and similar environments. World Health Organization, Geneva, p. 71. (http://www.who.int/water_sanitation_health/bathing/srwe2full.pdf)

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A Note About Resources:

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

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Additional Resources