2018 Annex to the Model Aquatic Health Code

Scientific Rationale

Mini-MAHC: Reducing the Spread of *Cryptosporidium*






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

Extracted from the 2018 MAHC

CS295591-A

Mini-MAHC Annex

Reducing the Spread of *Cryptosporidium*

CDC's Model Aquatic Health Code (MAHC) consists of two guidance documents:

1. Code Language (3rd Edition, 2018)
2. Annex/ Rationale (3rd Edition, 2018)

Purpose:

Specific public health issues addressed in the MAHC are often spread across multiple chapters. Mini MAHCs are intended to make the MAHC more accessible by summarizing the code and annex language into a single, concise document. This will help environmental health practitioners and pool operators quickly find relevant MAHC guidelines and rationale so they can use the information to promote patron and staff health and safety.

This Mini-MAHC Annex focuses on the rationale behind recommendations for reducing the spread of *Cryptosporidium* (Crypto) following contamination through: inactivation of Crypto by secondary U.V. or ozone disinfection systems, inspection of systems, and remediation after diarrheal fecal incidents to prevent the spread of germs that cause disease associated with swallowing contaminated water. It references content from the 2018 MAHC Annex (3rd Edition).

About *Cryptosporidium*

- *Cryptosporidium* is a microscopic germ—a parasite that causes cryptosporidiosis or prolonged, watery diarrhea.
- Crypto can be found in water, food, soil or on surfaces or hands that have been contaminated by the feces of humans or animals infected with the parasite.
- Crypto is very chlorine tolerant and can survive for days, even in well-maintained pools and splash pads.
- Once the water is contaminated by a diarrheal fecal release, all it takes is for someone to swallow a small amount of water to become ill.
- Crypto is the leading cause of outbreaks linked to treated aquatic venues in the United States.
- The parasite is found in every region of the United States and throughout the world.

IMPORTANT

Unless otherwise noted,

- Provisions in Chapter 4 (Aquatic Facility Design Standards and Construction) apply only to new construction or substantial alteration to an existing aquatic facility or venue.
- Provisions in Chapter 5 (Operation & Maintenance) apply to all aquatic facilities covered by the MAHC regardless of when constructed.
- Provisions in Chapter 6 (Policies & Management) apply to all aquatic facilities covered by the MAHC regardless of when constructed.

Citations were removed to condense the Mini-MAHCs. A list of references are in the complete version of the 2018 MAHC Annex (3rd Edition).

1.0 Preface

1.2 Recreational Water-Associated Illness Outbreaks and Injuries

1.2.1 RWI Outbreaks

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

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

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

1.2.2 Significance of *Cryptosporidium*

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

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

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

4.0 Aquatic Facility Design Standards and Construction

4.7.1.2 Combined Aquatic Venue Treatment

There are some important considerations to take into account when considering treatment of combined AQUATIC VENUES, and this practice is generally discouraged for most installations. First, to respond to a contamination event, it would be necessary to shut down all AQUATIC VENUES and water features on a combined AQUATIC VENUE treatment system since contamination of one AQUATIC VENUE would rapidly contaminate all combined AQUATIC VENUES. Second, including an INCREASED RISK AQUATIC VENUE on a combined system would require SECONDARY DISINFECTION to be installed for all AQUATIC VENUES on the RECIRCULATION SYSTEM. The two scenarios would involve isolating *Cryptosporidium* to a single AQUATIC VENUE *(limiting the number of BATHERS*

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

4.7.3 Disinfection and pH Control

4.7.3.3 Secondary Disinfection Systems

4.7.3.3.1 General Requirements

4.7.3.3.1.1 ANSI Listing and Labeling

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

4.7.3.3.1.2 Required Facilities

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

Increased Risk Aquatic Venues

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

Intent

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

Facilities

These facilities include THERAPY POOLS, and WADING POOLS, water ACTIVITY POOLS, INTERACTIVE WATER PLAY AQUATIC VENUES *(e.g., spray pads)*, and other AQUATIC VENUES with no standing water designed primarily for young children, including children less than 5 years of age. In these facilities, the potential of diarrheal illness is elevated due to the population mix of the BATHERS and the design of the facility. The pathogens of concern in such facilities are *Cryptosporidium*, *Giardia*, *Shigella*, *E. coli* O157:H7, and norovirus. *Shigella* and *E coli* 0157:H7 are very sensitive to traditional CHLORINE DISINFECTION. However, the seriousness of illness caused by highly *(Cryptosporidium)* and moderately *(Giardia, norovirus)* CHLORINE tolerant pathogens is the reason a SECONDARY DISINFECTION SYSTEM is ***required*** for all new or SUBSTANTIALLY ALTERED construction of these types of AQUATIC FACILITIES after the adoption of this CODE. When older facilities are SUBSTANTIALLY ALTERED, they must retrofit to meet this treatment requirement.

4.7.3.3.2 Log Inactivation and Oocyst Reduction

4.7.3.3.2.1 Log Inactivation

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

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

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

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

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

4.7.3.3.2.2 Installation

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

4.7.3.3.2.4 Minimum Flow Rate Calculation

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

4.7.3.3.2.5 Equation

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

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

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

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

  C_0 = initial concentration = 10^8 OOCYSTS / V

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

  t = time (minutes)

  V = volume (gallons)

  Q = flow rate (gpm)

  T = number of TURNOVERS = Qt/V

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

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

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

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

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

  multiply both sides by -1/rt

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

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

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

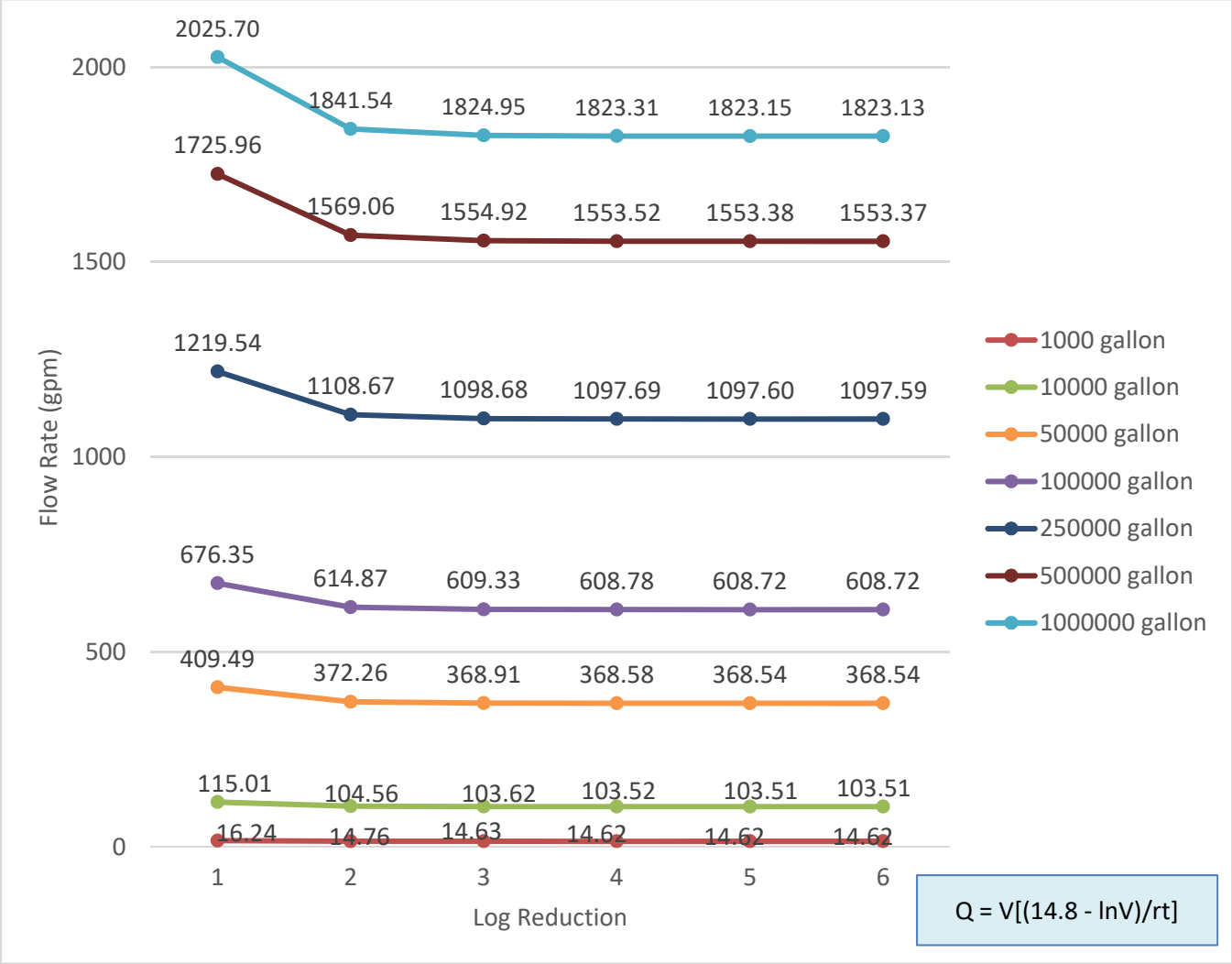
  $Q = V\{[\ln(10^8/V) - \ln 37.85]/rt\}$

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

  $Q = V[(14.79 - \ln V)/rt]$

- If a 9 hour (540 minute) dilution time is assumed, this equation can be used to calculate the data displayed in the following graph.

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



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

Purpose

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

VENUE is free of viable *Cryptosporidium* OOCYSTS, or at least have the number below an infective concentration every day the AQUATIC VENUE opens to the public.

Example of Equation

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

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

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

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

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

4.7.3.3.2.7 Flow Rate Measurements

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

Maximum Concentrations

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

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

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

4.7.3.3.3 Ultraviolet Light Systems

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

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

4.7.3.3.3.1 Third Party Validation

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

4.7.3.3.3.1.1 Validation Standard

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

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

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

Validation Factor

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

Transmissivity (Transmission)

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

98% transmission, operators should therefore be aware that the equipment may only deliver half the performance when installed.

Validation Range

A validated system will have different performance levels at different water qualities and flows. The relationship between these is traditionally represented as a performance curve where the performance can be noted at any point on this curve. However the lowest transmission test point and the highest flow tested are normally considered the extents of the validated range. This means that any UV unit tested at 95% and above is NOT validated at transmissions lower than 95%. For the same reason, a unit tested at a maximum flow of 500 gpm is NOT validated for any flow over 500 gpm. Validation factors can reduce equipment validated performance by 30%, so it is essential that systems without validation factors built into performance curves are not considered validated. The performance of a UV system in the field is measured by a combination of flow and intensity readings from the UV sensors. Performance in the field can be verified on inspection by regulators who will compare actual sensor readings with those indicated on the performance charts, so these charts must be retained at the AQUATIC FACILITY for each validated system. UV equipment is utilized for its ability to DISINFECT CHLORINE-tolerant pathogens and for its ability to reduce combined CHLORINES in the POOL water. For the latter, typically a calculated dose of 60mJ/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 TREATMENT SYSTEM the CODE allows some operational and equipment concessions. Operators should note that the regulations as stated represent BEST PRACTICE; but where specific circumstances dictate, then the equipment specifications may be reduced. For a SUPPLEMENTAL TREATMENT SYSTEM, the operator may consider reducing the dose applied to the process. This will reduce performance accordingly and operators should consider carefully such reduction in performance, and assure themselves that the equipment will still provide a beneficial level of performance.

4.7.3.3.3.4.1 Alarm/Interlock Setpoint

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

4.7.3.3.3.9 Minimum RED

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

4.7.3.3.4 Ozone Disinfection

4.7.3.3.4.1 Log Inactivation

Ozone is a SECONDARY DISINFECTION SYSTEM and must meet the minimum requirements of all SECONDARY DISINFECTION SYSTEMS as defined in MAHC 4.7.3.3. Ozone is an antimicrobial OXIDIZER. Its use as a SECONDARY DISINFECTION SYSTEM in commercial swimming POOLS in the United States dates back to the 1930s. Ozone is proven to kill *Cryptosporidium*, *Giardia, E. coli*, and *Pseudomonas aeruginosa*, along with any other

microorganism potentially found in AQUATIC VENUES, and is a strong OXIDIZER. Exposure to ozone gas can result in irritation to the eyes and respiratory tract if not generated and handled correctly. Therefore OSHA has identified a time weighted average *(TWA)* of 0.1 ppm *(0.1 mg/L)* as the PEL for ozone.

4.7.3.3.4.2 Third Party Validation

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

4.7.3.3.4.3 Suitable for Use

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

Suitable materials and their uses are:

1. Ozone/Air or Ozone/Oxygen:

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

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

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

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

3. Gaskets and O-rings

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

4. Joint Sealing

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

4.7.3.3.4.7 Installation and Injection Point

4.7.3.3.4.7.2 Gas Monitor / Controller

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

5.0 Operations and Maintenance

5.7.3.2 Secondary or Supplemental Treatment Systems

Due to the risk of outbreaks of RWIs associated with halogen-tolerant pathogens such as *Cryptosporidium*, it is strongly recommended that all AQUATIC FACILITIES include SECONDARY DISINFECTION SYSTEMS to minimize the risk to the public associated with these outbreaks. All existing regulations covering fecal events or detection of pathogens must still be adhered to when SECONDARY DISINFECTION SYSTEMS are utilized. SECONDARY DISINFECTION SYSTEMS can only minimize the risk and are not a guarantee of treatment due to the possibility of cross contamination of the POOL or water feature and the time required to pass the entire volume of water through the treatment process. As the general effectiveness of a SECONDARY DISINFECTION SYSTEM is affected by the AQUATIC VENUE TURNOVER RATE and mixing/circulation within the AQUATIC VENUE, the MAHC requirements for filter recirculation and TURNOVER RATES must be followed. The performance of SECONDARY DISINFECTION SYSTEMS will be enhanced when the shortest TURNOVER TIMES are achieved for any particular type of AQUATIC FACILITY. The use of certain types of AQUATIC VENUES presents an increased risk of RWI transmission to users. These AQUATIC VENUES include THERAPY POOLS, WADING POOLS, SPRAY PADS, swim schools, INTERACTIVE WATER PLAY AQUATIC VENUES, and AQUATIC FEATURES. Given that users of these types of facilities frequently have naive immune systems *(e.g., children less than 5 years of age)*, higher prevalence of disease *(e.g., children less than 5 years of age and older adults)*, compromised immune systems, or open wounds, additional precautions against RWIs are warranted. CDC data on public AQUATIC VENUES indicate DISINFECTANT violations were identified during 9.2% of POOL, 19.2% of SPA, 19.2% of WADING POOL, and 10.1% of INTERACTIVE WATER PLAY VENUE routine inspections. The use of INTERACTIVE WATER PLAY AQUATIC VENUES has previously been associated with outbreaks of gastroenteritis. In 1999, an estimated 2,100 people became ill with *Shigella sonnei* and/or *Cryptosporidium parvum* infections after playing at an "interactive" water fountain at a beachside park in Florida. In one of the largest outbreaks reported, approximately 2,300 persons developed cryptosporidiosis following exposure to a New York spray park. The environmental investigation revealed that filtration and DISINFECTION of the recycled water were not sufficient to protect the PATRONS from this disease. In response, emergency legislation was passed, which required the installation of SECONDARY DISINFECTION *(e.g., UV radiation or ozonation)* on water returning through the spray features.

5.7.3.2.1 Ultraviolet Light

5.7.3.2.1.2 Log Inactivation

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

5.7.3.7 Automated Controllers and Equipment Monitoring

5.7.3.7.7 Ozone System

As a SECONDARY DISINFECTION SYSTEM, it is critical to MONITOR the system on a regular basis to ensure it is performing as required and, if not, repaired.

5.7.3.7.8 UV System

As a SECONDARY DISINFECTION SYSTEM, it is critical to MONITOR the system on a regular basis to ensure it is performing as required and, if not, repaired.

6.0 Policies and Management

6.4 Facility Management

Facility management is critical in preventing illness and injury as summarized in this section. The CDC identifies the most frequently reported contributing factors to the spread of infectious pathogens that cause RWIs, in particular gastroenteritis. Another report identified the most frequently reported type of RWI outbreak as gastroenteritis, the incidence of which is increasing. Prevention of RWIs at treated venues requires POOL operators to:

- Maintain appropriate DISINFECTANT concentration and pH to maximize DISINFECTANT effectiveness, and
- Ensure optimal water circulation and filtration.

A study of POOL inspection data underscored the need for improved maintenance. A total of 4,873 *(11.6%)* of 42,161 inspections identified serious violations that threatened the public's health and resulted in immediate POOL closure. Of 40,585 inspections, 3,549 *(8.7%)* identified DISINFECTANT concentration violations; of 38,247 inspections, 4,506 *(11.8%)* identified pH violations. Automated chemical feeder violations were documented during 2,260 *(6.3%)* of 36,137 inspections. Only one (6%) of 16 included data on AQUATIC FACILITY setting; almost all POOL (99.5% [55,622/55,913]) and hot tub/SPA (99.1% [20,259/20,449]) inspection records were missing data on AQUATIC FACILITY setting. Use of the setting algorithm increased the number of inspection records with setting data; however, after the setting algorithm was run, 75.6% (42,249/55,913) of POOL and 84.2% (17,213/20,449) of hot tub/SPA inspection records still were missing AQUATIC FACILITY setting data, thus no analyses stratified by setting were conducted. The process of submitting, reformatting, STANDARDIZING, and analyzing these data highlighted several areas where the collection and STORAGE of AQUATIC FACILITY inspection data could be improved. To optimize collection and analysis of AQUATIC FACILITY inspection data and thus utility in informing program planning, implementation and evaluation, a collaboration of federal, state, and local partners from different disciplines is needed. This collaboration should include environmental health practitioners with technical knowledge about the operation and maintenance of public AQUATIC FACILITIES and with inspection experience, epidemiologists skilled in conducting surveillance and data analysis, and information technology specialists with expertise in database construction. This collaboration could provide input on identifying public AQUATIC FACILITY CODE elements deemed critical to protecting public health and on the creation of needed resources (e.g., STANDARD inspection forms, training for inspectors, criteria for the construction of databases, and of tools to analyze data). Kiddie/WADING POOL inspections had the highest percentage of immediate closures *(21.6%)*. Inspections of kiddie/WADING POOLS identified the highest percentage of DISINFECTANT concentration violations *(19.2%)*, followed by inspections of INTERACTIVE WATER PLAY VENUES *(10.1%)*. See MAHC Sections 1.2.1 (RWI Outbreaks), 1.2.2 (Significance of *Cryptosporidium*), 1.2.3 (Drowning and Injuries), and 1.2.4 (Pool Chemical-Related Injuries) for further discussion and background. The information identified in these reports, along with existing recreational water injury data and first hand inspector experience, drove the development of the critical risk factors for recreational water injury and illness at treated AQUATIC VENUES. The eight broad critical risk factors for recreational water illness and injury are:

- Management; supervision; training; operation;
- Lifeguard services;
- DISINFECTANT residual;
- pH *(low or hi)*;
- Water clarity;
- Facility ENCLOSURE / entry protection;
- Entrapment protection; and
- Water supply / waste disposal.

Low concentration or absent DISINFECTANT leads to reduced inactivation of pathogens and these conditions have been associated with infectious disease outbreaks. Low pH has been associated with loss of dental enamel. Dental erosion begins to occur below pH 6.0 and rapidly accelerates as the pH drops. High pH reduces the efficacy of CHLORINE-based DISINFECTION by reducing the amount of molecular HOCl, the active form that is available for DISINFECTION. At pH 7.0, about 70% of the HOCl is molecular, at pH 7.5 about 50% is molecular, at pH 8.0

about 20% is molecular, and at pH 8.5 only 10% is molecular. As a result, the MAHC decided to set upper and lower limits for pH (recommended pH range 7.2–7.8) as an IMMINENT HEALTH HAZARD.

6.4.1.6 Daily Water Monitoring and Testing Records

These duties include but are not limited to:

- Measure and record *(or supervise and ensure the measurement and recording of)* all information as required by MAHC operations, testing, MONITORING, and reporting requirements;
- Maintain the filtration and RECIRCULATION SYSTEM as required to maintain minimum flow rates required by MAHC 4.7.1;
- Backwash the filtration system when the filter gauge pressure differential reaches a level specified by the equipment manufacturer or as specified in the MAHC 4.7.2;
- Maintain DISINFECTANT residuals according MAHC 4.7.3;
- Maintain water chemistry according to MAHC 5.7.3;
- MONITOR water temperature to ensure it is within range specified in MAHC 5.7.4.7;
- Clean accessible POOL surfaces as necessary to remove slime/biofilm accumulation (see MAHC 5.10.5.4 for further explanation);
- Add replacement water as needed to meet all MAHC requirements; and
- Ensure HYGIENE FACILITIES are clean, sanitary, and supplies needs for swimmer hygiene such as toilet paper and soap or hand SANITIZER are available for use as per MAHC 5.10.

6.5 Fecal/Vomit/Blood Contamination Response

The following discussion gives the rationale behind the remediation recommendations. Fecal contamination of recreational water is an increasing problem in the United States and other countries. Since the mid-1980s, the number of outbreaks of diarrheal illness associated with recreational water has been increasing in the United States. Of these outbreaks, DISINFECTED, man-made swimming venues, the target of the MAHC, have had the greatest increase. These outbreaks are usually a result of people swimming while they have infectious, pathogen-containing diarrhea caused by pathogens such as *Cryptosporidium*, *Giardia*, *Shigella*, *Salmonella*, or *E. coli* O157:H7. Contamination of swimming water by infected persons and subsequent swallowing of contaminated water by other swimmers continues the spread of infectious pathogens that cause diarrheal illness. Diarrheal illness is common in the United States with surveys indicating that 7.2-9.3% of the general public have had diarrhea in the previous month. Additional studies demonstrated that people routinely have a mean of 0.14 grams *(range = 0.1 to 10 grams)* of fecal contamination on their buttocks and peri-anal surface. The increase in outbreaks, the high prevalence of diarrheal illness in the public, and likelihood of frequent fecal contamination of POOLS by BATHERS raised the question of how to respond to overt fecal releases, particularly formed stools that were more visible, in POOLS. The need to develop a response plan was amplified by the emergence of the CHLORINE-tolerant parasite *Cryptosporidium* as the leading cause of DISINFECTED venue-associated outbreaks of diarrheal illness. First, formed stools were thought to be a significantly lower risk for spreading illness compared to diarrhea, since most pathogens are shed in the greatest numbers in diarrhea. As the highest risk material, diarrhea was considered the worst case contamination scenario that could potentially contain *Cryptosporidium*. As a result, a response should require the extreme treatment conditions needed to inactivate *Cryptosporidium*. Formed stool was assessed as a lower risk than diarrhea but several questions remained. Should formed stools be treated as potentially infectious materials? If so, then should the stool be treated as a potential *Cryptosporidium* contamination event like diarrhea *(i.e., longer inactivation time)* or could it be treated to inactivate all other pathogens other than *Cryptosporidium (i.e., shorter inactivation time)*. To collect data relevant to answering the questions above, a study to collect fecal releases from POOLS in the United States was conducted in

1999. POOL staff volunteers from across the United States collected almost 300 samples from fecal incidents that occurred at water parks and POOLS. The CDC then tested these samples for *Cryptosporidium* and *Giardia*. *Giardia* was chosen as a representative surrogate for moderately-CHLORINE resistant pathogens like hepatitis A virus and norovirus. Using conditions to inactivate *Giardia* would inactivate most pathogens other than *Cryptosporidium*. None of the sampled feces tested positive for *Cryptosporidium*, but *Giardia* was found in 4.4% of the samples collected. These results suggested that formed fecal incidents posed only a very small *Cryptosporidium* threat but should be treated as a risk for spreading other pathogens such as *Giardia*. As a result of these data and the discussion above, it was decided to treat formed stools as potential *Giardia* contamination events, and liquid stool as potential *Cryptosporidium* contamination events. It was thought that norovirus contamination posed the greatest threat from vomit contamination and that the virus would be inactivated by a formed stool response using *Giardia* inactivation times as discussed above. Further assessment also suggested that blood contamination of POOL water posed little health risk due to the sensitivity of bloodborne pathogens *(e.g., viruses, bacteria)* to environmental exposure, dilution in the water, and chlorination. In addition, POOL water exposures would lack the requisite bloodborne exposure routes needed to spread the pathogens to other people.

6.5.3 Aquatic Venue Water Contamination Disinfection

6.5.3.1 Formed-Stool Contamination

For *formed-stool contamination*, a FREE CHLORINE value of 2 mg/L was selected to keep the POOL closure time to approximately 30 minutes. Other CHLORINE concentrations or closure times can be used as long as the CT INACTIVATION VALUE is kept constant. The CT INACTIVATION VALUE is the concentration *(C)* of FAC in mg/L multiplied by time *(T)* in minutes: *(CT INACTIVATION VALUE = C x T)*.

For formed-stool contaminated water the CT INACTIVATION VALUE for *Giardia (45)* is used as a basis for calculations:

Table 6.5.3.1: Giardia Inactivation Time for Formed-Stool Contamination

Chlorine Levels (mg/L)	Disinfection Time*
1.0	45 minutes
2.0	25 minutes
3.0	19 minutes

**These closure times are based on a 99.9% inactivation of Giardia cysts by chlorine, pH 7.5, 77°F (25°C). The closure times were derived from EPA. The closure times do not take into account "dead spots" and other areas of poor POOL water mixing.*

6.5.3.1.1 Pools Containing Chlorine Stabilizers

CHLORINE stabilizers such as CYA slow DISINFECTION; therefore, higher CHLORINE levels are likely necessary to reach the CT INACTIVATION VALUE for *Giardia* inactivation in POOLS using CHLORINE stabilizers. However, at this time there is no STANDARDIZED protocol to compensate for CHLORINE stabilizers and no data determining how the inactivation of *Giardia* is affected by CHLORINE stabilizers under POOL conditions. A SAFETY value of 2 has been incorporated until these data can be gathered.

6.5.3.2 Diarrheal-Stool Contamination

For ***diarrheal-stool contamination***, inactivation times are based on *Cryptosporidium* inactivation times. The CT INACTIVATION VALUE for *Cryptosporidium* is 15,300. If a different CHLORINE concentration or inactivation time is used, an operator must ensure that the CT INACTIVATION VALUES remain the same.

For example, to determine the length of time needed to DISINFECT a POOL at 20 mg/L after a diarrheal accident, use the following formula: ***C x T = 15,300***.

Solve for time: T= 15,300 ÷ 20 mg/L = 12.75 hours.

Therefore, it would take 12.75 hours to inactivate *Cryptosporidium* at 20 mg/L. See table below:

Table 6.5.3.2: Cryptosporidium Inactivation Time for Diarrheal Contamination

Chlorine Levels (mg/l)	Disinfection Time
1.0	15,300 minutes (255 hours)
10.0	1,530 minutes (25.5 hours)
20.0	765 minutes (12.75 hours)

The CT_{3log} used is for a 3-log inactivation to achieve a decrease in the concentration of OOCYSTS below one infectious dose per volume of water swallowed *(1 OOCYST/100 mL)*. Similar to the assumptions made for SECONDARY DISINFECTION *(See MAHC 4.7.3.3.2.5)*, this calculation assumes a single contamination event *(e.g. diarrheal incident)* of ~100 mL could introduce 10^8 *Cryptosporidium* OOCYSTS into the water. This allows for a SAFETY factor to include smaller volume venues and still achieve the required concentration. An additional SAFETY factor not included is the impact of the filtration system since filter OOCYST removal efficacy varies widely. This may be more quantifiable in the future so that it could be included in the calculation. Volume calculations indicate that small volume AQUATIC VENUES like splash pads should be able to achieve this goal by using the CT INACTIVATION VALUE cited:

10^8 OOCYSTS / 10,000 gallons =

10^8 OOCYSTS / (10,000 gallons X 3785.4 mL/gallon) =

2.64 OOCYSTS/mL = 264 OOCYSTS / 100 mL

With the 3-log inactivation, this volume will contain 0.264 OOCYSTS per 100 mL which is below the required one OOCYST/100 mL and larger volume facilities will exceed this requirement.

6.5.3.2.1 Pools Containing Chlorine Stabilizers

Chlorine stabilizers such as CYA slow disinfection (see MAHC Annex 5.7.3.1.3.1 for more discussion) therefore, higher chlorine levels are necessary to reach the CT inactivation value for Cryptosporidium inactivation in pools that use chlorine stabilizers. As the stabilizer concentration rises, parasite inactivation is inhibited to the point where inactivation is similar to natural decay of the parasite. As a result, higher levels of stabilizer must be reduced to reach 3-log inactivation levels using hyperchlorination. Recent data show that 3-log inactivation of Cryptosporidium is possible with CYA concentrations of 15-16 ppm or less. A 3-log inactivation could not be achieved with 50 ppm or 100 ppm CYA. A 1-log inactivation of oocysts was achieved with 50 ppm cyanurate concentrations after an average contact time of 61.9 hours with 20 ppm free chlorine residual, for an average estimated CT inactivation value for 1-log inactivation of 76,500 mg min/L. With 40 ppm free chlorine residual and 50 ppm CYA, a 1-log inactivation of oocysts was achieved after an average contact time of 17.2 hours, giving an average estimated CT inactivation value for 1-log inactivation of 40,000 mg min/L. Increasing the concentration to 100 ppm CYA showed even more limited oocyst inactivation, which did not differ much from natural decay curves for Cryptosporidium in water. Because 3-log oocyst inactivation was achieved with 16 ppm CYA and was not achieved with 50 ppm CYA, the remediation protocol must be conducted in water with ≤15 ppm CYA. If the CYA concentration is above 15 ppm, the pool will need to be partially drained to reduce the concentration. Alternate methods of reducing the CYA concentration are acceptable, as long as test data shows that the CYA concentration is at or below 15 ppm. The chlorine concentrations specified in the code must be used. Using chlorine concentrations other than those listed (multiplying to get the CT using other concentrations as can be done using hyperchlorination in the absence of stabilizer) assumes a linear response for inactivation but the data do not support linearity so only the listed concentrations are warranted. Along with the pH level and free chlorine residual, the CYA level should be checked and adjusted if necessary prior to reopening the pool. Temperature is a critical parameter of measuring a CT inactivation value. Although pH changes with temperature, the more critical aspect is that inactivation of pathogens is well documented to decrease with falling temperature. As a result, the limited data available for pools requires the protocol to be conducted at the temperature where the data was collected, or above, as higher temperatures are known to speed inactivation. Most inactivation research on Cryptosporidium has been conducted to aid drinking water treatment. As a result, the data are at lower temperatures (e.g., 41oF [5oC] to simulate winter conditions) and pH values (e.g., pH 6), which are more typical

of real-life drinking water conditions but of little benefit to aquatic facility operation. Any data to document how a 5oC drop in temperature would impact the 3 log CT inactivation value at pH 7.5 is not currently available and, due to the difficulties, time, and cost of such research, may never be collected. Aquatic venues with secondary disinfection systems could be closed and allowed to circulate for the length of time calculated in MAHC 4.7.3.3.2 to reduce the level of Cryptosporidium below one oocyst/100mL. Other aquatic venues without secondary disinfection systems may choose to completely drain the water from the aquatic venue and replace with fresh water if they are unable to reduce the stabilizer level or hyperchlorinate.