Model Aquatic Health Code

Monitoring & Testing Module ANNEX Sections for the First 60-day Review Posted for Public Comment on 12/12/2012

Currently Open for Public Comment that Closes on 2/10/2013

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.

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

MAHC Monitoring & Testing Module Abstract

Ensuring water and air quality is important for maintaining a safe and healthy environment for pool and spa users and operators. The Monitoring and Testing Module identifies activities and procedures that pool and spa operators should follow to proactively evaluate the water and air quality in their facilities. The Monitoring and Testing Module contains requirements for new and existing aquatics facilities that include:

1) Ensuring that water quality testing devices comply with existing standards.
2) Monitoring automated controllers and treatment systems to ensure proper functioning.
3) Use of dye testing to evaluate pool circulation.
4) Procedures for collecting water samples from in-line sample ports and from bulk pool water, including frequency and timing of sample collection.
5) Frequency of testing for specific water quality chemical parameters.

MAHC Monitoring & Testing Module Review Guidance

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

Review Reminders:

- Please download and use the **MAHC Comment Form** (http://www.cdc.gov/healthywater/swimming/pools/mahc/structure-content/) to submit your detailed, succinct comments and suggested edits. Return your review form by 2/10/2013, as an email attachment to **MAHC@cdc.gov**.

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

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

into the overall MAHC structure. Additional MAHC draft modules that contain this content will be or already have been posted for your review.

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

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

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

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

Douglas C. Sackett, Director
MAHC Steering Committee

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

Reviewer Note on Module Section Numbering:

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

Reviewer Note on the MAHC Annex

Rationale

The annex is provided to:

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

Content

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

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

Appendices

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

Acronyms in this Module: See the Monitoring & Testing Module, Code Section

Glossary Terms in this Module: See the Monitoring & Testing Module, Code Section

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

Model Aquatic Health Code
Monitoring & Testing Module Annex
4.0 Design 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

4.6.2.2 Air Quality – Health

Monitoring for trichloramines can be effectively accomplished by training pool operators to be on alert for the distinctive chloramine odor. The odor threshold for trichloramine is 0.1 mg/m^3 and health symptoms start happening around 0.3-0.5 mg/m^3, so odor monitoring generally works well as an early warning system.

4.6.2.2.1 Turnover Rates

Monitoring CO_2 levels can be used as an alternative to monitoring air quality/outside air. The facility design engineer should specify what the alternative CO_2 level limit should be. Air turnover can include a few sources: by recycling air from other parts of the building, or using outside air, or a mixture of the two. Use of CO_2, in addition to odor and humidity control, should be effective for controlling air turnover-related health issues, assuming the facility is designed properly.

4.6.2.3.1 Relative Humidity

Relative humidity levels should be monitored using a properly calibrated humidity meter.

4.7 Recirculation and Water Treatment

4.7.1 Recirculation Systems and Equipment
4.7.2 Filtration

Keyword	Section	Annex
	4.7.3	Disinfection
	4.7.3.1	Oxidants
	4.7.3.2	Stabilizers
	4.7.3.3	Supplemental/Other
	4.7.3.4	pH
	4.7.3.5	Levels
	4.7.3.6	Feed Equipment
Water Quality Testing Devices	4.7.3.7	Water Quality Testing Devices and Kits

WQTDs should be stored as specified by the manufacturer's instructions. Failure to properly store WQTSs will result in incorrect readings. NSF/ANSI Standard 50 for WQTDs in 2011 currently contains specified precision and accuracy requirements for measuring pH, free & total chlorine, and free & total bromine. There are three levels of accuracy and precision deemed level 1, 2 & 3, with the highest accuracy and precision in level 1 devices. In late 2011-2012 the following parameters will be added: saturation index, Alkalinity, Cyanuric Acid, Calcium Hardness, Total Dissolved Solids, and Oxidation Reduction Potential.

It is important for an operator to use equipment that is easy to read and as objective as possible. The current, common means of testing pools using a colorimeter test is highly subjective because the color and intensity must be compared. Titration testing for free and combined chlorine is an objective test, which is accurate to 0.2 mg/L with an easily recognizable start and end point. Titration testing is recommended over colorimetric testing. Due to the use of inconsistent concentration gradations (i.e., the difference in concentration between adjacent color blocks) and the subsequent rapid darkening of the color blocks (e.g., above 1.5 mg/L), the accuracy of colorimetric test methods is likely to be lower than for titration test methods. Colorimetric methods are accurate only to +/- half the difference between the adjacent color blocks, and thus the confidence limits for these methods are wider at higher concentrations (e.g., above 1.5 mg/L). Where portable spectrophotometer test kits are affordable, these are the most accurate kits available for use at poolside.

Most water tests involve color development. Interferences in the water can cause them to produce a different color, or

Keyword Section Annex

produce the wrong color intensity, or be unable to produce the expected color. Color matching tests for chlorine/bromine provide accuracy equal to approximately half the difference between known values of the color standards. As the chlorine/bromine concentration rises, the greater the difference will be between the known color standards. Thus, the readings become subjective as the difference increases. The following chart summarizes some common interferences and how they impact the test color in disinfectant tests.

Table 4.7.3.8

Table 4.7.3.8: Water Tests and Interference

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

High chlorine effects on:

Chlorine testing:

If the water sample indicates high chlorine levels, usually over 10 ppm, the DPD reagents may partially or totally bleach out,

resulting in a false low or zero chlorine reading. Reference the WQTD's use instructions to guard against false readings and interferences.

pH testing:

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

Total alkalinity testing:

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

Metals:

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

Metals of calcium testing:

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

High calcium effects on chlorine testing:

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

Potassium monopersulfate shock:

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

Automated Controller

4.7.3.8 Automated Controllers

Automated chemical controllers are recommended for use on every aquatic venue. The use of automated controllers does not negate the requirements for regular water testing. Automated units require verification of proper function and the probes do fail or slip out of calibration. This can only be detected by monitoring the water quality. This monitoring frequency is not as rigorous as venues without automated systems. Venues that do not have automatic controllers will require more frequent water testing.

Microbiological Testing Equipment

4.7.3.9 Microbiological Testing Equipment

Microbiological testing equipment and methods should be EPA-Approved or conforming to Standard Methods[1].

Routine microbiological testing for pools, hot tubs, and other

[1] APHA et al. (2012) *Standard Methods for the Examination of Water and Wastewater*, 22nd ed. E.W. Rice, R.B. Baird, A.D. Eaton, and L.S. Clesceri (eds). New York: American Public Health Association.

aquatic venues is not recommended in the MAHC. Routine monitoring of chemical levels (e.g., pH, disinfectant concentration) and proper operation and maintenance of the aquatic venue have historically been considered to be sufficient to ensure that proper barriers are maintained to minimize potential infectious disease risks from chlorine sensitive pathogens. Currently, routine monitoring for chlorine-resistant microorganisms (e.g., *Cryptosporidium parvum*) is not a feasible and cost-effective disease prevention approach. Chemical tests such as Free Residual Chlorine, pH, Contact Time (CT) values and others provide a good indication of operational control of an aquatic feature. However, while these tests provide an indication of sanitization potential, they may not provide complete assurance of the microbial quality of pool/spa water.

While agencies such as the World Health Organization[2], the South Australia Environmental and Public Health Service[3], and the United Kingdom Health Protection Agency[4] have established standards for routine monitoring of public and semi-public pools and hot tubs for microbial parameters including enteric bacteria (fecal organisms or *E. coli*), *Pseudomonas aeruginosa* and *Legionella*, there is insufficient scientific data for the purposes of this MAHC to indicate that these routine monitoring standards provide an increased level of public health protection beyond adherence to current best practices. The routine monitoring recommendations in the MAHC can be reconsidered to potentially include routine monitoring for microbial parameters if compelling scientific data indicate that such testing provides additional, measurable public health protections beyond use of best practices for disinfection, spa/pool operation and maintenance.

Although routine microbial testing is not recommended by the MAHC at this time, microbiological testing can be useful as

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[2] WHO. (2006) *Guidelines for safe recreational waters*. Volume 2. Swimming pools and similar recreational environments. Geneva, Switzerland:WHO. Retrieved from http://whqlibdoc.who.int/publications/2006/9241546808_eng.pdf

[3] Broadbent C. (1996) *Guidance on water quality for heated spas*. Rundle Mall, South Australia: Public and Environmental Health Service.

[4] Newbold J. (2006) *Management of spa pools: controlling the risk of infection*. London, United Kingdom: Health Protection Agency.

supporting data for evaluating the need for (or effectiveness of) troubleshooting activities, remediation activities, and aquatic facility upgrades. As indicated by WHO[1] recommendations, microbiological testing of water samples from aquatic venues can be useful for the following reasons:

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

It is known that certain microorganisms, because of their ecology and/or structure, can be resistant to chemical disinfectants (e.g., chlorine, bromine). *Legionella pneumophila*, *Pseudomonas aeruginosa*, *Cryptosporidium parvum* oocysts, *Entamoeba histolytica* cysts, and Mycobacterium avium complex are a few examples of pathogenic microbes that have been reported to show some resistance to chemical disinfectants. In addition, sessile microorganisms in biofilm are likely to receive additional protection from oxidizers (such as chlorine) when the exposure concentration of these oxidizers is reduced at the interface with the biofilm due to reaction with biofilm material.

Biofilm is a complex community of microorganisms which attach to the sides, piping, and filters of spas and pools [5]. Even at elevated concentrations, oxidizing and non-oxidizing chemicals have reduced effectiveness in controlling biofilm when their concentrations and contact times are not sufficient for penetrating the biofilm[6]. Biofilm formation in aquatic venues is also a concern because microorganisms in the biofilm or the biofilm itself can detach and multiply[7]. Following best practice

[5] Camper AK et al. (1985) Growth and persistence of pathogens on granular activated carbon filters. *Journal of Applied Environmental Microbiology*, 50:1378–82.
[6] Pearson W. (2003) "Legionella 2003." *Association of Water Technologies Inc.,* Association of Water Technologies, 2003. Web. 19 Aug 2010. Retrieved from http://www.awt.org/IndustryResources/Legionella03.pdf
[7] Declerck P. (2010) Biofilms: the environmental playground of *Legionella pneumophila*. *Environmental Microbiology*, *12*(3), 557-566.

guidelines for aquatic venue cleaning and continuous disinfection is critical to avoid biofilm growth and expansion problems[8,9].

If biofilm-related problems arise, it can be useful to incorporate biofilm sampling to develop a comprehensive evaluation of the risk factors for water quality impairment and potential solutions to identified problems[10].

Table 4.7.3.9 identifies microorganisms for which chlorination may have, or is known to have, reduced efficacy[11,12,13]. Table 4.7.3.9 also identifies methods that may be used to detect these microbes in pool and spa systems, but the methods identified are not necessarily rapid. Additional research is needed to evaluate the benefits of microbiological testing data for aquatic venues, especially for improving public health protection. This is particularly important for the protozoans, amoebas, and sessile bacterial pathogens that co-exist in biofilms. It should be noted that the use of fecal indicator organisms for aquatic venue water quality evaluation may not be sufficient for certain aquatic venue operation, maintenance, and public health investigations, especially in public health investigations related to inhalation, skin breaks, or ocular exposure routes. Since health risks in pools and similar environments may be fecal or non-fecal in origin, investigation of fecal indicators and non-fecally-transmitted microorganisms (e.g. *P. aeruginosa*, *S. aureus* and *Legionella* spp.) may be warranted.

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[8] Clements W. (Ed) (2000) *ASHRAE guideline: Minimizing the risk of legionellosis associated with building water systems*. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc.

[9] Donlan RM and Costerton JW. (2002) Biofilms: survival mechanisms of clinically relevant microorganisms. *Clinical Microbiology Review*, *15*, 167-93.

[10] Paulson D. (Ed.) (2010) *Applied biomedical microbiology: A biofilms approach.* Chapter 8: Matias F, et. al., Disinfection and its influence on biofilm ecology . Chapter 9: Goerers D, Understanding the importance of biofilm growth in hot tubs. Boca Raton, Fl: CRC Press.

[11] Hurst C et al. (2002) *Manual of environmental microbiology*. Washington DC: American Public Health Association. 184, 186-188.

[12] Heymann D. (Ed.) (2004) *Control of communicable diseases manual*. Washington, DC: American Public Health Association, pp. 138-141, 230-231, 383-385.

[13] Eaton A et al. (2005) *Standard methods for the examination of water and wastewater*. Washington, DC: American Public Health Association, 9-1, 9-28 thru 9-31, 9-168.

Keyword	Section	Annex
Table 4.7.3.9: Known Pathogens		***Table 4.7.3.9: Known Pathogenic Organisms of Concern in Chlorinated Aquatic Venues***

Keyword Section Annex

Organism	Illness	Route of Infection	Resistant To Chlorine	Environmental Biofilm Amplification	Test Method
Pseudomonas Aeruginosa[1]	Hot tub Folliculitis Conjunctivitis Pneumonia Swimmer's Ear	Skin Eyes Inhalation Ears	Yes when planktonic[2] Yes when sessile in biofilms	Yes	APHA Standard Method 9213 E-F APHA Standard Method Rapid PCR test Available
Enteric Bacteria	Gastroenteritis Hip and Knee joint replacement infections, replacement heart valve infections Conjunctivitis Pneumonia	Fecal/Oral Skin breaks Eyes Inhalation	No when planktonic Yes when sessile in biofilm	Yes	APHA Standard Method for Coliforms 9221 A-F APHA Standard Method 9260 A-L for specific pathogens APHA pathogen specific PCR test Bacteroides/Enterococci PCR tests under investigation by EPA to replace Coliforms
Legionella	Legionnaires' Disease, Pontiac Fever Hip and Knee joint replacement infections, replacement heart valve infections	Inhalation Skin breaks	Yes when planktonic[3] Yes when sessile in biofilm	Yes	APHA Standard Method 9260 J CDC/ISO Method is Gold Standard APHA Standard Method Rapid PCR test
Mycobacterium Avium complex (MAC)	Hypersensitivity pneumonitis Dermatitis	Inhalation Skin Breaks	Yes when planktonic Yes when sessile in biofilm	Yes	APHA Standard Method 9260 M Rapid PCR
Stapylococcus aureus and Methicillin resistant Staph aureus (MRSA)	Conjunctivitis Antibiotic resistant skin infection possibly fatal	Eyes Skin Breaks	No when planktonic Yes when sessile in biofilm	Yes	APHA Standard Method 9213 B 6 and 7 Rapid PCR test
Naegleria fowleri Acanthamoeba	Primary amoebic meningoencephalitis (uncommon but high mortality rate) Conjunctivitis and Keratoconjunc-tivitis (may cause blindness particularly in contact lense wearers)	Water accidentally inhaled in nose or pharynx Eye, skin, mucous membranes	Yes when planktonic Yes when sessile in biofilm	Yes	APHA Standard Method PCR test APHA Standard Method 9711 C
Cryptosporidium and Giardia	Gastroenteritis Biliary Tract Infections Reactive Arthritis	Fecal/Oral	Cysts are resistant in planktonic and sessile forms	Yes	Standard Method 9711 B PCR tests available for genus and species identification
Adenoviruses	Conjunctivitis, gastroenteritis	Eyes Fecal/Oral	No	Unknown	Cell culture PCR
Enteroviruses	Gastroenteritis Viral meningitis	Fecal/Oral	No	Unknown	APHA Standard Method 9510 EPA Method 1615
Noroviruses	Gastrointestinal	Fecal/Oral	No	Unknown	EPA Method 1615 RT-PCR Methods
Helminths and Roundworms	Ascariasis Baylisascariasis	Fecal/Oral	Cysts are resistant in planktonic and sessile forms	Yes	APHA Standard Method 10750 PCR tests available for species identification
Fungi	Ringworm	Skin	Spores are resistant	Yes	Culture and PCR tests

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Table Notes:

1 - NOTE: a) Many elderly and/or immuno- compromised people use hot tubs making them more susceptible to disease; b) *P. aeruginosa* can be resistant to chlorine and is found in biofilm; c) Hot tub folliculitis is the most common illness associated with hot tubs; and 4) Coliform testing is not an indication of *P. aeruginosa* contamination; d) Since this is a non-reportable disease, we have no information on the incidence of this disease.

2 - Grobe, Wingender, & Flemming, 2001; Price, 1988; Clements, 2000.

3 - Muraca, Stout, & Yu, 1987; Clements, 2000.

It is not feasible or cost effective to test for all infectious organisms. Therefore Table 4.7.3.9 identifies those organisms which have readily available test methods and/or cause illnesses that are common, very serious, or fatal. It is important to note that these test methods may not allow for rapid remediation, decision making, or public health intervention on a timely basis.

The Heterotrophic Plate Counts (HPC) method has not been included in the list of microbial water quality tests in Table 4.7.3.9. While HPC data are generally a good indicator of microbial water quality and efficacy of pool operations (e.g., water treatment), this parameter has been reported to show no correlation to the presence of *Legionella*[14], planktonic pathogens[10], or the presence of biofilm[9]. HPC tests (as do all culture tests) under-report the actual concentration of viable bacteria. Therefore, it is recommended that the use of this test be restricted for assessing the level of planktonic, non-pathogenic bacteria only. HPC data are not sufficient to assess the public health risk of pools, spas, and water parks[9,15].

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[14] Hodgson M, and Casey B. (1996) Prevalence of legionella bacteria in building water systems. In *IAQ 96. Paths to Better Building Environments.* Conference of the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. Atlanta.
[15] Costerton JW. (2007) The biofilm primer. Germany: Springer-Verlag.1-97.

Since the MAHC is intended to be a living document with changes anticipated as our knowledge increases, it is prudent to acknowledge that a paradigm shift is occurring in the world of microbiology that likely will impact how pathogen testing will be conducted and interpreted in the future. Culture tests are gradually being replaced with culture-independent test methods such as Polymerase Chain Reaction (PCR) testing and microarray testing. Years ago when PCR was first used commercially the cost of the tests was prohibitively expensive. Now test costs have decreased and are competitive with culture dependent tests. A recent development is the commercialization of microarray testing which can screen for the presence of a wide variety of bacterial and viral pathogens without the need for an isolation step. However, the costs associated with microarray testing are prohibitively expensive as of this publication.

EPA is re-evaluating the use of culture-based fecal indicator bacteria (FIB) tests in recreational water testing (i.e., total and fecal coliforms, *E. coli* and *Enterococcus*) and is researching the use of PCR for *Bacteroides* and *Enterococcus* testing as a possible replacement for these culture tests. Two of the most compelling reasons for this re-evaluation are:

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

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

Keyword Section Annex

in the future PCR may be an effective option for disinfection studies[16].

[16] Brescia CC et al. (2009) *Cryptosporidium* propidium monoazide-PCR, a molecular biology-based technique for genotyping of viable *Cryptosporidium* oocysts. *Applied and Environmental Microbiology*, 75:6856-6863.

Model Aquatic Health Code
Monitoring & Testing 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**
Testing	***5.7.3.1***	***Testing***

Keyword	Section	Annex

Dye Testing

Dye testing is recommended to assess complete circulation of the pool water. Complete circulation will allow proper levels of sanitizer and adequate filtration in all areas of the pool. Dye testing shows potential dead spots in the pool and allows the operator to make adjustments to the inlet system to achieve a balanced return of water into the pool. Dye testing can also show the presence of leaks in the pool shell.

The operator commonly has two choices for dye testing; crystal violet, which is a purple chemical, or fluorescein, which will turn the water a yellow green, can be used. Each test has its pros and cons. The operator should carefully read both the manufacturer's directions and the MSDS sheet for the chemical used.

It should be noted that there is little scientific evidence supporting guidance on best practices for conducting dye testing evaluations of pools. Example dye testing instructions can be found through the following web site: http://www.alisonosinski.com/wp-content/pdf/pool_tip_57.pdf. A general rule of thumb is that after 5-10 minutes after applying dye to the pool recirculation system, any area of the pool that doesn't have dye is likely a dead spot. The pool operator can try adjusting return jets to minimize dead spots, but if significant dead spots remain then consultation with the pool designer or builder may be needed. For older pools, consultation with a commercial service firm may be helpful.

WQTDs and Kits

5.7.3.2 Water Quality Testing Devices and Kits

Water quality testing is important to monitor proper pool operations and ensure a safe and healthy environment for pool users. Water quality testing can also be useful for evaluating the need for (or effectiveness of) troubleshooting activities, remediation activities, and facility upgrades.

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As discussed in the Annex discussion for Section 4.7.3.7, routine water sample collection is recommended only for inorganic testing (i.e., not for microbiological testing). It is recommended that routine monitoring samples should be collected from an in-line sample port when available. Such in-line sampling ports facilitate sample collection, reflect an approximately average quality of water that is recirculated in the pool system, and avoid the time and effort needed to collect composite samples from the pool.

When collecting samples for event-specific applications (e.g., water quality troubleshooting, outbreak investigations, facility upgrades), it is recommended that the study team identify sample collection sites based on the focus and needs of their study. For event-specific applications, sample collection from an in-line port may still be appropriate for inorganics testing and microbiological testing for enteric (fecal-associated) microbes. An in-line sampling location associated with the pool recirculation system can be an effective location to collect samples for microbiological analyses when the focus of the investigation is on microbe detection. For example, sand filter backflush samples have enabled the detection of parasitic pathogens in numerous studies[17,18,19]. In-line port samples have also been effective for the detection of biofilm-associated microbes[20]. These researchers observed substantially higher positivity rates for *P. aeruginosa* in pool inlet water versus samples collected from the pool, and suggested this was due to biofilm growth in inlet piping.

When conducting exposure characterizations for biofilm-associated pathogens, collecting samples from the bulk pool water is recommended. As suggested by Amagliani et al (2012), recirculation system components are covered in biofilm and it is likely that biofilm sloughing will contribute to higher detection rates (and likely higher concentrations) in in-line pipe samples than in bulk pool water samples (where the ratio of wetted surface area to

[17] Shields et al. (2008) Prevalence of *Cryptosporidium* spp. And *Giardia intestinalis* in Swimming Pools, Atlanta, Georgia. *Emerging Infectious Diseases*, 14(6):948-950.
[18] Schets et al. (2004) *Cryptosporidium* and *Giardia* in swimming pools in the Netherlands. *Journal of Water and Health*, 2(3):191-200.
[19] Cantey et al. (In Press) Outbreak of Cryptosporidiosis Associated with a Man-Made, Chlorinated Lake; Tarrant County, Texas 2008. *J Environ Health*.
[20] Amagliani et al. (2012) Molecular detection of *Pseudomonas aeruginosa* in recreational water. *International Journal of Environmental Health Research, 22*(1), 60-70.

Keyword Section Annex

water volume is significantly lower).

When collecting samples from pools, an 18-inch (45.7 cm) water depth for sample collection is recommended. Both the NSPF CPO manual and the NRPA AFO manual instruct the operator to reach at least 18 inches (45.7 cm) below the water's surface to collect the water sample. In an outdoor pool, there is chemical interaction with ultraviolet light at the surface which will affect the reading. Most of the chemical contaminants in a pool are located within the top 18 inches, which is why most studies of pool contaminants are performed by collecting samples at a depth of ≤ 30 cm (11.8 inches) below the pool water surface[21,22]. These contaminants will give false pH and sanitizer readings in indoor and outdoor pools. To sample, plunge the assembly (mouth first) quickly to the marked depth, invert, and let the bottle fill. Remove when full of water, begin testing.

Sample Collection

5.7.4 Water Sample Collection for Routine Monitoring

Testing Frequency

5.7.5 Water Quality Chemical Testing Frequency

[21] De Laat et al. (2011) Concentration levels of urea in swimming pool water and reactivity of chlorine with urea. *Water Research*, 45(3):1139-1146.
[22] Weaver et al. (2009) Volatile disinfection by-product analysis from chlorinated indoor swimming pools. *Water Research*, 43(13):3308-3318.

Keyword Section Annex

Table 5.7.5: Water Testing Frequency Reference Chart

	Start-up*	Manual testing	Automated controllers	Closing*	Start-up*	Start-up*
Free Chlorine	Yes	2 hrs	4 hrs	Yes	-	-
Combined Chlorine	Yes	2 hrs	4 hrs	Yes	-	-
pH	Yes	2 hrs	4 hrs	Yes	-	-
TA	-	-	-	-	Yes	-
CH	-	-	-	-	-	Yes
CYA	-	-	-	-	-	Yes†
TDS	-	-	-	-	-	Yes
Microbiological	Testing shall be conducted after a fecal incident.					
* Manual testing to be done at these times						
† Unless TriChlor (trichloro-s-triazinetrione) or DiChlor (sodium dichloro-s-triazinetrione) are used for daily sanitizer or shock, then weekly						
Note: manual testing should be done after a significant weather event for outdoor facilities.						

Chemical Levels

5.7.5.1 When using colorimetric testing methods, combined chlorine testing consists of measuring free chlorine (FC), measuring total chlorine (TC), and subtracting the FC from the TC. When using titrimetric methods, it is easiest to perform a direct measure. The analyst should simply count each drop of titrant and multiply by the correct factor to attain the combine chlorine level.

A properly calibrated automatic chemical monitoring system which maintains records and can be monitored remotely via a secure website could be acceptable for daily testing, if the system allows for the health department to have access to view a read-only log which monitors the chemistry at a facility.

5.7.6 Water Clarity

Water clarity is a useful measure of general water quality. Visual observation of main drains is important for bather safety to avoid drowning incidents and injury prevention (for bather visibility). For pools, the use of a Secchi disk is not recommended.

For more information on Secchi disks, see:

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

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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