Model Aquatic Health Code
Contamination Burden Module ANNEX Draft Sections for the First 60-day Review

Posted for Public Comment on 07/20/2012
Currently Open for Public Comment that Closes on 10/14/2012

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

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 Contamination Burden Module Abstract

Understanding the types of contaminants and the magnitude of disinfectant demand by various environmental factors (e.g., particulate) is an essential component to design and operate a recirculation and filtration system. Limited data currently exists, but a substantial research agenda has been created. The following is a summary of the existing data and areas where data are lacking. Since the Contamination Burden "module" is informational, this module is ANNEX-based only – NO CODE section accompanies it. After being posted for public comment, the information contained in this module will be merged into the appropriate MAHC modules upon final completion. The section numbering system will be different in this draft as there are no specific code sections yet assigned to any of this information.

MAHC Contamination Burden 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 10/14/2012, as an email attachment to **MAHC@cdc.gov**.

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

- To provide context for this module review, please consult the **MAHC Strawman Outline** (http://www.cdc.gov/healthywater/pdf/swimming/pools/mahc/structure-content/mahc-strawman.pdf). 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 Contamination Burden Annex Module shows a Table of Contents giving the context of the Contamination Burden 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:

DBP	Disinfection By-Products
HOCl	Hypochlorous acid
PHMB	Polyhexamethylene biguanide hydrochloride
PPM	Parts per million
US-EPA	United States the Environmental Protection Agency
UV	Ultraviolet

Glossary Terms in this Module:

"Aquatic Facility" means a physical place that contains one or more aquatic venues and support infrastructure under a single management structure.

"Bather" means a person at an aquatic venue who has contact with water either through spray or partial or total immersion. Bathers can be exposed to contaminated water as well as potentially contaminate the water.

"Chlorine" means an element that at room temperature and pressure is a heavy green gas with characteristic odor and is extremely toxic. It can be compressed in liquid form and stored in heavy steel tanks, but most pools now add other chlorine compounds (e.g. hypochlorite) that similar to the liquid form release hypochlorous acid when dissolved in water. Chlorinating agents are the most commonly used disinfectants for pools.

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

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

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

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

"EPA Registered" means all products registered by the US EPA will have a registration number on the label (usually it will state "EPA Reg No." followed by a series of numbers). This registration number can be verified by using the EPA National Pesticide Information Retrieval System (http://ppis.ceris.purdue.edu/#)

"Oxidation" means the process of changing the chemical structure of water contaminants by increasing the number of oxygen atoms or reducing the number of electrons of the contaminant, which allows the contaminant to be more readily removed from the water. It is the "chemical cleaning" of pool water. Oxidation can be achieved by common disinfectants (e.g., chlorine, bromine, ozone, potassium monopersulfate).

"pH" means a symbol that expresses the negative log of the concentration of hydrogen ions. When water ionizes, it produces hydrogen ions (H+) and hydroxide ions (OH-). If

there is an excess of hydrogen ions the water is acidic. If there is an excess of hydroxide ions the water is basic. pH ranges from 0 to 14. Pure water has a pH of 7.0. If pH is higher than 7.0, the water is said to be basic, or alkaline. If the water's pH is lower than 7.0, the water is acidic. As pH is raised, more ionization occurs and chlorine disinfectants decrease in effectiveness.

"Pool" means a subset of aquatic venue designed to have impounded/standing water for total or partial bather immersion.

"Trihalomethanes" means a group of compounds formed as disinfection by-products when halogens such as chlorine or bromine react with organic material in the water. Many are known to be long-term carcinogens.

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
Contamination Burden Module Annex

Section numbers may remain unassigned until final MAHC release

Keyword	Section	Annex
Particle Contamination Burden	***1.0***	***Particle Contamination Burden***

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

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

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

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requirements and help with defining the required filtration and circulation capacities.

Disinfectant Demand

2.0 Disinfectant Demand

2.1 Disinfectant consumption can occur by the reaction of the disinfectant with BATHERS, BATHER waste, and other environmentally-introduced CONTAMINANTS, as well as simple decomposition of the active halides (i.e. CHLORINE into hypochlorous acid, HOCl) into inactive halide ions (chloride or bromide). Disinfectant decomposition rates will also vary depending on a variety of factors including PH, water temperature, ultraviolet light, and BATHER load. Data on disinfectant demand are lacking in the literature on all EPA-registered disinfectants (bromine, PHMB, and metal systems), but there are some data available for CHLORINE disinfectant demand.

Chlorine Demand

3.0 Chlorine Demand

3.1 Several studies have investigated BATHER load contribution to CHLORINE demand in POOL water; however, there is a lack in consistency in how BATHER load was measured. Some studies report data as CHLORINE demand, others as potassium permanganate demand, dissolved organic carbon or total organic carbon.

3.2 The available data for CHLORINE disinfectant demand indicates that that the CHLORINE demand from BATHERS can vary by over an order of magnitude, with the largest value measured being 10 g Cl_2/bather (or 2.2 lb/100 bathers).

3.3 There are few published data on the CHLORINE demand that occurs in POOLS due to the simple decomposition of CHLORINE. It is well known that CHLORINE is not stable at high temperatures and in the presence of UV. Both of these factors will reduce active CHLORINE to inactive chloride, without any BATHER waste being present.

3.4 The rate of CHLORINE loss (pounds of CHLORINE per hour) due to UV degradation will depend on a number of factors, including the size of the POOL, the depth of the

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water and the intensity of the sunshine. It will also depend on the amount of cyanuric acid present, since cyanuric acid can help prevent the decomposition of CHLORINE by UV. Given the number of variables, it is difficult to predict CHLORINE decomposition rates in POOLs.

3.5 Additional research on the contributing factors to disinfectant demand (i.e. nitrogenous waste) may be warranted in the future as treatment methods are developed to reduce or eliminate them by means other than OXIDATION. It is anticipated that this research would identify the introduction rate of the CONTAMINANT, resulting concentrations, and the effect that reduction or elimination of this CONTAMINANT would have on disinfectant demand or other ancillary benefits (i.e. reduction of combined CHLORINEs).

3.6 Further data collection on CHLORINE usage in real world POOL situations under different environmental and operational conditions could be used to develop an effective rate law from which the sizing of chemical feed pumps could then be calculated. The criteria for specifying a chemical feed pump for a swimming POOL are based on its ability to feed against the process piping pressure and to provide sufficient feed rate to maintain a disinfectant residual in the water. Several states require chemical feed pumps for CHLORINE to be capable of providing up to 10 ppm of CHLORINE in the pipe returning water from the recirculation system back to the POOL. Once actual CHLORINE usage is obtained, a surplus safety factor could be introduced to slightly oversize the feed pump to ensure that the disinfectant dosing amount can be increased to meet increases in demand.

Disinfection Byproduct Issues

4.0 Disinfection Byproduct Issues

4.1 Chlorination, using CHLORINE as the disinfectant, is the most common procedure for swimming POOL water DISINFECTION and inactivation of waterborne microbial pathogens. Swimmers' activity and environmentally-introduced material provides a broad range of precursors with which disinfectants can react (e.g., perspiration, urine, mucus, skin particles, hair, body lotions, fecal material, soil, etc.). When CHLORINE reacts with these

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precursors, a variety of chemical reactions take place, including the formation of DISINFECTION BY-PRODUCTS (DBPs).

4.2 DBPs can be organic [e.g., TRIHALOMETHANEs, chlorinated phenols, haloketones, haloacetic acids, and haloacetonitriles (HANs)] or inorganic (e.g. chloramines and cyanogen chloride). All inorganic chloramines, and particularly trichloramine, are very volatile and partition easily from water into air. The major by-products of DISINFECTION using Hypobromous acid (HOBr) and Hypochlorous acid (HOCl) are bromoform ($CHBr_3$) and chloroform ($CHCl_3$), respectively. Chloroform and bromoform are highly volatile compounds that can be inhaled in swimming POOL environments and also readily absorbed through the skin.

4.3 The main organic DBPs are

- TRIHALOMETHANEs *(total TRIHALOMETHANE is the sum of the concentrations of chloroform, bromoform, bromodichloromethane, and dibromochloromethane)*,
- chlorinated phenols *(2-chloro-, 2,4-dichloro- and 2,4,6-trichlorophenol)*, haloketones *(1,1-dichloropropanone, 1,1,1-trichloropropanone)*,
- haloacetic acids *(Total haloacetic acids include the sum of the concentrations of mono-, di-, and trichloroacetic acids and mono- and dibromoacetic acids)*;
    - haloacetonitriles (HANs) include (dichloro-, trichloro-, dibromo- and bromochloroacetonitrile), chloropicrin, chloral hydrate, 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone, etc.

4.4 According to European Union regulations, the concentration of TRIHALOMETHANEs in drinking water should not exceed one hundred micrograms per liter (100 µg/L) of water for consumption; while in the United States the Environmental Protection Agency (USEPA) has established a legal maximum of 80 µg/L.

4.5 Inorganic DBPs include chloramines and cyanogen chloride. Chloramines include monochloramine (NH_2Cl),

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DICHLORAMINE ($NHCl_2$) and trichloramine (NCl_3) and are generated from the reaction of hypochlorite with ammonia and amino-compounds that originate from sweat and urine of the swimmers. All chloramines, and particularly trichloramine, are very volatile and partition easily from water into air.

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

- the number of swimmers in the POOL,
- the CHLORINE dose,
- the bromide content,
- the extent of out-gassing of volatile DBPs,
- PH, and
- the use of DBPs-containing water (mostly CHLORINE-treated surface water) for the POOL water supply.

4.7 Studies have documented potential links between respiratory ailments (e.g., asthma) and swimming, especially in indoor swimming POOLs. Air quality in indoor aquatic facilities has emerged as an area of concern with respect to human health. If there is poor ventilation in the buildings or swimming POOL, it could be the cause of negative health effects for BATHERs from inhalation exposure to the chloramines.

4.8 It should be noted however, that despite the health risks of DBPs in general, the concentration of organic DBPs found in POOLs is generally low. Therefore, although research results have shown that DISINFECTANT BY-PRODUCTS do form in detectable concentrations in most POOLs, it appears that the benefits of DISINFECTION far outweigh the risks posed by its by-products. This conclusion is shared by the World Health Organization, which states that “the risks from exposure to chlorination by-products in reasonably well-managed swimming POOLs would be considered to be small and must be set against the benefits of aerobic exercise and the risks of infectious

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disease in the absence of DISINFECTION."[1] Improved water quality management is recommended to minimize formation and accumulation of these compounds.

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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