Vote to Raise the Disinfection Floor for Recreational Water:

This November the Council for the Model Aquatic Health Code (CMAHC) will vote on updates for the 2021 Model Aquatic Health Code (MAHC). One of the most important topics during this update cycle involves change requests (CRs) regarding the impact of cyanuric acid on disinfection in aquatic venues. Have your voice heard, become a member of the CMAHC and vote on the updates!!! Go to www.cmahc.org. Below is a discussion on the scientific reason behind the CRs.

How CYA impacts disinfection:

The debate over the use of cyanuric acid in recreational water has been continued since the chemical was first introduced. While cyanuric acid helps pool operators maintain chlorine residuals in outdoor pools, it decreases the effectiveness of chlorine to kill pathogens and algae. Why does this happen? The answer is simple: Cyanuric acid (CYA) reduces the amount of hypochlorous acid (HOCl) in the water. HOCl is the primary sanitizer in chlorine-based disinfection systems for pools.

Here is how it works. When chlorine becomes bound to CYA, it is no longer available to be broken down by sunlight. However, chlorine in this state is also no longer available to carry out the reactions necessary to destroy microorganisms. Most of this effect occurs at relatively low levels of CYA. Most of the benefit gained by adding CYA is seen with the first 15 ppm. Roughly 70% of the chlorine residual (free chorine, FC) is preserved in an hour of sunlight at this concentration of CYA. At the same time most of the HOCl is also lost within the first 15 ppm cyanuric acid. The HOCl concentration drops from 46% when CYA is NOT present to 5% when there is 15 ppm CYA. The graph below shows both interactions:

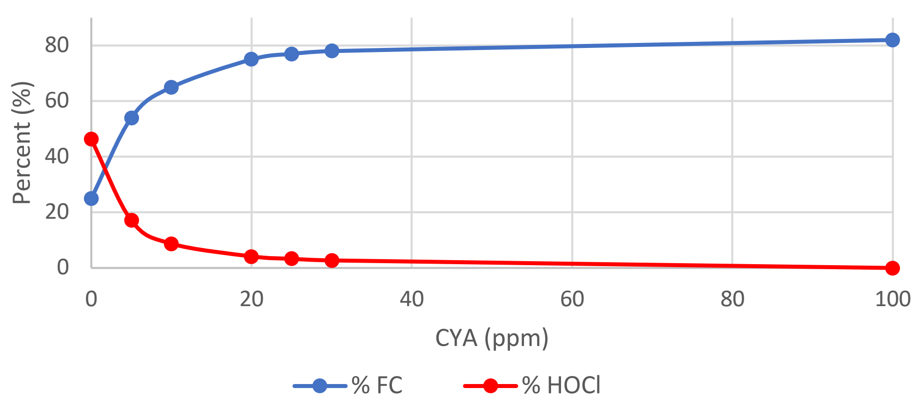

*Table 1:Percent Free Chlorine Remaining After One Hour of Sunlight (Canelli 1974) and Percent of HOCl vs CYA Concentration(Falk 2019).*HOCl Calculated at: pH: 7.5; Temp: 30.5 °C; TDS: 800 ppm*

The reaction between chlorine and CYA is not permanent. In fact, the forces that govern this reaction are constantly driving an equilibrium, or ratio, between CYA-bound and unbound chlorine. This means that as HOCl is used up, some of the CYA-bound chlorine becomes unbound and forms HOCl. As CYA concentrations increase, a higher percentage of chlorine become bound and less is free to form HOCl. In order to increase HOCl concentrations, enough chlorine must be added to account for the chlorine that will become CYA-bound and to increase the amount of HOCl. The following analogy explains the relationship between CYA, chlorine and sunlight:

If we compare chlorine to soldiers in a war, hypochlorous acid (HOCl) molecules are like the soldiers on the battlefield ready to destroy the invading pathogens and algae. In an outdoor pool, sunlight can cause the soldiers to get worn out before they have a chance to fight the invaders. Adding CYA is like building barracks and keeping most of the soldiers in reserve (CYA bound chlorine), where they do not get worn down by the sun, but also do not do any fighting. As soldiers on the battlefield fall, some of the soldiers in the barracks are sent to the field to replace them. If the ratio of barracks (CYA) and soldiers (chlorine) is maintained properly, then the pool maintains ample supply of soldiers on the battlefield to defend against the invading algae and pathogens. If too much CYA and/or not enough chlorine is present, too many soldiers end up in reserve, and too few soldiers get to the battlefield to defend the pool. The pool's defending forces get overwhelmed, and the invaders take over.

The invaders like algae and some bacteria can reproduce in swimming pool water. Even if there were an infinite number of soldiers in reserve, if there are not enough soldiers on the battlefield to destroy the invaders faster than they can reproduce, the war is lost. This explains why a pool with the prescribed amount of chlorine (1-4 ppm FC) and high levels of CYA can end up with algae blooms.

The Ratio Concept:

So how do we make sure that we have enough HOCl? The pool industry does not have an inexpensive and easy way of measuring hypochlorous acid concentrations. The industry standard method for measuring FAC is the N,N-diethyl-p-phenylenediamine (DPD) method. However, the DPD method does not distinguish between CYA-bound and unbound chlorine, therefore the FC measured by DPD (DPD-FC) does not correlate to HOCl concentrations when CYA is present. Hypochlorous acid concentration can be calculated using the following measurements: DPD-FC, temperature, pH, CYA and total dissolved solids, with DPD-FC and CYA having the largest impact. These calculations are quite complex, and operators and service professionals need a simple tool for ensuring they have enough HOCl.

Since this is such a complex and important issue, the Council for the Model Aquatic Health Code (CMAHC) put together an ad hoc committee to investigate the scientific data available for determining the impact of CYA on public health. They found that by setting a maximum CYA to FC ratio (ppm CYA/ppm FC), a minimum HOCl concentration could be maintained. This gives operators the ability to maintain a minimum HOCl concentration using the tools they already have at hand. In other words, they can be sure enough soldiers are on the battlefield. The committee published a paper with their findings, a model for comparing relative risks to swimmers for gastrointestinal illnesses and a tool for calculating HOCl concentrations (Falk 2019).

Determining the Floor for Disinfection and Comparing the Risk:

Using the HOCl calculator from the paper we can better compare disinfection practices when CYA is in the water. The 2018 Model Aquatic Health Code recommends a maximum CYA of 90 ppm, and a minimum FC of 2 ppm, when CYA is present. This roughly translates to a maximum ratio of 45 ppm CYA/ppm FC. With CYA and FC at these levels, at room temperature and the highest pH recommended, 7.8, the disinfection concentration would be 0.0077 ppm HOCl. We can consider this minimum disinfection concentration for typical operating conditions or the disinfection floor. The same water without CYA would have 0.3234 ppm HOCl, or roughly 42 times the amount of primary sanitizer. For water where sunlight does not break down FC, the presence of CYA creates a huge cost to disinfection with no benefit.

In outdoor waters, the costs to disinfection should be balanced with the benefit of extending the chlorine residual. If a ratio of 15 ppm CYA/ppm FC or higher is maintained, then the minimum HOCl is ~

0.0235 ppm HOCl. This raises the disinfection floor by more than three times the current recommendations. According to the model, decreasing the CYA/FC ratio from 45 ppm CYA/ ppm FC to 15 ppm CYA/ ppm FC would decrease the risk of E. coli infection per visit by 9 times.

Another way to compare the risk, and perhaps more meaningful, is to compare the time needed to inactivate different germs based on HOCl concentrations based on the Chick-Watson disinfection model. This model assumes time needed to inactivate a pathogen is inversely proportional to the concentration of the disinfectant. In other words, it will take longer to inactivate a germ with less disinfectant, and if we know how long it takes at one concentration, we can reasonably predict how long it will take at another. The table below shows the inactivation times for 1 ppm FAC at different CYA/FC ratios using HOCl concentrations at the published water parameters.

Germ	Ratio of Max CYA ppm/FAC ppm		
	0 ppm	15 ppm	45 ppm
	HOCl (ppm) of 1 ppm FAC		
	0.4881*	0.0265*	0.0086*
	Time (min)		
E. coli O157:H7 Bacterium	1 min.**	18 min.	57 min
Hepatitis A Virus	20 min.**	6 hrs.	19 hrs.
Giardia Protozoan	45 min.**	14 hrs.	2 days.
Cryptosporidium Protozoan	11 days.**	196 days.	603 days
*HOCl Calculated using Supplemental Materials from Falk 2019. pH: 7.5; Temp: 25 °C; TDS 800 ppm. **3-log inactivation rates derived from MAHC A 5.7.3.1.1.2.			

As shown, the kill times increase dramatically with increasing CYA/FC ratio. Compared to the existing MAHC ratio of 45 ppm CYA/ ppm FC, the 15 ppm CYA/ ppm FC ratio would take roughly one third the time to inactivate these pathogens, meaningfully raising the floor for disinfection.

What are the CRs of Interest:

3.2-0033: This CR introduces the term DPD-FC. Free chorine (FC) is defined as the amount of hypochlorous acid (HOCl) and hypochlorite ion (OCl^-) in the water. The industry standard method for determining FC (DPD method), does not differentiate between CYA bound chlorine and unbound free chlorine. When CYA is present, this measurement does not reflect the true FC in the water. This term gives us a way of indicating this.

5.7.3.1.1.2.1-0001: This CR proposes to change the minimum DPD-FC for pools using CYA from 2 ppm to 1 ppm. As a stand-alone CR, this change is unacceptable because if no other changes are made, it would allow 1 ppm DPD-FC with 90 ppm CYA, which means that the disinfection floor would be lowered to 0.0038 ppm HOCl. This level is about half the minimum HOCl concentration currently allowed in the MAHC. The 15:1, 30:1 and 45:1 ratio CRs discussed below also change the minimum to 1 ppm DPD-FC, but add the requirement that the CYA:DPD-FC ratio may not be exceeded.

5.7.3.1.1.2-0002: This CR proposes to set a maximum 15 to 1 ratio of CYA to DPD-FC, instead of 45 to 1. In other words to raise the floor for disinfection from 0.0086 to 0.0235 ppm HOCl, when pH is 7.8; at room temperature; and TDS is 800 ppm. It also justifies this change, because operators have been taught for years that combined chlorine is not a sufficient sanitizer. Higher concentrations of CYA than this would drop the HOCl concentration so low that 1 ppm chlorine would be less effective than 1 ppm monochloramine for killing *Giardia*. Additionally, pools kept at 15 ppm CYA would not need to be drained for crypto contamination response.

At the same time, this ratio would provide significant protection of chorine residuals from degradation caused by sunlight. Studies show that the majority of the chlorine stabilization occurs below this amount of CYA.

5.7.3.1.1.2-0001: This CR proposes to set a maximum 30 to 1 ratio of CYA to DPD-FC. At pH 7.8, room temperature and 800 ppm TDS, the HOCl concentration for this ratio is 0.0116 ppm. This CR is from the CMAHC ad hoc committee, who originally recommended a 20:1 ratio and then changed it to 30:1.

5.7.3.1.1.2.2-0002: This CR proposes setting the maximum ratio of CYA to DPD-FC at 45 to 1. All three of the ratio CRs (15:1, 30:1, 45:1) recommend that the minimum DPD-FC concentration when CYA is present be changed from 2 ppm to 1 ppm. So although this 45:1 ratio looks like it is not decreasing the disinfection floor from where it is currently, it does pose a higher risk for pools operating with 1-2 ppm DPD-FC.

5.7.3.1.1.2.2-0001: This CR proposes to keep the minimum of 1 ppm FC for pools without CYA and 2 ppm DPD-FC for pools with CYA, but also adds in the following table where increasing CYA concentrations will require increasing DPD-FC:

Minimum DPD-FC, ppm	Range of CYA, ppm
2	1 to 30
3	31 to 60
4	61 to 90

5.7.3.1.3.1-0002: The current MAHC, recommends CYA not be used for indoor pools, this CR would prohibit it.

5.7.3.1.3.1-0003: This CR proposes to delete the prohibition of CYA for spas and therapy pools. This is unacceptable as these venues have a higher risk for disease transmission. Disinfection requirements should not be lowered in these venues.

5.7.3.1.3.2-0001: This CR proposes "if CYA level tests above 90 ppm (mg/L), the aquatic venue may remain open during its normal operating hours that day but when it is closed for the day the swimming pool may not reopened until the CYA level is lowered to 75 ppm or less. If a pool that operates 24 hours a day, the CYA level must be lowered to 75 ppm or less within 24 hours.".

5.7.3.1.3.2-0002: This CR uses that ratio concept to keep the minimum DPD-FC of 2 ppm when CYA is present and set 40 ppm maximum for CYA, based on the CYA CMAHC Ad hoc Committee's published 20:1 ratio.

5.7.3.1.3.2-0003: This CR proposes raising the minimum DPD-FC to 3 ppm when CYA is used and setting a 60 ppm maximum for CYA. This is based on the CYA CMAHC Ad hoc Committee's published 20:1 ratio.

5.7.3.1.3.2-0004: This CR proposes to raise the CYA maximum to 180 ppm. In addition to raising the risk of illness in pools, there are practical issues with this CR. Most test kits in the industry do not measure above 100 ppm, so measuring concentrations above this requires dilution. This increases the error of the test and makes testing more difficult for service professionals. The CR requires individuals testing above 90 ppm CYA to prove that they can do so accurately, adding to the training requirements for those individuals. This CR does not address the fact that NSF-50 certifications for some test kits only require them to be accurate within ±50%. This means water with a concentration of 360 ppm could report as low as a result of 180 ppm CYA. Nor does this CR address the difficulties of using ORP to control chorine feed with CYA concentrations as high as 180 ppm.

5.7.5.8.2-0002: This CR proposes to require daily testing of CYA. Increased testing is vital for operations using trichlor or dichlor as these sanitizers increase the CYA 0.6 ppm for every 1 ppm DPD-FC added.

5.7.5.8.2-0003: This CR, submitted by the CYA CMAHC Ad hoc Committee, proposes to require weekly testing of CYA. Increased testing is vital for operations using trichlor or dichlor as these sanitizers increase the CYA 0.6 ppm for every 1 ppm DPD-FC added.

6.1.2.1.1.5-0001: This CR proposes to add the impact of CYA concentrations on HOCl concentrations to pool operator courses.

6.5.3.1.1-0001: This CR proposes to change the formed stool remediation to ensure sufficient HOCl is present for inactivation of *Giardia*. The remediation times will vary depending on the CYA:DPD-FC ratio.

6.6.3.1-0003: This CR proposes that <1 ppm DPD-FC, > 300 ppm CYA, or exceeding a 45:1 CYA:DPD-FC ratio should be reason for immediate correction of closure. The operational limit would require action be taken to reduce the cyanuric acid, but action would not need to be taken immediately. The closure limit would require a facility to close if they are not able to immediately address the issue. The 300 ppm limit is based on the toxicity of CYA and exposure calculations from NSF International[i]. This CR changes the 2 ppm minimum DPD-FC requirement for pools with CYA to 1 ppm DPD-FC.

6.6.3.1-0004: This CR proposes that exceeding 90 ppm CYA should be reason for closure. Since the CR references the operational section of the code, if the CYA limit were raised to 180 ppm, then the limit for closure would also be 180 ppm. The operational limit would require action be taken to correct the CYA concentration, but the action would not need to be immediate.

6.6.3.1-0005: This CR proposes that <1 ppm DPD-FC, >300 ppm CYA, or exceeding a 150:1 CYA:DPD- FC ratio should be used for immediate correction or closure. The 300 ppm value is based on the toxicity limit for CYA from NSF International. This CR changes the 2 ppm minimum DPD-FC requirement for pools with CYA to 1 ppm DPD-FC.

6.6.3.1-0001: This CR proposes that the MAHC keep the disinfectant levels for closure that are currently in the MAHC (i.e. 1 ppm FC for pools not using CYA and 2 ppm DPD-FC for pools using CYA), and also requires that pools be immediately corrected or closed if the CYA concentration is above 117 ppm. The 117 ppm limit is based on the toxicity of CYA and exposure calculations from the World Health Organization (WHO)[ii].

Recommendations:

The voting system is not a this or that system. If there are more than one similar CRs that you agree with, you can vote yes for all of them. Additionally, a “no” vote is just as powerful as a “yes” vote. We recommend voting to adopt the following CRs. We believe they provide a meaningful improvement to the disinfection of recreational water, and thereby decreasing the risk of bathers contracting recreational water illnesses and improving the whole industry. They raise the floor for disinfection by increasing the minimum amount of HOCl in the water, without imposing major changes to pool operations.

Vote Yes

<table>
<tr><td>3.2-0033</td><td>DPD-FC definition</td></tr>
<tr><td>5.7.3.1.1.2-0002
Or
5.7.3.1.1.2.2-0001</td><td>Maximum 15:1 CYA:DPD-FC ratio
Or
Table<table><tr><td>Minimum DPD-FC, ppm</td><td>Range of CYA, ppm</td></tr><tr><td>2</td><td>1 to 30</td></tr><tr><td>3</td><td>31 to 60</td></tr><tr><td>4</td><td>61 to 90</td></tr></table></td></tr>
<tr><td>5.7.3.1.3.2-0001</td><td>If CYA > 90 ppm, drain to 75 ppm overnight</td></tr>
<tr><td>5.7.5.8.2-0003</td><td>Weekly testing of CYA</td></tr>
<tr><td>6.1.2.1.1.5-0001</td><td>Including CYA vs HOCl in operator training courses</td></tr>
<tr><td>6.5.3.1.1-0001</td><td>Formed stool remediation based on HOCl</td></tr>
<tr><td>6.6.3.1-0001</td><td>Closure for
> 117 ppm CYA
<1 ppm FC for pools without CYA
<2 ppm DPD-FC for pools with CYA</td></tr>
</table>

We recommend voting against the adoption of the following CRs. We believe they would decrease the minimum disinfection for recreational waters in the industry, thereby increasing risk of illness for bathers and hurting the industry.

Vote No

5.7.3.1.1.2.2-0002	Maximum 45:1 CYA:DPD-FC ratio
5.7.3.1.1.2.1-0001	Change minimum DPD-FC for pools with CYA from 2 ppm to 1 ppm.
5.7.3.1.3.1-0003	Delete the prohibition of CYA for spas and therapy pools.
5.7.3.1.3.2-0004	Raise the CYA limit to 180 ppm.
6.6.3.1-0001	Closure for >150:1 CYA:DPD-FC ratio or >300 ppm CYA

[i] Cox, K., Hamilton, S. Cyanuric acid (CAS #108-80-5): Estimated maximum allowable concentration in pool water, NSF International, Study number NSF00001, May 28, 2019. This study is available in the attachments to CR 6.6.3.1-0005.

[ii] WHO 2006 Guidelines for safe recreational water environments, V 2: Swimming pools and similar environments, https://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/