Public Comments and Responses for Contamination Burden Annex after First 60-day Review Period

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1. Thomas Kuechler, Occidental Chemical Corporation (Sauget, IL)

- *Comment:*
  Glossary "Disinfection By-Product" – *As written, all products of the reaction are DBPs, which is not the intent. The intent is to define and discuss the undesired products. --* "Disinfection By-Product" means ~~a~~ an undesired 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).

  Changes to Code/Annex:
  Agree. Changed as suggested.

- *Comment:*
  Glossary "Oxidation" – *Not all oxidizers used for pools are disinfectants. Potassium monopersulfate, is not registered for use as a disinfectant in pool water, it is just used as an oxidizer. --* "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~~ oxidizers (e.g., chlorine, bromine, ozone, potassium monopersulfate).

  Changes to Code/Annex:
  Reworded definition; however, proposed definition is a circular reference.

- *Comment:*
  Glossary "pH" – *The last sentence should be deleted as it is beyond the scope of the simple definition of pH. --* "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.~~

Changes to Code/Annex:
Disagree, while this is a true statement, the MAHC prefers to leave it in this section because it is relevant to why pH is of such importance to chlorine disinfection in pool water.

- *Comment:*
  Glossary "Trichloramine" – *Trichloramine is not defined in the glossary, while dichloramine is defined. However, NCl_3 is of greater interest than $NHCl_2$ and thus should also be included in the glossary. $NHCl_2$ is generally found at very low concentrations, since it much less stable than NCl_3. --* Add to Glossary: "Trichloramine" means a disinfection by-product formed when chlorine binds to nitrogenous waste in pool water to form an amine-containing compound with three chlorine atoms (NCl_3). It is a known acute respiratory and ocular irritant.

  Changes to Code/Annex:
  Agree. Changed as suggested.

- *Comment:*
  2.1 – *CHLORINE does not decompose into HOCl. HOBr decomposes into bromide. The draft language is thus incorrect or unclear. The proposed changes correct the draft language. --* 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 or hypobromous acid, HOBr) into inactive halide ions (chloride or bromide).

  Changes to Code/Annex:
  Agree. Typo corrected.

- *Comment:*
  2.1 – *As written, the draft language seems to imply that bromine, PHMB, and metal systems comprise all EPA-registered disinfectants and that CHLORINE is*

not. The proposed changes improves the text. -- Data on disinfectant demand are generally lacking in the literature on all EPA-registered disinfectants ~~(bromine, PHMB, and metal systems), but there are some data available for CHLORINE disinfectant demand~~. There are some data available for CHLORINE disinfectant demand, but there is very little data for bromine, PHMB, and metal systems.

Changes to Code/Annex:
Agree. Simplified the sentence.

- *Comment:*
  3.1, 3.2, 3.3 – *There are no references cited. The text should refer to the studies used.*

  Changes to Code/Annex:
  Agree added statement in 3.0 Chlorine Demand and references have been cited.

- *Comment:*
  3.4 –*"Concentration" is more precise than the vague term "amount". --* It will also depend on the ~~amount~~ concentration of cyanuric acid present, since cyanuric acid can help prevent the decomposition of CHLORINE by UV.

  Changes to Code/Annex:
  Agree, changed as suggested.

- *Comment:*
  3.4 – *Added text is self-explanatory. --* Add to end of section: The rate of CHLORINE loss can be reduced by the use of other oxidizers, including potassium monopersulfate and ozone, or UV, which can destroy contaminants which would otherwise react with CHLORINE.

  Changes to Code/Annex:
  Agree, changed as suggested, but not in this section. Added to introductory statement under 3.5

- *Comment:*
  4.1 – *Most pools use municipal water, which has been chlorinated and contains*

DBPs, for filling. -- Add to end of this section: DBPs can also be introduced into the POOL via the water used to fill the POOL.

Changes to Code/Annex:
Agree. Revised to say, "DBPs may also be introduced into the POOL via the water used to fill the POOL depending on the supply water quality."

- *Comment:*
  4.2 – *Delete this sentence, which is redundant to section 4.5. --* ~~All inorganic chloramines, and particularly trichloramine, are very volatile and partition easily from water into air.~~

  Changes to Code/Annex:
  Agree delete sentence.

- *Comment:*
  4.4 – *Provide a reference to the EU regulations cited. The abbreviation "US-EPA" is already defined on page 4. Provide a reference to the EPA regulation cited. --* According to European Union regulations, the concentration of TRIHALOMETHANEs in drinking water should not exceed one hundred micrograms per liter (100 µg/L, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:330:0032:0054:EN:PDF) of water for consumption; while in the United States the ~~Environmental Protection Agency (USEPA)~~ US-EPA has established a legal maximum of 80 µg/L. (http://water.epa.gov/drink/contaminants/index.cfm)

  Changes to Code/Annex:
  Agree, Additional references added (see footnotes in CB Annex provisions). Also changed text to US EPA acronym.

- *Comment:*
  4.5 – *There are both inorganic and organic chloramines formed in pool water. This discussion is just about the inorganic chloramines, therefore the word "inorganic" has been added. See comment above on adding trichloramine to the Glossary. --* Inorganic DBPs include inorganic chloramines and cyanogen chloride. Inorganic chloramines include monochloramine (NH_2Cl), DICHLORAMINE ($NHCl_2$) and ~~trichloramine~~ 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~~ ~~inorganic~~ ~~chloramines, and particularly trichloramine~~ TRICHLORAMINE, is relatively volatile and partitions easily from water into air.

- *Changes to Code/Annex:*
  Added "Organic Chloramines" to bulleted list in 4.3. Added "inorganic" to beginning of 4.5. Added a new last sentence in 4.5: removing" inorganics" from the sentence because dichloramine and monochloramine are fairly soluble in water where trichloramine is more likely to partition in air.

- *Comment:*
  4.6 – *This section discusses DBPs, not just chloramines. The amount and type of DBPs formed depend heavily on the amount and chemical structure of the organic precursors present. This in turn, depends on not just the number of swimmers, but how clean they are and how much they urinate in the pool, as well as what types of contaminants they introduce (lotions, makeup, personal care products, etc).* -- The conditions that determine production and air levels of ~~chloramines~~ DBPs have been suggested to depend on several factors:

  - the number of swimmers in the POOL,
  - the CHLORINE dose,
  - the concentration of organic precursors in the pool water,
  - the chemical structure of the organic precursors,
  - 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~~.

  Changes to Code/Annex:
  Changed "chloramines" to DBPs as suggested. Changed bulleted additions as suggested except for last bullet which was not included because DBPs from fill water are not a significant contributor unless chloramines are found in fill water. Also included a section about the need for further research on the formation and retention rate of DBP's in pool water.

- *Comment:*
  4.7 – *The text should provide references to the studies used.*

  Changes to Code/Annex:

Agree. References added in document as suggested.

- *Comment:*
  NEW SECTION 4.9 – *The draft says very little about urea which is a major contaminant in pool water. Urea is a significant contributor to both the overall chlorine demand and the formation of chloramines. New suggested language is given.* -- Add the following new section: 4.9 A major contaminant in POOL water is urea. Urea is chiefly derived from swimmers urinating in pool water, but is also present in swimmer's sweat. It has been shown that urea reacts with hypochlorous acid to produce NCl_3 ~~directly~~. However, while breakpoint destruction of ammonia is very fast, reaction of hypochlorous acid with urea is very slow. Therefore, urea is difficult to remove quickly by shocking the pool water. There are no guidelines in the U.S. for monitoring the urea concentration in pool water or suggested levels of concern. Input of urea is most effectively minimized by changes in swimmers' behavior. – **REFERENCE**:
  - http://www.ncbi.nlm.nih.gov/pubmed/20964367
  - E. Blatchley III, M. Cheng, "Reaction mechanism for chlorination of urea", Environmental Science & Technology, 2010, 44 (22) 8529-8534

  Changes to Code/Annex:
  Removed the word "directly" as suggested.

- *Comment:*
  Footnote 1, pg 12 – *The WHO Guidelines were revised and issued in 2006. The newer reference should be used. Footnote 1 is from Chapter 4.* -- WHO (2000): Guidelines for safe recreational-water environments, Volume 2: Swimming pools, spas and similar recreational-water environments. ~~Final draft for consultation, August 2000~~ 2006, Chapter 4. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/.

  Changes to Code/Annex:
  Agree, changed as suggested.

- *Comment:*
  Bibliography – *The format for the references is inconsistent. References should be modified to provide a consistent format.*

Changes to Code/Annex:
Agree, need to make sure the format is consistent across all the modules

- *Comment:*
  References – *The first name on this reference is written incorrectly.* -- ~~Clifford, P. W.,~~Weisel, C. P., Richardson, S. D., Nemery, B., Aggazzotti, G., Baraldi, E., Blatchley, E. R., Blount, B. C., Carlsen, K., Eggleston, P. A., Frimmel, F. H., Goodman, M., Gordon, G., Grinshpun, S. A., Heederik, D., Kogevinas, M., LaKind, J. S., Nieuwenhuijsen, M. J., Piper, F. C., & Sattar S. A. (2009). Childhood asthma and environmental exposures at swimming pools: State of the science and research recommendations. Environmental Health Perspectives, 117, 500-507.

  Changes to Code/Annex:
  Agree, changed as suggested.

- *Comment:*
  References – *The first name on this reference is written incorrectly.* -- ~~Kim, J.~~ Kim, H. Shim, J. Lee, S., Formation of disinfection by-products in chlorinated swimming pool water. Chemosphere, 46, 2002, 123-130.

  Changes to Code/Annex:
  Agree, changed as suggested.

- *Comment:*
  References – *The WHO Guidelines were revised and issued in 2006. The newer reference should be used.* -- WHO (2000): Guidelines for safe recreational-water environments, Volume 2: Swimming pools, spas and similar recreational-water environments. ~~Final draft for consultation, August 2000~~ 2006. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/.

  Changes to Code/Annex:
  Agree, changed as suggested.

- *Comment:*
  References for New Section 4.9 –
  i. E. Blatchley III, M. Cheng, “Reaction mechanism for chlorination of urea”, Environmental Science & Technology, 2010, 44 (22) 8529-8534.
  ii. J. De Laat, W. Feng, D. Freyfer, F. Dossier-Berne, “Concentration levels of urea in swimming pool water and reactivity of chlorine with urea”, Water Research, 2011, 45(3) 1139-1146.
  iii. C. Schmalz, F. Frimmel, C. Zwiener, “Trichloramine in swimming pools – Formation and mass transfer”, Water Research, 2011, 45(8) 2681-2690.

  Changes to Code/Annex:
  Agree, Reviewed references and included as suggested

- *Comment:*
  Additional References to Consult –
  i. J. De Laat, F. Berne, R. Brunet, C. Hue, “Chlorination byproducts formed during disinfection of swimming pool waters. Literature review”, J Europeen d'Hydrologie, 2009, 40(2) 109-128.
  ii. S. Weng, E. Blatchley III, “DBP dynamics in a chlorinated, indoor swimming pool under conditions of heavy use: National swimming competition”, Water Research, 2011, 45(16) 5241-5248.
  iii. S. Weng, J. Li, E. Blatchley III, “Effects of UV254 irradiation on residual chlorine and DBPs in chlorination of model organic-N precursors in swimming pools”, Water Research, 2012, 46, 2674-2682.
  iv. V. Bessonneau, M. Derbez, M. Clément, O. Thomas, “Determinants of chlorination by-products in indoor swimming pools”, International J of Hygiene & Environmental Health, 2011, 215(1) 76-85.

  Changes to Code/Annex:
  Agree, Reviewed references and included as suggested

2. Richard Falk, Pool Owner (San Rafael, CA)

- *Comment:*
  Glossary “Trihalomethane” – *Editorial and Scientific Studies. There are many different kinds of disinfection by-products. THMs are just one group of them, specifically one or more halogens bound to a single carbon. Partly because they are neutral small molecules, they have dermal absorption and are also volatile (see your section 4.2).*

Note that only the brominated THMs are mutagens/carcinogens while the chlorinated THM chloroform is not (see references). Unfortunately, Total THMs are often measured when it should really be brominated THMs that should be examined and policy regarding use of bromine and of water containing bromide should be reconsidered. -- "**Trihalomethanes**" means a specific group of compounds formed as disinfection byproducts when halogens such as chlorine or bromine react with organic material in the water. ~~Many~~ The brominated THMs are known to be long-term carcinogens. –

Changes to Code/Annex:

Some trihalomethanes are known to be carcinogens. Added word "specific" and modified the last sentence in the definition.

- *Comment:*
  "Disinfection By-Product" means ~~a~~ an undesired 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). –
  REFERENCES:
    i. Constan AA, Wong BA, Everitt JI, Butterworth BE. Chloroform Inhalation Exposure Conditions Necessary to Initiate Liver Toxicity in Female B6C3F1 Mice. Toxicological Sciences. 2002 Apr;66(2):201-208.
    ii. Golden RJ, Holm SE, Robinson DE, Julkunen PH, Reese EA. Chloroform Mode of Action: Implications for Cancer Risk Assessment. Regulatory Toxicology and Pharmacology. 1997 Oct;26(2):142-155.
    iii. Larson JL, Templin MV, Wolf DC, Jamison KC, Leinninger JR, Mèry S, Morgan KT, Wong BA, Conolly RB, Butterworth BE. A 90-Day Chloroform Inhalation Study in Female and Male B6C3F1 Mice: Implications for Cancer Risk Assessment. Toxicological Sciences. 1996 Mar;30(1):118-137.
    iv. Reitz RH, Mendrala AL, Corley RA, Quast JF, Gargas ML, Andersen ME, Staats DA, Conolly RB. Estimating the risk of liver cancer associated with human exposures to chloroform using physiologically based pharmacokinetic modeling. Toxicology and Applied Pharmacology. 1990 Sep;105(3):443-459.
    v. EPA Integrated Risk Information System (IRIS) entry for Chloroform: http://www.epa.gov/iris/subst/0025.htm

Changes to Code/Annex:
These references have been added to the research agenda for future review.

- *Comment:*
  1.1 – *Editorial. The recirculation system can, and usually is, designed to handle the maximum typical contaminant load, but may be designed with additional buffering. That is, it is not a problem for the system to be somewhat over-designed (though too much would waste energy).* -- Essentially, the recirculation system needs to be designed to

remove particles at least 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.

Changes to Code/Annex:
Agree, changed as suggested

- *Comment:*
  New Section between 3.1 and 3.2 – *Editorial. In the absence of existing scientific literature proposing models, you should propose a reasonable one yourself that can then be tested/validated (i.e. a hypothesis).* -- Chlorine demand from bathers may be modeled by looking at three different sources of such demand:

  1. Initial introduction of chemicals that leave the bather's skin and swimsuit when first entering the pool. This includes accumulated sweat and urine as well as excess suntan lotion and other personal care products. This chlorine demand may be significantly reduced by rinsing off prior to entry into the pool. This demand is a one-time event for each unique bather and is not a function of how long the bather is in the pool.
  2. Continued introduction of sweat and urine into the pool water. The amount varies by bather and the amount of sweat increases with greater physical activity. Thus the nature of pool use will affect chlorine demand with wading creating lower demand and competitive swimming creating higher demand. This demand is a function of how long the bather is in the pool.
  3. Continued reaction of chlorine with skin (including lotions remaining on skin), hair and swimsuits. Some of this demand may be reduced by rinsing, but a fixed amount remains that is largely proportional to the surface area exposed to the water. This demand is a function of how long the bather is in the pool.

  Changes to Code/Annex:
  Disagree. Modeling cannot be done until sufficient data are generated. Model systems for measuring the inputs outlined above are being developed and data collected. With those data, modeling can be done systematically.

- *Comment:*
  3.2 – *Editorial. I have tracked the chlorine demand in hot (104ºF) residential spas and for "clean" bathers it surprisingly comes to a fairly consistent 9 grams Cl2 per bather-hour independent of spa size. One can't readily detect the very low demand in a residential pool, but based on reports from commercial/public pool operators and chlorine injection pump manufacturers, the chlorine demand from bather load is on the order of 4 grams per bather-hour in well-managed pools. Obviously this isn't for competitive swimming, but for more typical mixed use pools (i.e. some swimmers, some waders).* -- 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 Cl2/bather (or 2.2 lb/100 bathers). However, some portion of chlorine demand is a function of the length of time a bather remains in the water so should be based on bather-hours. Based on 3.1.5 above, the formula may be modeled by A*unique-bathers + B*bather-hours where A is a constant that depends on the cleanliness of the bather upon entry while B is a constant that depends primarily on the nature of activity of the bather.

Changes to Code/Annex:
Disagree with text addition to 3.2, since this bullet is a presentation of the variance of the data. We agree that this is worth investigating in the future as more data are collected. Data on chlorine demand should be rigorously collected and published in peer-reviewed journals to make it useful for future studies and modeling.

- *Comment:*
  3.3 – *Editorial. It is not true that dilute concentrations of chlorine are not stable at high temperatures. The stability of chlorine is a function of temperature and of concentration. You are mixing up the relative instability of chlorinating liquid as a function of temperature and comparing concentrations of 100,000 ppm against < 10 ppm. The breakdown of chlorine varies roughly as the square of the concentration so it is relatively stable in dilute concentrations. It does, of course, outgas more quickly at higher temperatures, but that is not decomposition. See the link to the table from Odyssey Manufacturing showing the rough concentration dependence on chlorine degradation rates. The degradation rate drops rapidly as concentration decreases. On the other hand, real pool water contains some heavy metals that act as catalysts to degradation. Nevertheless, Wojtowicz showed that tap water indoors in polyethylene containers at 90-105ºF loses 2%-4% per day which is fairly low. There is a higher loss rate in the presence of Cyanuric Acid (CYA) due to its slow oxidation by hypochlorite ion. In real pools, this appears to be a fairly low loss rate of around 3 ppm CYA per month giving a around 7.5 ppm FC per month chlorine demand. In residential spas, one sees CYA drop at around 5 ppm per month (with CYA at 30-40 ppm). The presence of CYA significantly reduces the rate of chlorine loss from outgassing since the active chlorine level is significantly reduced and the chlorinated isocyanurates are not volatile.*
  -- 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 concentrated CHLORINE is not stable at high temperatures and any concentration is not stable in the presence of UV. Chlorine is also volatile and outgasses from the water as a function of temperature and aeration. Both of these factors will reduce active CHLORINE ~~to inactive chloride~~ concentration, without any BATHER waste being present. –
  REFERENCE –
    - http://www.odysseymanufacturing.com/about_product.htm
    - Wojtowicz JA. Effect of Cyanuric Acid on Swimming Pool Maintenance. 2004 Spring;5(1):15-19.
    - Henry's Law Constants: http://www.rolf-sander.net/henry/

Changes to Code/Annex:
Disagree. The committee is not sure how much chlorine is lost due to outgassing of HOCl vs outgassing of Cl_2 vs decomposition, but most of the chlorine in the pool should be HOCl/OCl- rather than Cl_2, and the Henry's law constant for HOCl (730 M/atm) is much higher than that for Cl_2 (0.086 M/atm), indicating that HOCl is much more likely to stay in the water than Cl_2.

- *Comment:*
  3.4 – *Scientific Studies. It is not difficult to predict chlorine loss in the presence of sunlight even accounting for pool depth. I have put together a spreadsheet that calculates chlorine loss at peak overhead (summer) noontime sun accounting for pool depth. It shows that at the pool surface hypochlorous acid has a half-life of 2 hours 10 minutes while hypochlorite ion has a half-life of 20 minutes. At pH 7.5 with a near 50/50 mixture of the two, the half-life is around 35 minutes. At a pool depth of 4.5 to 10 feet, the half-life increases to about 1 hour at those depths (if FC is 3-6 ppm with no CYA). Essentially, some of the loss near the surface partially shields lower depths. Note that the breakdown of chlorine from UV results in chlorine and hydroxyl radicals with the latter being very short-lived but powerful non-selective oxidizers. This may explain the slower buildup an lower steady-state levels of some organic precursors in outdoor pools exposed to sunlight. I have also modeled chlorine loss in the presence of Cyanuric Acid (CYA) from residential pool data on pool forums and there is still a chlorine decomposition from chlorine bound to CYA though it is slower, but CYA itself shields lower depths in a non-linear fashion such that even maintaining the same hypochlorous acid and hypochlorite ion concentrations by roughly maintaining the same FC/CYA ratio, the absolute chlorine loss rate is lower at higher CYA levels. This effect will not be noticeable in high bather-load (e.g. commercial/public) pools above around 20-30 ppm CYA since the chlorine loss from bather load is much larger than the loss from sunlight.*
  -- 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 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 specific POOLS.~~ **REFERENCE:**
    - Feng Y, Smith DW, Bolton JR. Photolysis of aqueous free chlorine species (HOCl and OCl) with 254 nm ultraviolet light. Journal of Environmental Engineering and Science. 2007 May;6(3): 277-284.
    - Absorption coefficients for water: http://www.lsbu.ac.uk/water/vibrat.html
    - Reference Solar Spectral Irradiance (ASTM G-173): http://rredc.nrel.gov/solar/spectra/am1.5/ASTMG173/ASTMG173.html

  Changes to Code/Annex:
  Disagree with suggested change, instead added the word 'specific'. As Mr. Falk points out, the chlorine loss can be measured, but it is difficult to generalize those measurements to predict the loss from specific pools under different conditions from

those that were measured.

- *Comment:*
  4.3 – *Editorial and Scientific Studies. Fix the indent bullet points for the haloketones and haloacetonitriles. In the study I reference, over 100 DBPs were identified. In addition to the categories you described, there are also other haloalkanes other than trihalomethane, other haloacids, halo-di-acids, haloaldehydes, halonitromethanes, haloamides, haloalcohols, and other halogenated DBPs (benzenes, anilines, pyrazoles). I'm not sure identifying "main" components by concentration is as important as identifying them relative to their known effects.* – Some classes of organic DBPs are:

    - TRIHALOMETHANES …
    - chlorinated phenols (…)
    - haloketones (bromopropanone, 1,1-dichloropropanone, 1,1,1-trichloropropanone, etc.)
    - haloacetic acids (…)
    - haloacetonitriles …

  -- **REFERENCE:** Richardson SD, DeMarini DM, Kogevinas M, Fernandez P, Marco E, Lourencetti C, Ballesté C, Heederik D, Meliefste K, McKague AB, Marcos R, Font-Ribera L, Grimalt JO, Villanueva CM. What's in the pool? A comprehensive identification of disinfection by-products and assessment of mutagenicity of chlorinated and brominated swimming pool water. Environmental Health Perspectives. 2010 Nov;118(11):1523-30.

  Changes to Code/Annex:
  Agree. changed as suggested and with addition of reference.

- *Comment:*
  4.4 – *Editorial. Though the drinking water standard for the EU may be 100 µg/L, the DIN 19643 standard for swimming pools is 20 µg/L.* -- 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. The DIN 19643 swimming pool standard specifies a standard maximum of 20 µg/L.

  Changes to Code/Annex:
  Agreed and changed as suggested including the additional reference.

- *Comment:*
  4.6 – *Editorial. It is not the dose of chlorine that is relevant, but the concentration of the active species (e.g. hypochlorous acid or in some cases hypochlorite ion) that determines the rate of reactions with those species. This becomes important when considering the effects of Cyanuric Acid (CYA) since that significantly lowers the active chlorine concentration and therefore the rate of creation of disinfection by-products assuming the same precursor concentrations. So for reaction of chlorine with precursors that do not remain in the pool (i.e. skin, swimsuits, hair), a lower active chlorine level would produce proportionately lower quantities of disinfection by-products. For reaction with chemicals introduced into pool water, there will not be a reduction in disinfection by-product amount or rate if such precursors are allowed to build up, but if they are removed through coagulation/filtration, oxidation (e.g. ozone, AOX) or by water dilution, then the rate of their creation and amount present will be reduced. --* the CHLORINE ~~dose~~ concentration

  Changes to Code/Annex:
  Agree; changed as suggested.

- *Comment:*
  4.8 – *Scientific Studies (summaries and references). --* (The following is with regard to chlorinated drinking water because there are far fewer epidemiological studies with regard to exposure to THMs in swimming pools). “Epidemiological studies have not identified an increased risk of cardiovascular disease associated with chlorinated or chloraminated drinking-water. Studies of other disinfectants have not been conducted.” “The epidemiological evidence is insufficient to support a causal relationship between bladder cancer and long-term exposure to chlorinated drinking-water,THMs, chloroform or other THM species. The epidemiological evidence is inconclusive and equivocal for an association between colon cancer and long-term exposure to chlorinated drinking-water, THMs, chloroform or other THM species. The information is insufficient to allow an evaluation of the observed risks for rectal cancer and risks for other cancers observed in single analytical studies.” “Studies have considered exposures to chlorinated drinking-water, THMs or THM species and various adverse outcomes of pregnancy. A scientific panel recently convened by the US Environmental Protection Agency reviewed the epidemiological studies and concluded that the results of currently published studies do not provide convincing evidence that chlorinated water or THMs cause adverse pregnancy outcomes.” – **REFERENCE:** WHO (2000). Environmental Health Criteria 216 (including corrigenda from 11/30/2004).
  http://whqlibdoc.who.int/ehc/WHO_EHC_216.pdf

  Changes to Code/Annex:

This reference has been added to the bibliography, but no change to document since the discussion refers to drinking water, it will not be included in the text of the annex.

3. Mary Ostrowski, American Chemistry Council (Washington D.C.)

- *Comment:*
  Glossary "Chlorine – *Vague description of chlorine; original language did not indicate the reasons for widespread use of chlorine as a swimming pool disinfectant* -- **"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 to liquid form and stored in heavy steel tanks to be used as a swimming pool disinfectant, but most pools now use other chlorine-based compounds (e.g. calcium hypochlorite or sodium hypochlorite) as disinfectants. Chlorine and chlorine-based disinfectants release hypochlorous acid and hypochlorite ion when dissolved in water; together these are known as "free chlorine," which helps destroy a wide range of waterborne pathogens and also oxidizes small bits of organic debris and impurities. Chlorine provides a residual level of protection that continues to disinfect the water long after it's applied. Chlorinating agents are the most commonly used disinfectants for pools. – REFERENCE: Agency for Toxic Substances & Disease Registry; ToxFAQs for Chlorine (online, accessed Sept. 30, 2012) National Swimming Pool Foundation Aquatic Management Series, Vol. 4: Recreational Water Illnesses

  Changes to Code/Annex:

  Agreed to change 2nd sentence to include "to be used as a swimming pool disinfectant," but most pools now use other chlorine-based compounds (e.g. "calcium" hypochlorite or "sodium hypochlorite) as disinfectants. Chlorine and chlorine-based disinfectants" release hypochlorous acid and "hypochlorite ion" when dissolved in water.

  Did not include the last sentence because there is a definition of free chlorine in the water quality module.

  Agreed and added ToxFaQs reference.

- *Comment:*
  Glossary "Oxidation" – *Potassium monopersulfate is not registered with EPA as a disinfectant and should not be referenced as a "disinfectant".* -- **"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) or other oxidizers (potassium monopersulfate). – REFERENCE: No potassium monopersulfate compounds are registered with the EPA as disinfectants.

Changes to Code/Annex:
Agreed, definition changed but proposed language is circular reference.

- *Comment:*
  4.6 – *Swimmer contribution of nitrogen-based organic load to pool water can be related to hygiene; pool water temperature helps determine DBP formation (not just chloramines); good air circulation in indoor pools can help reduce indoor air DBP levels.* -- The conditions that determine production and air levels of DBPs have been suggested to depend on several factors: the number of swimmers in the pool and their associated hygiene, the chlorine dose, the bromide content, the water temperature, the extent of out-gassing of volatile DBPs, pH, indoor air circulation and the use of DBP-containing water (mostly chlorine-treated surface water) for the pool water supply. – REFERENCE: LaKind et al. (2010), The Good, the Bad, and the Volatile: Can We Have Both Healthy Pools and Healthy People? *Environ. Sci. Technol.,* 44, 3205-3210
  Zwiener et al. (2007), Drowning in Disinfection Byproducts? Assessing Swimming Pool Water, *Environ. Sci. Technol.*, 41, 363-372.

  Changes to Code/Annex:
  Agree; changed as suggested.

- *Comment:*
  4.7 – *Studies have examined, but not conclusively documented links between respiratory ailments such as asthma and swimming. Swimming is deemed highly advisable for asthmatics under good hygienic conditions in well-managed swimming pools.*-- Studies have examined the link between air quality in indoor aquatic facilities and respiratory effects, including asthma. 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. To date, however, research results are mixed and inconclusive. The one prospective study available (Font, Ribera, 2011) suggests swimming does not increase the risk of asthma. To the contrary, the study found swimming increased lung function and reduced the risk of asthma symptoms at age seven. The health benefits associated with swimming include improvement of asthma symptoms and cardiovascular fitness. Pediatricians have long recommended swimming for asthmatic children because of its lower asthmogenicity compared to other forms of exercise. The Belgian Superior Health Council reviewed the available science related to pool swimming and the development of childhood asthma. The Council, in its 2011 report No. 8748 (and reiterated in its 2012 report) concludes swimming remains highly advisable, even in the case of asthma. According to the Council, "For this target group, the advantages of swimming under good hygienic conditions in monitored pools outweigh the risk of toxicity linked to chlorine and its by-products." -- **REFERENCE**:
    - LaKind et al. (2010). The Good, the Bad, and the Volatile: Can We Have Both Healthy Pools and Healthy People? *Environ. Sci. Technol.,* 44, 3205-3210

- Font-Ribera et al. (2011). Swimming pool attendance, asthma, allergies, and lung function in the Avon Longitudinal Study of Parents and Children cohort, *Am J Respir Crit Care Med*, 183 (5): 582-8.
- PUBLICATION OF THE SUPERIOR HEALTH COUNCIL No. 8748 (Belgium www.css-hgr.be, available in English from http://www.eurochlor.org/media/60032/shc-8748-babyswimmers.pdf)
- PUBLICATION OF THE SUPERIOR HEALTH COUNCIL No. 8614 (not available in English) Not sure if this one can be public document

Changes to Code/Annex:
Agree, changed as suggested. Replaced existing paragraph with proposed language for better clarity. References have been reviewed and Lakind, Font and SUPERIOR HEALTH COUNCIL No 8748 references have been included in annex.

4. Steven Chevalier, Tri-County Health Department (Greenwood Village, CO)

- *Comment:*
  Glossary "Disinfection" -- Viruses are not "alive" and therefore cannot be "killed". Suggest to also include the word "inactivate" in this definition. -- **"Disinfection"** means a treatment that kills **or inactivates** microorganisms (e.g., bacteria, viruses, and parasites – REFERENCE-- National Swimming Pool Foundation (2011). Pool and Spa Operator Handbook. p. 48

  Changes to Code/Annex:
  Agree; changed as suggested.

5. Jennifer Hatfield, APSP (Delray Beach, FL)

- *Comment:*
  Glossary "Oxidation" – *Potassium monopersulfate is not a disinfectant - suggest that the wording be …be achieved by chlorine, bromine, ozone and potassium monopersulfate -* - **"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, and potassium monopersulfate~~)~~.

  Changes to Code/Annex:
  Agreed; changed as suggested.

- *Comment:*
  Glossary "pH" – *Recommend change to H+ to* H^+*, and OH- to* OH^- -- **"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. See Basis for Change for visual of recommended changes here.

Changes to Code/Annex:
Agree; changed as suggested.

- *Comment:*
  2.1 – *Recommend changing PH (where P is in SMALL CAP FORMAT) to pH. --* 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 ~~P~~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.

  Changes to Code/Annex:
  Agree; changed as suggested.

- *Comment:*
  4.1 – *Add a space after the section ends, before 4.2 --* 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 precursors, a variety of chemical reactions take place, including the formation of DISINFECTION BY-PRODUCTS (DBPs).

  Changes to Code/Annex:
  Agree; changed as suggested.

- *Comment:*
  4.6 – *Same comment as 2.1 above --* 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, ~~P~~pH, and the use of DBPs-containing water (mostly CHLORINE-treated surface water) for the POOL water supply.

Changes to Code/Annex:
Agree; changed as suggested.

- *Comment:*
  4.8 – *General Comment: Should add a space after the section ends, before the "Note about Resources" section begins.* -- 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 BYPRODUCTS 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 disease in the absence of DISINFECTION."[1] Improved water quality management is recommended to minimize formation and accumulation of these compounds.

  Changes to Code/Annex:
  Agree; changed as suggested.