ANSI/APSP-11 2009

American National Standard for Water Quality in Public Pools and Spas

Approved June 15, 2009



APSP

The Association of Pool & Spa Professionals®

ANSI
APSP-11 2009

American National Standard

For Water Quality in Public Pools and Spas

Sponsor

The Association of Pool and Spa Professionals

Approved June 15, 2009

American National Standards Institute, Inc.

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Approval of an American National Standard requires verification by ANSI that the requirements for due process, consensus, and other criteria for approval have been met by the standard developer.

Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered and that a concerted effort be made toward their resolution.

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NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this standard.

The Association of Pool and Spa Professionals, 2111 Eisenhower Avenue, Alexandria, VA 22314

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Foreword

(This Foreword is not a part of the American National Standard ANSI/APSP-11 2009)

The ANSI/APSP-11 2009, *Standard for water quality in public pools and spas,* was approved by ANSI as a new standard on June 15, 2009.

The objective of this voluntary standard is to provide recommended minimum guidelines for the specifications for water quality parameters. It is intended to meet the need for incorporation into national or regional health codes, and also for adoption by state and/or local municipalities as a local code or ordinance. It is understood that for the sake of applicability and enforceability, the style and format of the standard may need adjustment to meet the code or ordinance style of the jurisdiction adopting this document.

This standard was drafted by the Recreational Water Quality Committee of The Association of Pool and Spa Professionals (APSP) in accordance with the American National Standards Institute's (ANSI) *Essential Requirements: Due process requirements for American National Standards.*

Consensus approval was achieved by a ballot of the ANSI Consensus Voting Body below and through an ANSI Public Review process. The ANSI Public Review provided an opportunity for additional input from industry, academia, regulatory agencies, safety experts, state code and health officials, and the public at large.

Suggestions for improvement of this standard should be sent to The Association of Pool and Spa Professionals, 2111 Eisenhower Avenue, Alexandria, VA 22314.

Inclusion in this list does not necessarily imply that the organization concurred with the submittal of the proposed standard to ANSI.

<u>Organization Represented</u> **<u>Name of Representative</u>**

Consensus approval in accordance with ANSI procedures was achieved by ballot of the following ANSI consensus voting body. Inclusion in this list does not necessarily imply that the organization concurred with the submittal of the proposed standard to ANSI.

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Aquatic Development Group .... Jim Dunn
Arch Chemicals Inc. .... J.P. Brennan
Belleair Pool Supply .... David Oxley
Busch Entertainment Corp. .... John Linn
Carson City (NV) Health and Human Services .... Neil Fox
Champagne Aqua Tech Pools .... Moseley Richard
Chesapeake Aquatic Consultants, LLC .... Frank Goldstein
City of Austin (TX) Parks and Recreation Department .... Farhad Madani
Conroe (TX) Independent School District .... Sam Fruia
County of Ventura (CA) Environmental Health Division .... Sean Debley
Cullman County (AL) Health Department .... Donna Dunn
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Gorlin Pools and Spas .... Steven Gorlin
Halogen Supply Company Inc. .... Larry Ryczek
Hyland Hills Park and Recreation District (Water World) .... Rick Fuller

Jeff Ellis & Associates .... Wayne Crokus
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LBI Pools & Spas .... Larry Biscornet
Los Angeles County, Environmental Health - Swimming Pool Program .... Bernard Franklin
National Plasterers Council .... Mitch Brooks
New Hampshire Dept. of Environmental Services .... Tim Wilson
New Jersey Department of Health, Public Health Sanitation and Safety Program .... Loel Muetter
NSF International .... Richard Martin
Oklahoma City-County Health Department .... Susan Campbell
Oregon Public Health Division .... Steve Keifer
Pentair Water Commercial Pool and Spa .... Tim Ruesch
Plano (TX) Health Department .... Tom Vyles
Portofino Pools .... Jack Manilla
Professional Pool Operators of America .... Kent Williams
Recreation Safety Institute .... Arthur Mittelstaedt
Santa Barbara Control Systems .... Pablo Navarro
Texas Dept. of State Health Services .... Kathleen Moore
Taylor Technologies .... Wayne Ivusich
Tropical Pools and Spas, Inc. .... Adam Alstott
U.S. Consumer Product Safety Commission (CPSC) .... Troy Whitfield
USA Swimming .... Sue Nelson
Van Kirk and Sons, Inc. .... Donald Cesarone Jr.
Walt Disney World Company .... Michael Beatty
Washington State Department of Health .... Gary Fraser
Water Odyssey by Fountain People .... Stan Caulkins

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*Suzie Campbell .... Oklahoma City-County Health Dept.
* Dr. Rick Coffey .... Zodiac
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Tom Seechuk .... LaMotte Company
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John Weber .... Advantis Technologies
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Introduction

This standard is the first comprehensive, data-driven, and knowledge-based national standard available for pool and spa water quality and chemistry. This standard was developed in response to the need expressed by public health officials for a national standard for water quality in public pools and spas. A 2004 survey of more than 5000 public health officials and sanitarians nationwide provided an overwhelming endorsement for the development of a national water quality standard.

The Recreational Water Quality (RWQ) Committee of The Association of Pool and Spa Professionals (APSP) actively partnered with public health officials during the development of this draft standard by visiting with key sanitarians and asking for feedback on the standard. Public health and code officials also played an important role in the development of consensus necessary for this standard to be published as an American National Standard.

Since APSP has been accredited by the American National Standards Institute (ANSI), its standards are developed according to ANSI's published requirements. Since 1983, APSP has published nine ANSI standards for the pool and spa industry. When this standard is published as an American National Standard, it will enable state and local health and code officials to adopt a uniform, national code governing the maintenance of swimming pools, spas, and other treated recreational water venues.

The ANSI process requires consensus approval through a uniform national public review and balanced-interest voting process. It affords a rigorous third-party process for standards development, providing due process, openness, and consensus agreement among a diversified group of stakeholders. These include public health and code officials, architects, regulatory agencies, academicians, representatives of safety organizations, consultants, subject matter experts, as well as pool and spa professionals. The balance of interests represented by voters is another key component of ANSI's requirements. During the ANSI process all objections are considered with an effort toward resolution. On account of the universal scope and depth of this unique standard, APSP encourages state and local public health and code officials to adopt it into their state laws and local codes.

The standards developed by APSP are the benchmark for the pool and spa industry because they are based on science, verifiable data, and best practices. The ANSI/APSP standards are voluntary minimum standards. Their goal is to provide for all viable technologies. APSP standards promote aquatic safety, provide consistency in design, provide construction and installation requirements for the nation, and provide the basis for adoption into law by state and local jurisdictions. For example, the International Code Council (ICC) in 2008 adopted ANSI/APSP-7 2006 *Standard for Suction Entrapment Avoidance in Swimming Pools, Wading Pools, Spas, Hot Tubs, and Catch Basins* into the body of the International Building Code (IBC, public pools and spas) and, by reference, into Appendix G of the International Residential Code (IRC, residential pools and spas). The IBC code has been adopted by all 50 states and 46 states have adopted the IRC.

During development of the standard, the RWQ Committee decided that in addition to writing a uniform national consensus standard, it wanted to provide readers with explanatory information about the values for the requirements listed in the body of the standard. In developing the Appendix A material, the committee questioned many standard practices in the industry and sought to provide scientific justification for the values in the body of the standard. The resulting Appendix A took over two years to write.

Many water quality parameters that do not have a direct impact on public health, but that can severely influence the operation of the pool, such as the effect of low calcium levels on corrosion, were included in the standard. The standard is primarily health and safety related and operating within the allowed ranges of all the parameters would be a minimum requirement and may not be sufficient to protect pool surfaces from damage. Further information on the protection of pool surfaces may be found in Appendix A. For purposes of public health, the requirements in the body of the standard generally reference a minimum or a maximum value, or both. It is important to remember that there is a range of values that are acceptable for pool and spa operation. Appendix A should be consulted for recommendations on the ideal ranges of operation in those instances when the body of the standard lists minimums/maximums. In order to distinguish the operational factors from the factors that could represent an immediate danger to public health, the section on pool closure was added. In this special section each of the highlighted factors — clarity, sanitizer level, pH, and temperature — were included because of their direct impact on public health

ANSI/APSP-11 2009 Standard for Water Quality in Public Pools and Spas

1 Scope

1.1 Public swimming pools and spas. This standard covers public swimming pools and spas to be used for bathing and operated by an owner, licensee, or concessionaire, regardless of whether a fee is charged for use.

1.1.1 Public swimming pools covered by this standard. Public swimming pools covered by this standard include Class A pools, Class B pools, Class C pools, Class D pools, Class E pools, and Class F pools. See section 2 for definitions.

1.1.2 Pools designed for interaction with marine life have special requirements and are not covered by this standard.

1.2 Variation in methods. This standard provides specifications for water quality parameters, but does not specify the technologies needed to achieve these values.

2 Definitions

Class A Pool: Class A pools are intended for use for accredited competitive aquatic events such as Federation Internationale de Natation Amateur (FINA), USA Swimming, USA Diving, National Collegiate Athletic Association (NCAA), National Federation of State High School Associations (NFSHSA), etc. The use of the pool is not limited to competitive events.

Class B Pool: Any pool intended for public recreational swimming not otherwise classified.

Class C Pool: Pools operated solely for and in conjunction with lodgings such as hotels and motels and pools intended for use for apartments, condominiums, property owners associations, and multi-family owned pools.

Class D, Other Pool: Any pool operated for medical treatment, therapy, exercise, lap swimming, recreational play, and other special purposes, including, but not limited to, wave or surf action pools, activity pools, splasher pools, kiddie pools, and play areas.

Class D-1, Wave Action Pools: Wave action pools include any pool designed to simulate breaking or cyclic waves for purposes of general play or surfing.

Class D-2, Activity Pools: Activity pools are those pools designed for casual water play ranging from simple splashing activity to the use of attractions placed in the pool for recreation.

Class D-3, Catch Pools: Catch pools are bodies of water located at the termination of a manufactured waterslide attraction provided for the purpose of terminating the slide action and providing a means for exit to a deck or walkway area.

Class D-4, Leisure Rivers: Manufactured streams of near-constant depth in which the water is moved by pumps or other means of propulsion to provide a river-like flow that transports bathers over a defined path that may include water features and play devices.

Class D-5, Vortex Pools: Circular pools equipped with a method of transporting water in the pool for the purpose of propelling riders at speeds dictated by the velocity of the moving stream.

Class D-6, Interactive Play Attractions: Only water treatment and filtration for these attractions are within the scope of this standard. A manufactured water play device or a combination of water-based play devices in which water flow volumes, pressures, or patterns are intended to be varied by the bather without negatively influencing the hydraulic conditions of other connected devices. Class D-6 attractions may incorporate devices or activities such as slides, climbing and crawling structures, visual effects, user-actuated mechanical devices and other elements of bather-driven and bather-controlled play. Class D-6 attractions do not incorporate captured or standing water greater than 12 inches deep as part of the bather activity area.

Class E Pool: Pools used for instruction, play, or therapy and with temperatures above 86 °F (30 °C).

Class F Pool: Wading pools.

3 Reasons for immediate pool closure

3.1 The pool or spa shall be closed immediately if any of the following water quality conditions occur:

- The water fails clarity test; or
- The sanitizer level is below minimum standard (see sections for chlorine, bromine, PHMB, metal-based systems); or
- The pH is outside the acceptable range; or
- The water temperature exceeds 104 °F (40 °C); or
- Fecal or vomit accident.

Note: For guidance on fecal accidents, see reference to the U.S. Centers for Disease Control and Prevention (CDC) in A9.1.

For specific values for each of these parameters, refer to 8.2 Clarity, section 5 Sanitizers, 7.1 pH, and 8.6 Temperature.

3.2 The pool or spa shall remain closed until the problem is corrected.

4 Code compliance

Pools and spas covered by this standard shall be operated to comply with all local, state, and federal codes governing safety and environmental regulations.

5 EPA-registered sanitizers and systems

5.1 Residual. A residual of an EPA-registered sanitizer shall be present at all times and in all areas of the pool or spa. One of the following EPA-registered sanitizer systems shall be used:

– Chlorine; or
– Bromine; or
– PHMB; or
– Metal-based systems.

Not all of these sanitizer systems are approved for all pool and spa uses. Please refer to the EPA label as well as applicable codes and regulations.

5.2 Free available chlorine (FAC)

5.2.1 Free available chlorine – pools. A minimum free available chlorine residual of 1.0 ppm shall be maintained at all times and in all areas of the pool. A maximum of 4.0 ppm shall not be exceeded when the pool is open to the public.

5.2.2 Free available chlorine – spas. A minimum free available chlorine residual of 2.0 ppm shall be maintained at all times and in all areas of the spa. A maximum of 5.0 ppm shall not be exceeded when the spa is open to the public.

Note: The U.S. Environmental Protection Agency (EPA) has established a maximum chlorine level of 4.0 ppm for re-entry of swimmers or bathers into pool water based on drinking water limits.[1] The maximum they have set for spas is 5.0 ppm. However, state or local health codes may allow or require the use of chlorine levels above 4.0 ppm for pools and 5.0 ppm for spas.

5.3 Bromine (Br)

5.3.1 Pools. A minimum bromine residual of 1.0 ppm (as Br_2) shall be maintained at all times and in all areas of the pool. A maximum of 8.0 ppm (as Br_2) shall not be exceeded when the pool is open to the public.

[1] U. S. Environmental Protection Agency (EPA), Reregistration Eligibility Decision (RED): Chlorine Gas (1999). Office of Pesticide Programs, (OPPT) EPA 738-R-99-001.

5.3.2 Spas. A minimum bromine residual of 2.0 ppm (as Br_2) shall be maintained at all times and in all areas of the spa. A maximum of 8.0 ppm (as Br_2) shall not be exceeded when the spa is open to the public.

5.3.3 Operators shall refer to the manufacturer's product label for specific use concentrations since allowable concentrations can vary depending upon which brominating compound is used.

5.4 PHMB (Poly(hexamethylene biguanide))

5.4.1 The level of PHMB shall be maintained between a minimum of 30 ppm and a maximum of 50 ppm (as product) for pools and spas.

5.5 Metal-based systems. Any system used must incorporate an EPA-registered sanitizer. Follow the product manufacturer's EPA-accepted label for use and/or operation requirements.

6 Supplemental sanitizers

6.1 Ozone

6.1.1 Ozone shall be used only in conjunction with an EPA-registered sanitizer.

6.1.2 Ozone concentrations in the air above the pool/spa water shall not exceed Occupational Safety and Health Administration (OSHA) permissible exposure limits, currently 0.1 ppm over an 8-hour Time Weighted Average.[2]

6.1.3 The ozone concentration may also not exceed the STEL (Short Term Exposure Limit) of 0.3 ppm for any 15-minute period.

6.1.4 When ozone is used for indoor installations, air monitoring is required.

6.2 Ultraviolet light (UV). UV lamps shall be used only in conjunction with an EPA-registered sanitizer.

[2] 29 CFR 1910.1000 Table Z-1, Feb. 28, 2006. www.osha.gov or www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992

7 Water balance[3]

7.1 pH. The pH shall be maintained between 7.2 and 7.8.

7.2 Total alkalinity. Total alkalinity shall be maintained between a minimum of 60 and a maximum of 180 ppm as $CaCO_3$.

7.3 Calcium hardness. Pool water calcium hardness shall be maintained between a minimum of 150 and a maximum of 1,000 ppm as $CaCO_3$. In spas, calcium hardness shall be maintained between a minimum of 100 and a maximum of 800 ppm as $CaCO_3$.

7.4 Total Dissolved Solids (TDS). Total Dissolved Solids shall not exceed 1500 ppm above the concentration at start up.

7.5 Langelier Saturation Index (LSI). See Appendix A for recommendations for the Langelier Saturation Index.

8 Physical/Environmental/Operational

8.1 Air quality

8.1.1 The indoor pool and spa area shall have its own dedicated ventilation equipment.

8.1.2 All pools and their related components that are installed in an indoor environment shall comply with the ventilation requirements of ANSI/ASHRAE 62.1-2004 *Ventilation for acceptable indoor air quality*, table 6-1, "Minimum Ventilation Rates in Breathing Zone," (Sports and Entertainment section).

8.2 Clarity

8.2.1 Pools. Pool water shall be of a clarity to permit an 8-inch diameter black and white Secchi disc or, main suction outlet (main drain), located on the bottom of the pool at its deepest

[3] For more information on interpretation of these limits, their effect on public health, and equipment protection, please refer to Appendix A.

point to be clearly visible and sharply defined from any point on the deck up to 30 feet away in a direct line of sight from the disc or main drain.

8.2.2 Spas. The bottom of the spa at its deepest point shall be clearly visible. (This test shall be performed when the water is in a non-turbulent state and bubbles have been allowed to dissipate.)

8.3 Cyanuric acid. When used, cyanuric acid levels shall not exceed 100 ppm.

8.4 Enzymes. See Appendix A.

8.5 Oxidation-Reduction Potential (ORP)

8.5.1 When an ORP controller is used, it shall not be relied upon as a method for measuring the concentration of sanitizer in the water.

8.5.2 The sanitizer level shall be measured with traditional wet chemical methods capable of detecting specific sanitizer residuals (e.g. DPD, N, N-diethyl-*p*-phenylenediamine for free available chlorine), to ensure that the minimum sanitizer residual is maintained.

8.6 Temperature

8.6.1 Water temperature shall never exceed 104 °F (40 ºC).

8.7 Testing frequency

8.7.1 The parameters for sanitizer, pH, clarity, and water temperature shall be met at all times. Exception: when shocking the pool, when closed for the season, or similar activities.

8.7.2 Testing frequency shall be sufficient to ensure that the sanitizer, pH, clarity, and water temperature (spa) standards set forth in this document are met at all times. Permanent records of testing results shall be maintained for a minimum of one year.

See Appendix A, section A8.7, for recommended testing frequencies.

8.8 Water replacement

8.8.1 Hot tubs and spas. The Water Replacement Interval (WRI) and Total Dissolved Solids (TDS) shall both be monitored. The water shall be replaced when either of the following conditions is met:

1. Total Dissolved Solids (TDS) has increased to 1500 ppm greater than TDS at spa start-up; or

2. The Water Replacement Interval (WRI) is less than or equal to the number of days since the last time the water was replaced. The WRI is calculated as follows:

   WRI (Days) = (1/3) x (Spa Volume in U.S. Gallons) / (Number of Bathers per Day)

NOTE: Start-up TDS includes source water TDS and any other inorganic salt added at start-up.

See Appendix A for examples of how to use this WRI calculation.

8.8.2 Swimming pools. It is recommended that regular water replacement be applied to pools, although certain circumstances may prohibit this practice (e.g., drought conditions) or make it unnecessary (e.g., supplementary water treatments such as reverse osmosis to extract contaminants from the water). A suggested water replacement calculation for pools may be found in Appendix A.

9 Microbiological

9.1 Bacteria and other pathogens. See Appendix A9.1.

9.2 Algae. Algae shall not be visible in the pool or spa when it is open for public use.

10 Contaminants

10.1 Combined chlorine

10.1.1 The concentration of combined chlorine in pools shall not exceed 0.2 ppm.

10.1.2 The concentration of combined chlorine in spas shall not exceed 0.5 ppm.

10.2 Foam. There shall be no persistent foam (foam remaining in a spa after the jets are turned off).

10.3 Metals. No requirements.

10.4 Nitrates. See Appendix A.

10.5 Phosphate. No requirements.

Appendix A — Rationales for chemical operational parameters

This appendix is not part of the American National Standard and is included for information only.

In Appendix A to this standard, for the first time, information is summarized about available data, scientific research, and studies related to the most important water quality parameters for treated recreational water venues. Each section of the Appendix provides supplementary information and important guidance in understanding each of the chemical operational parameters covered in the body of the standard with an explanation of why the values in the standard were set as they are. The Appendix also explains why certain parameters were not included in the standard and why, in some instances, values cannot be set or should not be set. As a result of the information and material compiled in this Appendix, readers will be able to advance their knowledge and understanding of the state of the art of water chemistry and quality.

Section A3 — Reasons for immediate pool closure

The U.S. Centers for Disease Control and Prevention (CDC) gives recommendations for proper response to fecal and vomit accidents. For facilities with multiple bodies of water, it may not be necessary to close the entire facility, but rather isolate the affected body of water for treatment.

Section 5 — EPA-registered sanitizers and systems

A5 — EPA-registered sanitizers

See Appendix A9.1, “Bacteria and Other Pathogens,” for EPA registration requirements and the distinction between sanitizers and disinfectants.

A5.2 — Free available chlorine (FAC)

The ideal free available chlorine concentration for swimming pools and spas is between 2.0 and 4.0 ppm. Hot water/heavy use or the presence of cyanuric acid may require operation at or near maximum levels.

The level of Free Available Chlorine (FAC) in a pool or spa is regulated by the U. S. Environmental Protection Agency (EPA). Pool and spa sanitizers must be registered by the EPA under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). The EPA has specified that chlorine sanitizers should be used such that a 1.0 – 4.0 ppm FAC residual is present in pool water and 2.0 – 5.0 ppm FAC residual is present in spa water. The pool levels are the same as those used in drinking water.

A minimum of 1.0 ppm FAC is needed to ensure that there will be sufficient chlorine to kill pathogens in the water and reduce the risk of disease transmission between bathers. The minimum for spas is higher due to the increased bather load in a spa. Justification for the 1 ppm minimum may be found in the guidelines for data requirements for EPA registration of pool and spa sanitizers (see A 9.1, “Bacteria and Other Pathogens”).

Inactivation times for organisms of interest in recreational water are available on the United States Centers for Disease Control and Prevention (CDC) healthyswimming website http://www.cdc.gov/healthyswimming/.[4] Table 1 below from the CDC shows the amount of time required (in minutes) for control of the organisms listed, with a 1.0 ppm free chlorine residual.

When manufacturers register pool/spa sanitizers with the EPA, they provide both efficacy and toxicity data. EPA determines minimum and maximum concentrations based on efficacy and toxicity. Toxicity is determined by exposure to the sanitizer and the by-products created when the sanitizer is applied. In making this determi-

[4] http://www.cdc.gov/healthyswimming/pdf/Fecal_Incident_Response_Recommendations_for_Pool_Staff.pdf.

nation, EPA considers the concentration needed for efficacy and a conservative estimation of the concentration that may cause adverse effects. This is described more fully in A9.1, "Bacteria and Other Pathogens."

Table 1 – Germ inactivation time for chlorinated water*

Germ	Time
***E. coli* O157:H7** **Bacterium**	Less than 1 minute
Hepatitis A **Virus**	About 16 minutes
Giardia **Protozoan**	About 45 minutes
Cryptosporidium **Protozoan**	About 15,300 minutes (10.6 days)
* Laboratory testing results using chlorine-demand-free water with 1ppm (1mg/L) chlorine at pH 7.5, 77 °F (25 °C) and in the absence of cyanuric acid	

Justification for the 4 ppm maximum may be found in the EPA re-registration documents. As a part of its process to re-register chlorine as a disinfectant under FIFRA, the EPA has established a maximum drinking water standard of 4 ppm free available chlorine.[5] The pool re-entry standard was based upon the new Maximum Residual Disinfectant Level (MRDL) of 4 ppm for drinking water.[6] Additionally, for pools, EPA has not raised the re-entry above 4 ppm due to lack of data regarding the health effects, particularly around disinfection byproducts. EPA has not issued a written policy on this issue, however, none of the chlorine manufacturers have been able to gain EPA approval of any pool chlorine labels that have a re-entry level greater than 4 ppm. The 4 ppm MRDL was established in 1998 (40 CFR parts 9,141, 142, pg 18). All EPA registered pesticide labels, have the following statement: "It is a violation of federal law to use this product in a manner inconsistent with its labeling." While the U.S. EPA has established a maximum chlorine level of 4.0 ppm for re-entry of swimmers or bathers into the water based on drinking water limits, some state or local health codes may allow or require the use of chlorine levels above 4.0 ppm. This standard has opted to follow federal law.

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[5] U. S. Environmental Protection Agency (EPA), *Reregistration Eligibility Decision (RED): Chlorine Gas (1999)*. Office of Pesticide Programs, (OPPT) EPA 738-R-99-001.

[6] 40 CFR Parts 9, 141 and 142, vol. 63, no. 241 (December 16, 1998).

MRDLG for Chlorine

a. Today's Rule. EPA is promulgating an MRDLG of 4 mg/L for chlorine based on a NOAEL from a chronic study in animals.

b. Background and Analysis. EPA proposed an MRDLG of 4 mg/L for chlorine. The MRDLG was based on a two-year rodent drinking water study in which chlorine was given to rats at doses ranging from 4 to 14 mg/ kg/ day and mice at doses ranging from 8 to 24 mg/kg/day (NTP, 1990). Neither systemic toxicity, nor effects on body weight and survival, were found. Thus, the MRDLG was based on a NOAEL of 14 mg/kg/day and application of a 100-fold uncertainty factor to account for inter- and intra-species differences (EPA, 1994a). New information on chlorine has become available since the 1994 proposal and was discussed in the 1997 DBP NODA and is included in the public docket (EPA, 1997c). This new information did not contain data that would change the MRDLG. EPA has therefore decided to finalize the proposed MRDLG of 4 mg/L for chlorine.

The EPA has approved labels containing up to 5.0 ppm available chlorine for spas. Presumably the higher levels are allowed due to the greater bather load as well as the decreased chance of ingestion.

A large spectrum of organisms is constantly introduced into the water by bathers and environmental sources such as wind-blown debris. The introduction of non-microbial contaminants from bathers and the environment can also result in high chlorine consumption. When chlorinating a pool or spa, sufficient chlorine must be added to provide an adequate residual chlorine level to ensure rapid kill of microorganisms and thus reduce the risk of disease transmission.

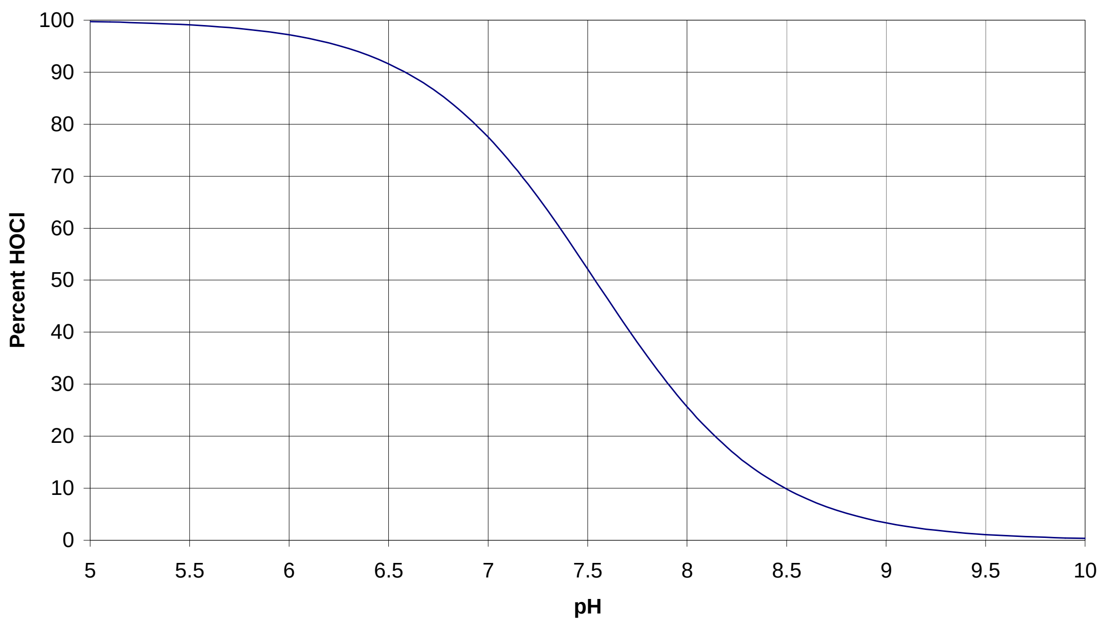
Hypochlorous acid is a weak acid and undergoes partial dissociation according to the following equilibrium:

$$(1)\ HOCl \rightleftharpoons H^+ + OCl^-$$

Where HOCl is hypochlorous acid, H^+ is hydrogen ion, and OCl^- is hypochlorite ion.

Figure 1 shows the calculated ratio of HOCl to total free chlorine (HOCl plus OCl^-) at 25 ºC as a function of pH.

Figure 1 – Percent of hypochlorous acid vs pH



Because hypochlorous acid is approximately 80 times more effective than the hypochlorite ion at disinfection [7], [8], [9], it is important to maintain the pH below 7.8 to avoid disease transmission in recreational water.

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[7] G. M. Fair, J.C. Morris, S. L. Chang, et al. "The Behavior of Chlorine as a Water Disinfectant," *Journal of the American Water Works Association* 40 (1948): 1051-1061.

J. C. Morris, "Future of Chlorination," *Journal of the American Water Works Association* 58 (1966): 1475-1482.

[8] S. S. Block, ed., *Disinfection, Sterilization, and Preservation,* 5th ed. (Philadelphia: Lippincott, Williams, and Wilkins, 2001).

A5.3 — Bromine

When manufacturers register pool/spa sanitizers with the EPA, they provide both efficacy and toxicity data. The EPA determines minimum and maximum concentrations based on efficacy and toxicity. Toxicity is determined by exposure to the sanitizer and the by-products created when the sanitizer is applied. In making this determination, EPA considers the concentration needed for efficacy and makes a conservative estimation of the concentration that may cause adverse effects. This is described more fully in A9.1, "Bacteria and Other Pathogens."

The ideal range for bromine concentrations in swimming pools is between 3.0 and 4.0 ppm. The ideal range for bromine concentrations in spas is between 4.0 and 6.0 ppm. Hot water/heavy use may require operation at or near maximum levels. When comparing bromine-releasing or bromine-producing products, the minimum bromine concentrations on the registered labels may vary.

The preferred method for testing bromine is to use a test kit designed for measuring bromine. Please note that when testing for bromine with a chlorine DPD test kit, the reading should be multiplied by 2.25 to obtain the bromine concentration.

Maintaining a sufficient bromine residual is important since large numbers of potentially pathogenic microorganisms are introduced into pools and spas by swimmers and by the environment. When brominating a pool or a spa, sufficient bromine must be added to provide an adequate bromine residual to ensure rapid kill of microorganisms, thereby lessening the likelihood for disease outbreaks.

Bromine reacts with ammonia to produce bromamines in much the same way that chlorine reacts with ammonia to produce chloramines. Unlike chloramines, the antimicrobial efficacy of inorganic bromamines is similar to that of hypobromous acid. However, regular oxidation by non-bromine oxidizers is necessary to destroy ammonia and other contaminants because bromine is not a sufficiently strong oxidizer.

Since both hypobromous acid and bromamines react with the reagents used to measure free bromine, they are not distinguished from each other as in the analogous chlorine system. Therefore, when testing for bromine, only the total bromine residual is typically measured. If needed, test methods for distinguishing bromine from bromamine are available.

Hypobromous acid is a weak acid and undergoes partial dissociation according to the following equilibrium:

(1) $HOBr \rightleftharpoons H^+ + OBr^-$

Where HOBr is hypobromous acid, H^+ is hydrogen ion, and OBr^- is hypobromite ion.

Figure 2 shows the calculated ratio of HOBr to total free bromine (HOBr plus OBr^-) at 25 ºC.

For pH values used in pools and spas[10], the efficacy of bromine is not significantly affected by pH. ORP may be used for bromine pools and spas, however, the ORP will be lower than that obtained with chlorine.[11] See section A8.5, "ORP."

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[9] J. C. Hoff, "Inactivation of Microbial Agents by Chemical Disinfectants," EPA-600/2-86-067. (Cincinnati OH: Water Engineering Research Laboratory, United States Environmental Protection Agency, 1986).

[10] The dissociation constant for HOBr at 25º C is 2.06 x 10-9. *CRC Handbook of Chemistry and Physics*, 63rd ed. (CRC Press, 1982).

[11] The half-reaction potentials at 25 ºC are:

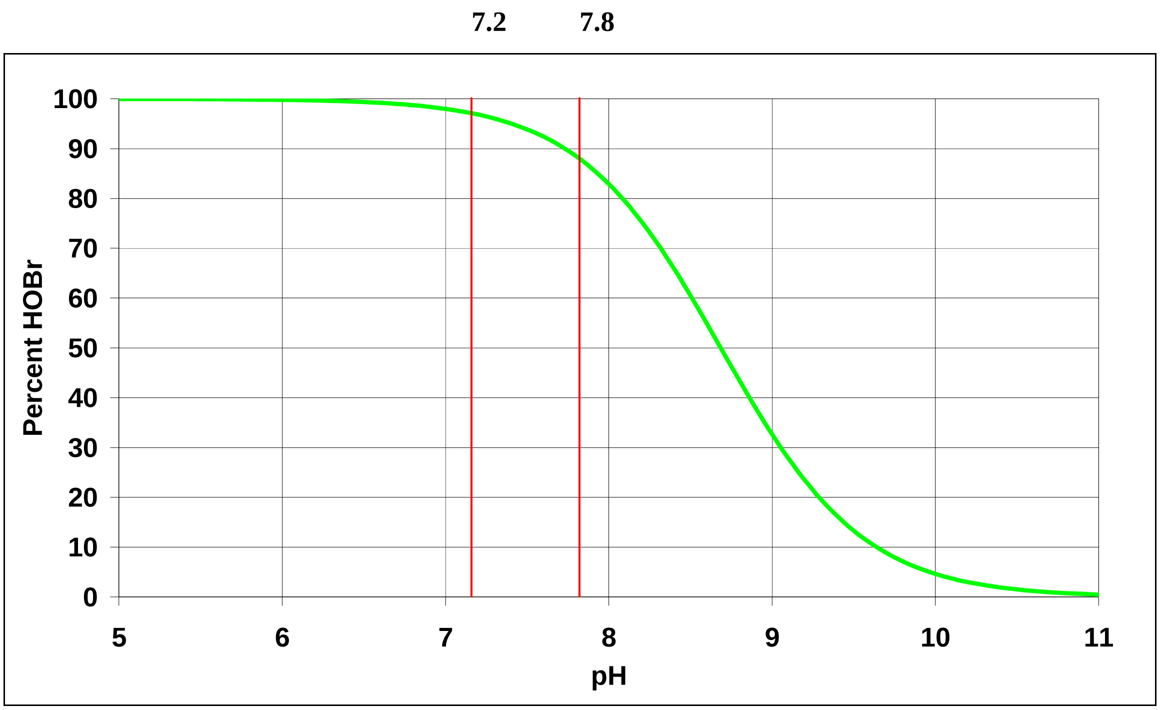
$Cl_2(aq) + 2e^- = 2Cl^-$ 1.396

$Br_2(aq) + 2e^- = 2Br^-$ 1.087

Lange's Handbook of Chemistry, 16th ed. Ed., James G. Speight (McGraw-Hill, 2005).

There is no known stabilizer that is effective for use with bromine that is comparable to chlorine stabilization with cyanuric acid.

Figure 2 – Percent of free hypobromous acid vs pH
Ideal pH range: 7.2 – 7.8



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A5.4 — PHMB

Poly(hexamethylene biguanide), or PHMB as it is more commonly known, is a polymeric biocide that has been registered by the U.S. EPA as a sanitizer. The full chemical name as displayed on product labels is poly(iminoimidocarbonyliminoimidocarbonyliminohexamethylene hydrochloride).

The EPA labels specify that PHMB should be applied at dosages of 30-50 ppm as product. All PHMB is sold as a water-based solution containing 20% active ingredient. This translates to a concentration of 6-10 ppm of active ingredient. Test strips and kits give values as ppm product, rather than ppm active.

When manufacturers register pool/spa sanitizers with the EPA, they provide both efficacy and toxicity data. EPA determines minimum and maximum concentrations based on efficacy and toxicity. Toxicity is determined by exposure to the sanitizer and the by-products created when the sanitizer is applied. In making this determination, EPA considers the concentration needed for efficacy and makes a conservative estimation of the concentration that may cause adverse effects. This is described more fully in A9.1, "Bacteria and Other Pathogens."

Since PHMB is not an oxidizer, ORP controllers do not measure the PHMB concentration and should not be used with PHMB sanitized recreational water. PHMB sanitizing ability is not dependent on the pH of the water.

Because PHMB is not an oxidizer, it requires the use of an oxidizer, such as hydrogen peroxide.

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A5.5 — Metal-based systems

Metals ions are used to inhibit bacteria and algae growth in swimming pool and spa water. Several methods of application are used including, but not limited to, electronic ionization, flow-through systems, and liquid products. Metal ions introduced by these systems can include copper, silver, and zinc.

EPA requires testing and registration for all products produced for the purpose of controlling growth of microorganisms. Refer to the EPA-accepted label for use and/or operation requirements. There can be substantive use and/or operation differences between systems. Halogen or oxidizer residuals may be required in addition to the metals in order for the system to be considered a sanitizer.

Metal-based systems may be registered as "sanitizers," "bactericides," "bacterial suppressants," or "algaecides." It is important that the system be registered as a "sanitizer" in order to ensure the safety of the swimmers.

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Section A6 — Supplemental sanitizers

A6.1 — Ozone

Ozone (O_3) is a gaseous molecule composed of three atoms of oxygen that are generated onsite by a device called an ozonator. Ozonators generate ozone by one of two means: ultraviolet light or corona discharge. Ozone is used primarily to oxidize water contaminants, but it can also be used to regenerate bromine from bromide ions and to act as a supplemental contact sanitizer. Although ozone is a powerful oxidizer, it should not be used as a stand-alone sanitizer since it does not impart a sustainable residual to the entire pool or spa. Therefore, ozone must always be used in conjunction with an EPA-registered sanitizer to ensure bathers are protected against disease and infection in the pool or spa water.

Ozone is toxic at high concentrations and an irritant at low concentrations. When ozone is used for indoor installations, air monitoring is required. The Occupational Safety and Health Administration (OSHA) has set permissible exposure limits for air contaminants. One such measure of exposure is the Time Weighted Average (TWA). OSHA has set ozone's TWA at 0.1 ppm over a period of 8 hours. Specifically, the ozone concentration in air shall not exceed the 8 hour Time Weighted Average in any 8-hour work shift of a 40-hour work week.

Ozone concentrations in water must be low enough to ensure that the air quality limits are met. There is no limit for ozone concentrations in water. Ozone concentrations are difficult to measure in water. Furthermore ozone has limited solubility in water and so the air concentration is a sufficient indicator/standard. Often the ozone limit in air is met by de-ozonating the water prior to its return to the pool or spa.

Follow manufacturer's instructions regarding installation and operation of ozone units.

References

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A6.2 — Ultraviolet light (UV)

UV lamps may be useful for supplemental sanitation in swimming pool and spa water. Although UV light is effective against microorganisms, UV lamps must not be used as stand-alone sanitizers since they do not impart a sanitizer residual to the body of water in the pool or spa. Therefore, UV lamps must always be used in conjunction with an EPA-registered sanitizer to ensure bathers are protected against disease and infection in the pool or spa water.

UV light wavelengths range from about 400 nm to 40 nm and are categorized as UV-A (400 – 320 nm), UV-B (320-280 nm), and UV-C (<280 nm). The practical germicidal wavelength for UV lamps ranges between 200 nm and 310 nm. Specifically UV-C light ranges 200 nm to 280 nm, and to some extent UV-B light ranges 280 nm to 315 nm are considered germicidal.

UV light inactivates microorganisms by damaging their nucleic acid, thereby preventing the microorganism from replicating. A microorganism that cannot replicate cannot infect a host.

The Earth's atmosphere effectively blocks most of the UV light from reaching the Earth's surface, and 99% of the UV light that does reach the Earth's surface is UV-A and is therefore not germicidal. Commercial UV lamps are generally referred to as either Low or Medium pressure UV lamps and produce UV light in the germicidal range between 200 – 320 nm. The term "pressure" refers to the internal gas pressure of the lamp.

Low-pressure lamps are referred to as monochromatic. They emit only one wavelength in the germicidal range, 254 nm. Low-pressure lamps have good germicidal efficiency and require little energy to operate.

Medium pressure lamps are referred to as polychromatic. They emit a spectrum of wavelengths at higher intensity across the germicidal range. They require an increased amount of energy to operate, but have good germicidal efficiency.

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Section A7 — Water balance

A7.1 — pH

The pH affects three key aspects of pool/spa operation and swimmer safety and comfort.

- Water maintained within the range of 7.2 – 7.8 is generally not irritating to the eyes and skin.[12]
- The range of 7.2 – 7.8 is a good pH range in terms of the sanitizing and oxidizing efficacy of chlorine-based sanitizers. At higher pH, only a small fraction of the free available chlorine will be in the hypochlorous acid form, and hypochlorous acid is far more effective as a sanitizer and oxidizer than is hypochlorite ion. At much lower pH, chlorine gas may form resulting in inefficiencies due to chlorine

[12] *The Oxford Companion to the Body*, ed., Colin Blakemore, et al. (New York: Oxford University Press, 2001, pp. 268 & 533.

loss and possible breathing hazards for bathers (see A5.2, Chlorine). The activity of other sanitizers, such as bromine and PHMB, is not as dependent on pH.

– pH is a key driver in maintaining water balance – by avoiding conditions in which water is either excessively corrosive to plumbing and pool surfaces or predisposed to deposit scale on exposed surfaces, resulting in rough pool surfaces, clogged plumbing, or reduced heat transfer from heaters. (See A7.5, Langelier Saturation Index).

The recommended range defines an achievable optimization of pH to satisfy these aspects.

Swimming pool and spa water shall be maintained between pH 7.2 and 7.8, and ideally between pH 7.4 and 7.6.

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A7.2 — Alkalinity

Total alkalinity includes contributions from bicarbonate, the much smaller amount of carbonate, and in stabilized pools, cyanurate ions. Total alkalinity is a measure of the pH buffering capacity of water, the ability of water to resist a pH change. Alkalinity is generally expressed in terms of the equivalent concentration of calcium carbonate in mg/L (or ppm). For adequate buffering of the pool pH, a total alkalinity of at least 60 ppm must be maintained. However, for protection of pool surfaces, it is important to have sufficient carbonate alkalinity. In calculating a calcium carbonate saturation index (Langelier Saturation Index) only the alkalinity associated with carbonate and bicarbonate is relevant.

The proper total alkalinity level in pool or spa water provides buffering so that pH does not swing in and out of the proper range in response to sanitizer addition, bather load, or other factors. With too little alkalinity there will not be enough buffering and the pH may quickly drift out of the proper range. At excessively high bicarbonate/carbonate alkalinity there will be a tendency for the pH of the water to drift upward, due to the rapid escape of carbon dioxide from the water into the air.

The portion of the alkalinity coming from carbonate and bicarbonate also affects calcium carbonate saturation. (See Langelier Saturation Index.) The maintenance of calcium carbonate saturation also reduces the tendency of pool water to etch plaster surfaces.

With optimum buffering from total alkalinity, it is easier to maintain pH, swimmer comfort, sanitizer efficacy, water balance, and clarity.

Total alkalinity shall be maintained between a minimum of 60 ppm and a maximum of 180 ppm as $CaCO_3$ and ideally between 80 ppm and 100 ppm as $CaCO_3$ where calcium hypochlorite, lithium hypochlorite, and sodium hypochlorite are used, because these sanitizers will cause the pH to rise. The ideal range where sodium dichlor, trichlor, chlorine gas, and bromine compounds are used is between 100 ppm and 120 ppm as $CaCO_3$, because these sanitizers will cause the pH to fall. Certain systems such as PHMB are relatively unaffected by total alkalinity.

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A7.3 — Calcium hardness

Maintenance of the Calcium Hardness in the recommended range helps to keep water balanced per the Langelier Saturation Index (LSI), influencing the water's corrosiveness or tendency to scale, depending on the degree of calcium saturation.

Total hardness is the measure of primarily calcium and magnesium combined. There are test kits for total hardness and others for calcium hardness. It is the calcium hardness that should be used in the LSI calculation.

Low levels of calcium hardness are not as important for non-cement-based surfaces. Regardless of pool surface, it is important to keep the calcium concentration below the maximum to avoid production of scale and cloudy water.

Pool water calcium hardness shall be maintained between a minimum of 150 ppm and a maximum of 1,000 ppm as $CaCO_3$, and ideally between 200 ppm and 400 ppm. In spas, calcium hardness shall be maintained between a minimum of 100 ppm and a maximum of 800 ppm as $CaCO_3$ and ideally between 150 ppm and 250 ppm.

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A7.4 — Total dissolved solids

Total Dissolved Solids (TDS) is a measure of all dissolved ions in the water and may or may not indicate a problematic condition. The following will contribute to TDS: source water, rain water, treatment chemicals, and bather waste. As the water evaporates the solids remain behind and become more concentrated. High TDS levels (1500 ppm above the concentration at start up) may correlate with the presence of undesirable substances that may cause poor water quality and indicate the need for water replacement.

A maximum level for TDS is not given, because salt water pools intentionally have high concentrations of sodium chloride. The sodium chloride will contribute to TDS, but will not cause decreased sanitizer efficacy or cloudy water.

TDS can decrease the efficacy of sanitizers if the dissolved ions include oxidizable materials, such as organics, that exert a chlorine demand. Water that is high in TDS may be cloudy or hazy and may tend to scale. High TDS can also accelerate galvanic corrosion of pool equipment. When calculating the Langelier Saturation Index (LSI) values, the TDS levels should be taken into consideration (see A7.5, LSI).

TDS is more of a problem in smaller water bodies such as spas, where the solids build up faster due to greater evaporation rates and higher bather loads.

A7.5 — Langelier Saturation Index (LSI)

The Langelier Saturation Index (LSI) is not an indication of human health and safety, it is rather an indication of the calcium carbonate solubility of the water and its effect on pool surfaces and equipment. While there are many different indices used, we are presenting one of the more common indices widely used throughout the pool and spa industry, the Langelier Saturation Index (LSI). Premature failure of equipment can occur with excessive corrosion. Clogging restrictions in piping due to excessive scaling can result in reduced flows, increased backpressures, or reduced heater efficiency.

The Langelier Saturation Index combines the following Chemical Operational Control Parameters that determine if water is saturated with respect to Calcium: pH, Calcium Hardness, Alkalinity, Temperature, and Total Dissolved Solids. The LSI is used to predict the tendency of the water to form calcium scale, or its ability to etch plaster, concrete, and grout. There may also be an indirect impact on corrosion of metal surfaces. Values below 0.0 indicate a net ability to be corrosive. Values above 0.0 indicate a tendency to scale.

A small positive value is preferred over a negative value because a slight scale layer provides some protection, and is less harmful than corrosion, which causes permanent damage to mechanical and structural components.

In swimming pools and spas, the LSI should be maintained between a minimum of -0.3 and a maximum of +0.5, and ideally between 0.0 and +0.5.

A commonly used equation to determine the LSI (SI) is given below:

$$SI = pH + TF + AF + CF - 12.1$$

pH is entered directly.

TF is the Temperature Factor.

AF is the Total Alkalinity Factor.

CF is the Calcium Hardness Factor.

12.1 is a constant applied for Total Dissolved Solids (TDS) between 0 and 1,000 ppm. When TDS is greater than 1000 ppm, for instance when a salt chlorine generator is being used, use Table 2 for the TDS factor:

Table 2 – TDS factor

TDS	Factor
<1000	12.10
1000	12.19
2000	12.29
3000	12.35
4000	12.41
5000	12.44

The factors are given in Table 3, based on the actual measured value for the particular parameter.

Table 3 –Langelier Saturation Index factors

Temperature		Total alkalinity*		Calcium hardness	
°F	TF	ppm	AF	ppm	CF
32	0.0	25	1.4	25	1.0
37	0.1	50	1.7	50	1.3
46	0.2	75	1.9	75	1.5
53	0.3	100	2.0	100	1.6
60	0.4	125	2.1	125	1.7
66	0.5	150	2.2	150	1.8
76	0.6	200	2.3	200	1.9
84	0.7	250	2.4	250	2.0
94	0.8	300	2.5	300	2.1
105	0.9	400	2.6	400	2.2
		800	2.9	800	2.5
Use the reading closest to your actual reading in choosing the factor. *Total alkalinity in this context refers to the total of carbonate and bicarbonate alkalinity. If cyanuric acid is used, a correction factor must be used (see cyanuric acid section below).					

From a comparison of the factors it can be seen that those having the greatest impact on LSI, and therefore on corrosiveness and tendency to scale, are pH, Total Alkalinity, and Calcium Hardness, while the factors having the least impact are Total Dissolved Solids and Temperature.

If the Saturation Index is calculated using the minimum and maximum values for the various control parameters for pools, the minimum and maximum LSI values lie well outside the required range:

All Minimum Values (pH = 7.2, Temp = 76 ºF, TA = 60 ppm, Ca = 150 ppm) SI = 7.2 + 0.6 + 1.7 + 1.8 - 12.1 =	-0.8
All Maximum Values (pH = 7.8, Temp = 84 ºF, TA = 180 ppm, Ca = 800 ppm) SI = 7.8 + 0.7 + 2.3 + 2.5 - 12.3 =	1

If the Saturation Index is calculated with the minimum and maximum ideal pool control parameter values, however, the required Saturation Index range is described:

All Minimum Ideal Values (pH = 7.4, Temp = 76 ºF, TA = 80 ppm, Ca = 200 ppm) SI = 7.4 + 0.6 + 1.9 + 1.9 - 12.1 =	-0.3
All Maximum Ideal Values (pH = 7.6, temp = 84 ºF, TA = 120 ppm, Ca = 400 ppm) SI = 7.6 + 0.7 + 2.1 + 2.2 - 12.1 =	0.5

In the following example, the LSI is ideal, however, not all of the chemical parameters are within acceptable ranges (pH = 8.1, temp = 84 ºF, TA = 100 ppm, Ca = 50 ppm)

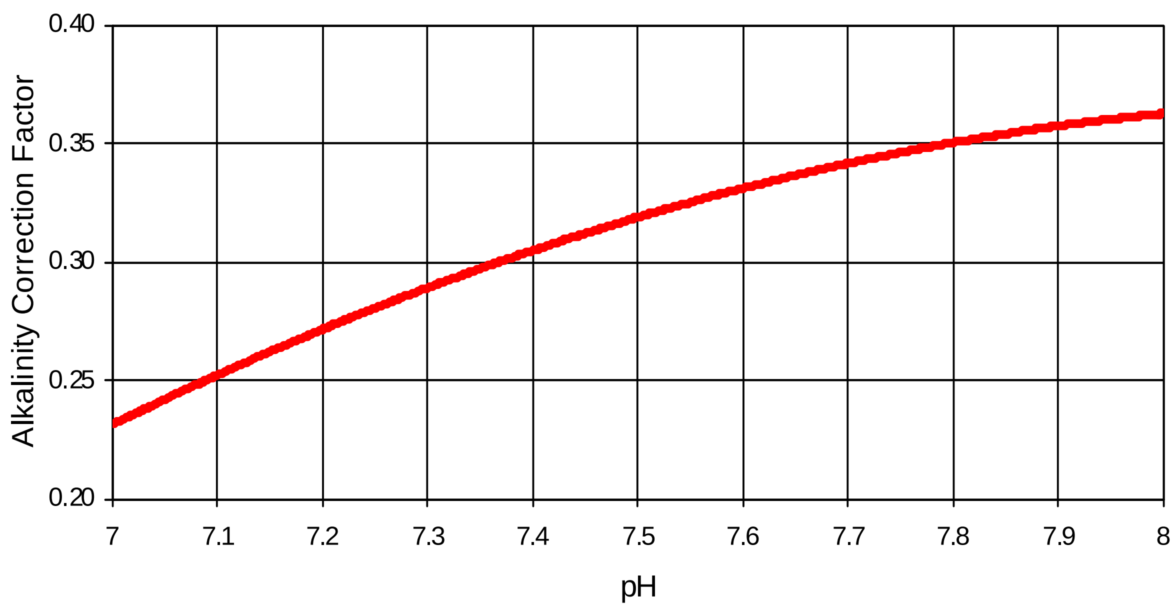
SI = 8.1 + 0.7 + 2.0 + 1.3 - 12.1 =	0.0

All of the individual parameters should be maintained within their acceptable ranges. Although the LSI is 0.0 in this example, corrosion of plaster can still occur at high pH if there is not sufficient calcium. LSI is simply a tool for predicting calcium carbonate solubility. The LSI is a reliable index of water quality when the individual parameters are within the range and the LSI is within -0.3 and +0.5.

It can be seen that if start up-water has a naturally high calcium hardness, adjustment of the alkalinity and pH can still result in balanced water – within limits. If one parameter is too far out of range, the other parameters cannot be adjusted sufficiently to compensate without creating undesirable operating conditions.

Finally, cyanuric acid can have an impact on the measured total alkalinity. Cyanuric acid is a good buffer in the pH range of typical pool operation, however it is not involved in the formation of calcium carbonate. The alkalinity of cyanuric acid, expressed as equivalent calcium carbonate, is about 1/3 of the cyanuric acid concentration, though the exact value varies with pH, as shown in figure 3 below.

Figure 3 – Cyanuric acid — alkalinity correction factor



In calculating a calcium carbonate saturation index (Langelier Saturation Index) only the alkalinity associated with carbonate and bicarbonate is relevant. Calcium carbonate saturation primarily relates to the concentrations of calcium and carbonate ions. The carbonate concentration in turn relates to the pH and the total bicarbonate/carbonate alkalinity. Thus it is recommended to subtract cyanurate alkalinity from the total measured alkalinity to determine the carbonate alkalinity before calculating the saturation index. This correction is most relevant at high CYA concentrations. Generally the correction used takes one of the two following forms:

Total Alkalinity (corrected) = Total Alkalinity (measured) – [CYA]/3

or,

Total Alkalinity (corrected) = Total Alkalinity (measured) – 0.3 x [CYA]

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Section A8 — Physical/Environmental/Operational

A8.1 — Air quality

Chlorine and bromine react with organic matter to form volatile disinfection byproducts such as trihalomethanes (THMs) and chloramines. The organic matter can be found in the source water, or it can be introduced by bathers in the form of perspiration, mucous, urine, and body oils.

Trihalomethanes are also referred to as "Total Trihalomethanes "(TTHM) and include the following halogenated organic compounds: chloroform, bromodichloromethane, dibromochloromethane, and bromoform. In pool and spa water treated with chlorine, chloroform has been reported as the predominant THM (Judd 1995). Since chloroform is volatile, it readily escapes into the air space above the water. Exposure to chloroform can occur through inhalation, ingestion, or contact with the skin or eyes.

Similarly, several articles have been written that review occupational and recreational exposures to chloramines. Unlike THMs, airborne chloramines are readily detected by smell, can cause objectionable odors, and can irritate the eyes and mucous membranes. Indoor facilities with poorly maintained swimming pools or spas and inadequate ventilation are prone to generate unacceptable levels of airborne chloramines. According to the U.S. Centers for Disease Control and Prevention (CDC), and many state health departments, bathers frequently develop acute symptoms after exposure to chloramines. These exposures often go unreported. Symptoms include acute respiratory illness, acute gastrointestinal illness, and eye illness. Monitoring airborne chloramines or THMs is difficult. Few laboratories have the capability, these species are unstable, and their concentrations can change rapidly over a few days or even within hours.

Given the difficulties associated with monitoring airborne disinfection byproducts, CDC has offered several practical steps to help improve indoor air quality on the healthy swimming website (http://www.cdc.gov/healthyswimming/).

Consultation with HVAC technical resources may be required to ensure ventilation is sufficient to remove airborne chloramines and THMs from indoor facilities. Ventilation should not be used as a substitute for proper pool and spa maintenance.

The limits established by ANSI/ASHRAE 62.1 – 2004 are minimums and do not encompass the full variety of swim venues and their indoor air quality issues. Some additional protections and conditions to consider including are:

- Ensure design promotes good recirculation and eliminates short-circuiting of the fresh air to exhaust;
- Evaluate the locations of the building exhaust and the fresh air replacement locations to reduce reentrainment problems;
- Ensure the natatorium is slightly negative pressure compared to any surrounding rooms to prevent vapors from the natatorium from escaping to other rooms;
- If there are water features in the facility that are spraying water into the air, additional safeguards are needed to ensure that proper ventilation and relative humidity levels are maintained;
- If water features are used spraying water into the air, some safeguards are needed to prevent microbial regrowth of the water standing in pipes overnight; and
- Additional ventilation and/or dehumidification equipment should be installed if existing equipment cannot control moisture.

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A8.2 — Clarity

Water clarity is essential to identify swimmers in distress. Ideally, a small child in distress at the bottom of the deepest part of the pool should be visible while the water surface is in movement, as in normal use. Additionally, clarity is important for swimmers to identify other swimmers, pool depth, and potential underwater hazards such as debris on the pool/spa bottom.

The 30-foot distance in the standard for pools is based on a number of different factors including pool width, pool depth, and typical height and positioning of lifeguard stands.

Turbidity is often an indicator of heavy bather load, poor water quality, or improper filtration. Turbidity measurement and pool or spa bottom visibility are the two generally accepted methods for determining water clarity. The World Health Organization has recommended a maximum acceptable value of 0.5 ntu (nephelometric turbidity units) as a useful, but not absolute, upper-limit guideline.

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A8.3 — Cyanuric acid

The 100 ppm limit is a common consensus among health authorities, for example:

U.S. CDC	100 ppm[13]
WHO	100 ppm[14]
"Ten State" Standard	100 ppm[15]

There is a degree of uncertainty in setting this value, but the consensus decision is not entirely arbitrary. The following factors, which will be discussed in more detail, were considered when setting the limit for cyanuric acid:

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[13] U. S. Centers for Disease Control and Prevention and U. S. Department of Housing and Urban Development. *Healthy housing reference manual*, chapter 14 (Atlanta: U.S. Department of Health and Human Services, 2006). http://www.cdc.gov/nceh/publications/books/housing/housing.htm#CONTENTS

[14] *Guidelines for Safe Recreational Water Environments*, vol. 2, *Swimming Pools and Similar Environments,* World Health Organization, 2006, ISBN 92-4-154680-8, p. xvii. http://www.who.int/water_sanitation_health/bathing/bathing2/en/

[15] *Recommended Standards for Swimming Pool Design and Operation*. Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Ontario, Pennsylvania, Wisconsin, 1996 Edition. Published by: Health Education Services, P.O. Box 7126, Albany, NY 12224, tel. (518) 439-7286.

– Effective use levels of cyanuric acid;

– Cyanuric acid/chlorine equilibria;

– Effect of cyanuric acid on Oxidation Reduction Potential (ORP); and

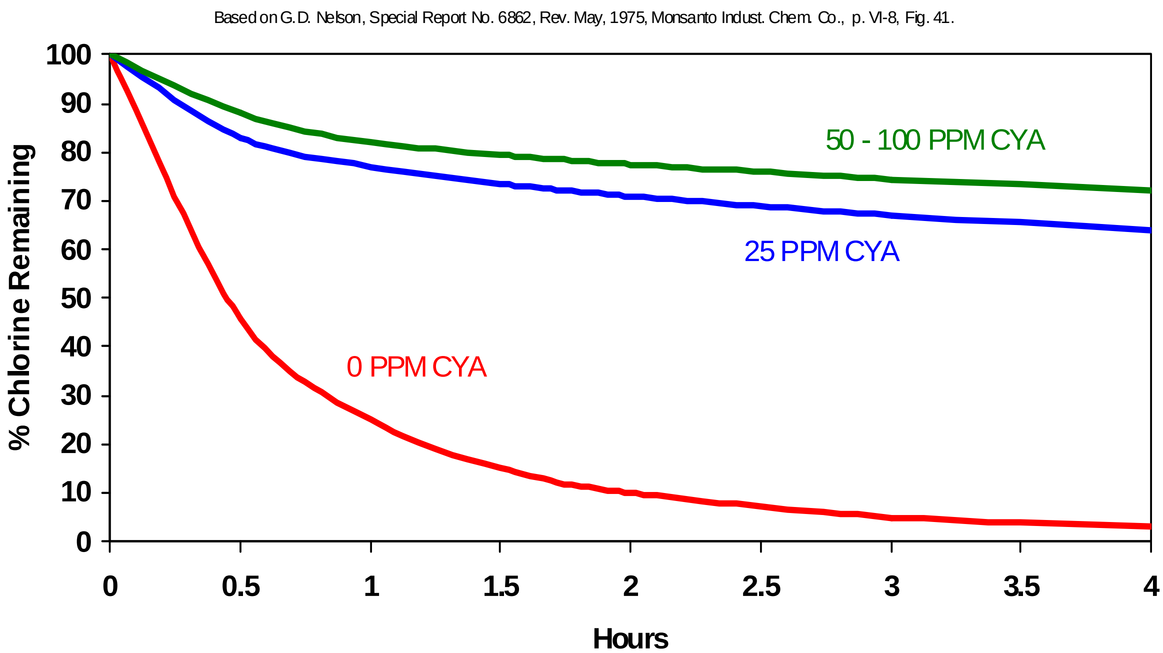
– Effect of cyanuric acid on chlorine kill rates.

Effective use levels of cyanuric acid

Cyanuric acid (CYA, "stabilizer" or "conditioner") is used to stabilize chlorine against destruction by sunlight. Cyanuric acid is not recommended for indoor pools or spas where protection from sunlight is not necessary. [16]

Stabilizer can be added to the pool as cyanuric acid, or introduced with stabilized chlorine sanitizers such as dichloroisocyanuric acid and trichloroisocyanuric acid. Without cyanuric acid in the water, bright sunlight can cause decomposition of most of the chlorine in pool water within an hour, as shown in the graph below. Addition of 25 PPM (mg/L) of cyanuric acid to the water can greatly slow this reduction of chlorine. Maximum stabilization occurs between 50 ppm and 100 ppm. No demonstrable increase in stabilization was seen above 100 ppm. The ideal range for cyanuric acid is 30 – 50 ppm when used. See figure 4.

Figure 4 – Impact of sunlight on chlorine residual

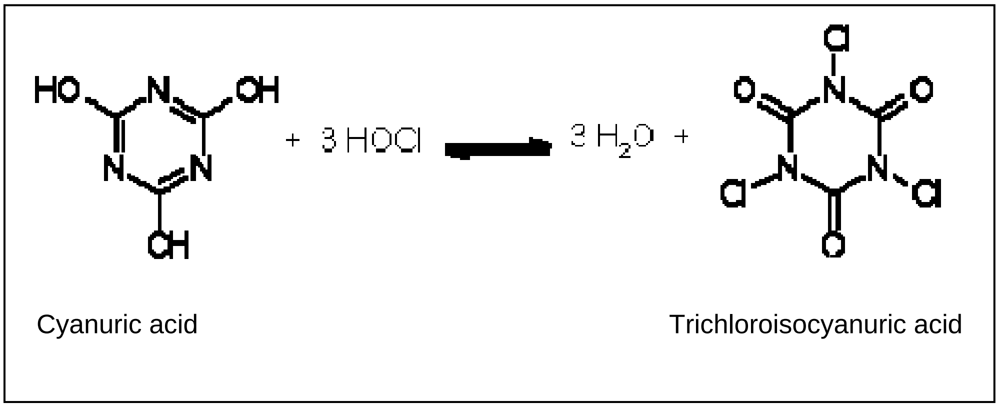


Cyanuric acid/chlorine equilibria and the effect of cyanuric acid on oxidation reduction potential (ORP)

When cyanuric acid is used, hypochlorous acid is always in equilibrium with cyanuric acid-bound available chlorine. As suggested by the equation in figure 5, the stabilization of chlorine residual results from a reaction of free chlorine (hypochlorous acid or hypochlorite) with cyanuric acid to give cyanuric acid-bound available chlorine.

This reaction is totally reversible, with a back reaction (to again reform hypochlorous acid) fast enough that cyanurate-bound chlorine generally tests as free chlorine. Free chlorine that has reacted with cyanuric acid is not permanently lost, but rather placed temporarily in reserve. However the affinity of chlorine for cyanuric acid is strong enough that most of the "Free Available Chlorine" at any given point in time is bonded to cyanurate and the hypochlorous acid concentration is only a fraction of what a free available chlorine test and pH would indicate. This is reflected in an Oxidation Reduction Potential (ORP) that decreases as the cyanuric acid concentration increases.

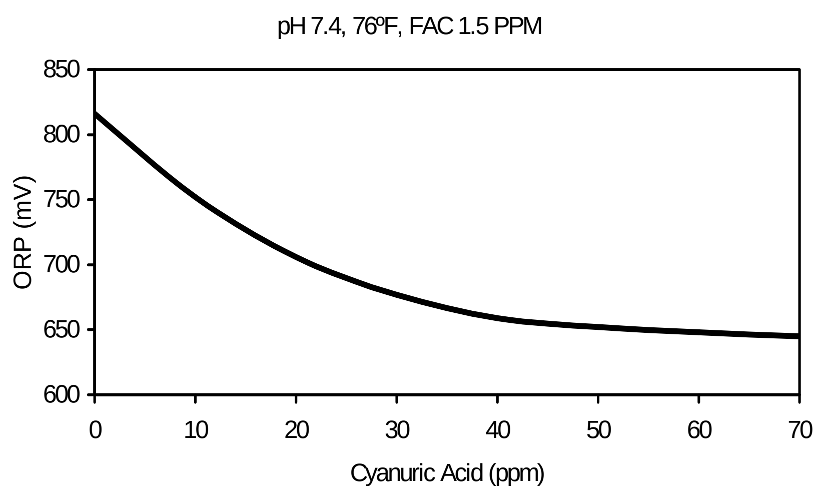
Figure 5 – Reaction of free chlorine with cyanuric acid



Note: A molecule of cyanuric acid can react reversibly with up to three molecules of hypochlorous acid.

Figure 6 – Impact of cyanuric acid on oxidation reduction potential

Figure 6 adapted from chapter 13 of the *Certified Aquatic Operator Manual*, 4th edition (2003), Kent G. Williams editor, National Recreation and Park Association.



Effect of cyanuric acid on chlorine kill rates

Lowering the hypochlorous acid concentration can have a significant impact on the rates of any reaction for which hypochlorous acid is involved in a rate limiting step. Specifically disinfection[16] and oxidation[17] of contaminants can be slowed by the lowered hypochlorous acid concentration.

Generally speaking the rate of disinfection or the rate of oxidation of a contaminant in the water by hypochlorous acid could be described by the following equation:[18]

$$-dN/dt = k\,[HOCl]^a\,N$$

in which:

> *N* represents a microbial concentration (such as deduced by a plate count) of the microbe to be killed or the concentration of the oxidizable species (such as various organic compounds, breakpoint susceptible chloramines, sulfide, or nitrite) to be destroyed;
>
> *–dN/dt* represents the rate of loss of the microbe or oxidizable material;
>
> *k* represents a rate constant;
>
> *a* is a positive real number that is specific to the type of reaction involved; and
>
> *[HOCl]* represents the hypochlorous acid concentration.

If this rate dependence on hypochlorous acid concentration is considered with the following equilibrium, it can be seen that increasing cyanuric acid will decrease the HOCl concentration, which could have a negative impact on sanitization and oxidation rates.

$$HOCl + CYA \rightleftarrows CYA - Cl + H_2O$$

The effect of cyanuric acid on oxidation of organics[19], kill rates of bacteria[20] and viruses[21], algae,[22] and protozoa[23] has been demonstrated. Some authorities or standards have suggested adjusting the required chlorine re-

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[16] *Pseudomonas Dermatitis/Folliculitis Associated with Pools and Hot Tubs — Colorado and Maine*, 1999 – 2000, December 8, 2000 / 49(48): 1087-1091. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4948a2.htm.

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sidual to the concentration of cyanuric acid to compensate for the reduction in rates of kill [24, 25, 26, 27, 28, 29]. These studies are not fully comprehensive and applicability to real pools has not been demonstrated. Specifically, we do not have any empirical evidence that a disease outbreak has been linked to a particular cyanuric acid level in a properly sanitized pool (i.e., when at least 1 ppm free available chlorine was present in the pool).

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[24] Australian Standard® "Private Swimming Pools—Water Quality", AS 3633—1989, Standards Australia (Standards Assoc. of Australia), ISBN 0 7262 5957 8, Table 3.2 (section 3.2, p.10).

[25] Pennsylvania Department of Health, "Fact Sheet on Cyanuric Acid and Stabilized Chlorine Products," July 24, 2003: http://www.dsf.health.state.pa.us/health/cwp/view.asp?a=180&q=234664.

[26] Kent G. Williams, *The Aquatic Facility Operator Manual*, The National Recreation & Park Association, National Aquatic Branch, 4th ed. 2003, p. 13-3.

[27] Jacques M. Steininger, "PPM or ORP: Which Should Be Used?" *Swimming Pool Age & Spa Merchandiser*, November 1985: http://www.sbcontrol.com/ppmorp.pdf.

[28] Wisconsin Administrative Code HFS 172 "Safety, Maintenance and Operation of Public Swimming Pools and Water Attractions", Subchapter II — Water Treatment Systems and Water Quality, Section HFS 172.14 "Disinfectant Feeding and Residuals" Paragraph (4) "Chemical Concentrations and Residuals", Wisconsin Department of Health and Family Services, Register, August, 2007, no. 620, http://www.legis.state.wi.us/rsb/code/hfs/hfs172.pdf

[29] 65529 "Disinfection, pH Control and Cyanuric Acid", *California Code of Regulations*, Title 22, Chapter 20, (Public Swimming Pools), Article 3 (Maintenance and Operation), p.12: http://www.solanocounty.com/resources/ResourceManagement/poolcode.pdf.

A8.4 — Enzymes

Enzymes are special proteins that catalyze (speed up) those chemical reactions that are important for the life and health of the organism producing them. There are many classes of enzymes, all of which are substrate specific. For example, two common types of enzymes used in pools and spas are proteases (protein-degrading enzymes) and lipases (lipid-degrading enzymes). By breaking down organic contaminants, enzymes of various types are commonly used in pool and spa water to improve water quality, pool operation, and aesthetics.

Enzyme-containing products are not EPA-registered sanitizers/disinfectants. Therefore, they must always be used in conjunction with a registered sanitizer.

Reference

Worthington Biochemical Corporation website: http://www.worthington-biochem.com/introBiochem/introEnzymes.html.

A8.5 — Oxidation reduction potential (ORP)

ORP (Oxidation Reduction Potential) is generally measured in millivolts by means of an electronic meter. It measures the relative proportion of oxidizing and reducing species in the water. Higher concentrations of oxidizers will give higher ORP readings. ORP is used to provide an approximation of the levels of oxidizing sanitizers such as chlorine and bromine and its typical use is to control the feed of these chemicals.

The use of ORP controllers does not eliminate or supersede the need for testing the sanitizer level with standard test kits. For PHMB-treated pools, levels for ORP values are not applicable.

ORP readings may be affected by a number of factors including, but not limited to the following: pH, probe condition, cyanuric acid, sanitizer type, metals, and supplemental oxidizers. Therefore, the ORP readings must be correlated with traditional methods capable of detecting specific sanitizer residuals (e.g., DPD) to have any value to the operator.

A drop in the ORP value may indicate a loss of sanitizer residual or a significant increase in pH and should alert the pool or spa operator to potentially unsanitary water conditions.

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A8.6 — Temperature

If the water temperature is too low, bather discomfort or hypothermia can result. Hypothermia is a condition in which the core body temperature drops below 95 °F (35 ºC). Symptoms of hypothermia may include drowsiness, weakness, confusion, uncontrollable shivering, and slowed breathing or heart rate.

If the water temperature is too high, there may be bather discomfort, excessive fuel requirements, increased evaporation, increased potential for scaling, or increased use of sanitizers. Overexposure to high water temperatures (hyperthermia) can result in nausea, dizziness, lethargy, or fainting.

In water as warm as 90 °F (32 °C), body heat rises because it cannot be dissipated fast enough. When the water is slightly warmer (e.g., 93 °F (34 °C)) dangerous internal body temperatures will be reached in approximately 30 minutes of moderate sustained exercise (Neilsen).

The American Red Cross recommends that the most healthful swimming pool temperature is 78 °F – 82 °F (26 ºC – 28 ºC).

The recommended water temperature for swim spas is 78 °F – 82 °F (26 ºC – 28 ºC).

The Consumer Product Safety Commission states, "hot tub water temperatures should never exceed 104 degrees Fahrenheit." Temperatures well below 104 °F (40 °C) are recommended for extended use (exceeding 10-15 minutes) or for pregnant women, people with certain medical conditions or medications, and for young children.

It is important to note that pools used for competitive swimming typically have lower water temperatures (77 °F – 82.4 °F, 25 ºC – 28 ºC) due to the increased activity level of the swimmers. Likewise, competitive diving pools typically have higher water temperatures (not less than 78.8 °F or 26 ºC) since the swimmers are entering and exiting the water quickly and are exposed to the ambient air more frequently.

Table 4 – Recommended pool temperatures

Temperature	Pool/spa type	Organization
FINA		
79 °F (26 °C ± 1 °C)	Class A Pools/Accredited Competitive Swimming	Federation International De Natation Amateur (FINA) (FINA is the governing body that regulates international competition including the Olympic Games)
Other competitive bodies that regulate aquatic competition		
78 – 80 °F (26-27 °C) during competition	Class A Pools/Accredited Competitive Swimming	USA Swimming
84 – 94 °F (29-34 °C)	Adaptive Aquatic Pools	*Adaptive Aquatic Programming: A Professional Guide*, Monica Lepore, G.William Gale, Shawn Stevens, 1998, Human Kinetics Publisher
79 – 81 °F (26-27 °C) for competition if connected to competitive pool If using separate diving venue 82 – 86 °F (28-30 °C) during competition	Class A Pools/Accredited Competitive Swimming	USA Diving
78 – 81 °F (26-27 °C)	Class A Pools/Accredited Competitive Swimming	USA Water Polo
Not less than 80 °F (27 °C)	Class A Pools/Accredited Competitive Swimming	U.S. Synchronized Swimming

79 – 81 °F (26-27 °C) for competition if connected to competitive pool If using separate diving venue 82 – 86 °F (28 – 30 °C) during competition	Class A Pools/Accredited Competitive Swimming	National Collegiate Athletic Association (NCAA)
78 – 82 °F (26 – 28 °C)		National Federation of State High School Associations (NFSHSA)
Other Sources		
79 – 81 °F (26 – 27 °C)	Competitive Swimming	*The Complete Swimming Pool Reference*, Second Edition, Dr. Tom Griffiths, 2003 Sagmore Publishing
83 – 86 °F (28 – 30 °C)	Youth instruction	
84 – 86 °F (29 – 30 °C)	Senior citizen and special populations	
86 – 90 °F (30 – 32 °C)	Therapeutic Pools	
82 – 85 °F (28 – 29 °C)		*American Red Cross Water Safety Instructors Manual*,1996, Mosby-Year Book, Inc.
82 – 85 °F (28 – 29 °C)		*Teaching Swimming Fundamentals*, YMCA of the USA,1999, Human Kinetics Publishers, Inc.
Not to exceed 104 °F (40 °C) / hot tubs-spas	Spas and Hot Tubs	*Suggested Health and Safety Guidelines for Public Spas and Hot-Tubs*, Center for Environmental Health, U.S. Department of Health and Human Services, Healthy Swimming Organization
Class A Pools are pools intended for use for accredited competitive aquatic events such as Federation Internationale de Natation (FINA), USA Swimming, USA Diving, National Collegiate Athletic Association, and National Federation of State High Schools Associations. The pool may also be used for recreation.		

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A8.7 — Testing frequency

It is essential to maintain records for sanitizer residual, pH, clarity, and water temperature (spa) because these four parameters are critical for public health. Failure to maintain these parameters within the required ranges will result in pool and spa closure.

Records should be maintained for both legal and operational use and shall be kept for a minimum of one year. However, retaining testing records longer than a year will allow season-to-season comparisons and may also be required according to local regulations.

Several factors will determine how often testing is required. Weather, water conditions, facility design, and bather load are the primary factors for determining how often pools and spas should be tested. Depending on the facility, testing may be required every 1 or 2 hours during operation.

In a bromine or an unstabilized chlorine pool or spa, sunlight will increase the rate of sanitizer loss. In this case, sanitizer concentrations should be checked more frequently. Evaporation will increase demand for make-up water. If the make-up water differs significantly from the pool water, the sanitizer, pH, alkalinity, and hardness should be tested after addition of the make-up water.

Rain and wind will introduce materials to the water such as plant debris (leaves, pollen), dirt, airborne pollutants, and other contaminants that will decrease sanitizer concentrations and increase the likelihood of chloramines. Rain also tends to decrease pH and alkalinity readings. After a major rainstorm, sanitizer, pH, and alkalinity should be tested.

Bathers introduce microorganisms and body oils that increase sanitizer demand. Bathers usually will cause a decrease in pH [30, 31, 32, 33, 34, 35, 36, 37, 38]. If there is a high bather load, particularly in a spa, the sanitizer and pH should be checked more frequently.

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[36] J. Burry, H. Coulson, I. Esser, V. Marti, S. Melling, A. Mills, A. Rawlings, G. Roberts, "The Secret of Measuring Sweat pH: With the Incorporation of Important Controls, There Are No Gender Differences in Axillary Sweat pH Values, *Journal of Investigative Dermatology* 117, no. 2 (August 2001): 549.

Testing frequency shall be sufficient to ensure that the water chemistry standards set forth in this document are met at all times. These are recommended minimum values for most situations. Testing frequency should increase in cases of high bather load or other factors such as changes due to weather, and may decrease for lightly used pools and spas.

Table 5 – Testing frequency

Parameter	**Pool** **Frequency of testing during periods of use**	**Spa** **Frequency of testing during periods of use**
Sanitizer	Every 2 hours	Every hour
pH	Twice per day	Twice per day
Clarity	Daily	Daily
Temperature	Daily	Daily
Alkalinity	Once per week	Daily
Hardness	Every two weeks	Every two weeks
Cyanuric acid	Once per month unless stabilized chlorine is used, then once every 2 weeks	N/A

Whatever test kit you use, with liquid, powder, or tablet test reagents, the kit should measure accurately sanitizer (e.g., free available chlorine, total chlorine, PHMB), pH, total alkalinity, calcium hardness, cyanuric acid (if used), hydrogen peroxide (if used), plus include calibrations for measuring bromine and ozone, if desired.

The two most widely used reagents for determining levels of sanitizer in pool and spa water are diethyl-p-phenylene diamine (DPD) and orthotolidine (OTO). OTO is not recommended for testing, but is used. Be aware that this reagent is a suspected carcinogen and is very acidic. It should never be added directly to the water.

A8.8 — Water replacement

Because water replacement recommendations have not traditionally been regulated in the United States, the following Appendix is more detailed in order to describe the justification and methods for calculating the water replacement interval.

Many contaminants enter pool and spa water from the environment, from the bathers themselves, and from by-products of chemicals used to treat the water. A swimmer will lose about two pints of sweat per hour if active in pool water at 75 °F with the ambient temperature at approximately 100 °F (Kuno, 1956). Although filtration and oxidation are effective in removing many of these contaminants, many of them remain and accumulate in the water. In pools and spas, water replacement is generally the only practical way to correct for excessive contaminants, calcium hardness, total dissolved solids (TDS), and cyanuric acid. Water replacement can be accomplished by periodic draining or by continuous dilution. Continuous dilution does not preclude the need for periodic draining and thorough cleaning of the pool or spa.

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[38] Gavin Hayden, Helen C. Milne, Mark J. Patterson, Myra A. Nimmo, "The Reproducibility of Closed-Pouch Sweat Collection and Thermoregulatory Responses to Exercise-Heat Stress," *European Journal of Applied Physiology* 91, no. 5-6 (May 2004): 748-751.

Wading pools, spray pads, or similar water bodies may be more appropriately treated as spas due to their high bather loads and small water volumes. It is advisable that the complete draining, cleaning, and disinfecting, and replacement with new properly balanced water be provided to remove as much of the visible greases, oils and biofilms that create "seeding" conditions into these types of pools. Complete draining is preferred over gradual water replacement for these types of facilities.

A regular water replacement program has a considerable impact on water quality. However, the data do not exist currently to place a value on the appropriate water replacement interval for pools or spas, although Canada and the European Union have set values. These organizations have set these standards based on other treatment systems, and these other factors should be kept in mind when deciding what water replacement interval is appropriate for a particular facility.

Spas: Total Dissolved Solids (TDS) or Water Replacement Interval (WRI)

The following procedure provides guidelines on how to determine the frequency for which spa or hot tub water should be replaced.

Test the TDS (Total Dissolved Solids) and calculate the WRI (Water Replacement Interval). When either of the following conditions is met, drain the spa completely, clean it thoroughly, and refill it with source water:

1. The Total Dissolved Solids (TDS) in the spa water exceeds the source-water TDS by 1,500 ppm or more; or
2. The Water Replacement Interval (WRI) is less than or equal to the number of days since the last time the water was drained. WRI is calculated as shown in the formula and examples below.

WRI = (0.33) (Spa Volume in gallons) ÷ (Cumulative No. Bathers per day since last change)

<u>Example 1</u>

The TDS of the original source water was measured and recorded to be 800 ppm. The TDS of the spa water is now reading 2,500 ppm. The difference is greater than 1,500 ppm (2,500 ppm - 800 ppm = 1,700 ppm) and therefore the spa should be drained.

<u>Example 2</u>

Consider a 600 gallon spa last drained and refilled on Sunday evening, with the usage pattern outlined in the table below.

600 Gallon Spa Usage Pattern								
	Sun	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
Bathers	Water changed at end of day	85	2	19	20	105	100	50

The WRI is computed in the table below and compared to the interval since the last change. If the Difference (WRI - Days since last change) is less than or equal to zero, the spa should be drained.

600 Gallon Spa Usage Pattern								
	Sun	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
Bathers	Water changed at end of day	85	2	19	20	105	100	50
WRI	-	2	2	11	5	1	2	1
Difference (WRI minus Days since last change)	-	1	0	10	3	-2	1	-1
Change Water (Difference =<0?)		No	Yes	No	No	Yes	No	Yes

Explanation of water replacement interval (WRI)

In the United States it has been common practice to use the following Water Replacement Interval (WRI) calculation:

WRI (Days) = (1/3) x (Spa Volume in U.S. Gallons) / (Number of Bathers per Day)

Although the justification for the 1/3 value has not been published in peer-reviewed journals, this value has been used in common practice in the pool and spa industry for about 15 years.

The "1500 ppm greater than TDS at spa start-up" value for water replacement is an historical bench mark. The increase in TDS is an indication of accumulated waste products and as such should be limited.

Due to higher bather-to-water ratios in hot tubs and spas, water replacement is often more economical and effective than continual chemical addition. Furthermore, frequent water changes and cleaning help control the microbiological population.

The water replacement interval shown above is equivalent to saying that the spa water must be drained when the number of bathers exceeds the gallons of spa water divided by three:

Maximum # of bathers = spa volume in gallons / 3

For instance in a hypothetical extreme case of a 300 gallon spa that had 100 bathers per day, the WRI would be:

WRI = 1/3 x 300 / 100 = 1 day

In this example it is easier to see that the maximum number of bathers (100) is equivalent to the spa volume of 300 gallons divided by 3.

Yet another way to express this would be to say that 3 gallons of water needs to be replaced for every bather that enters the water.

When the units are converted to metric, this replacement interval rounds to 0.01 cubic meters of water per bather, equivalent to the standard in the United Kingdom. (UK Health Protection Agency, 2006):

# of bathers = 100 x spa volume in cubic meters

When the number of bathers has been exceeded, the spa water must be drained and replaced.

Although the amount of incremental water replaced per bather may be calculated, it is recommended that the spa be completely drained based on the WRI calculation.

Pools: Water drain and replacement rate

The water should be drained and replaced at a rate of 7 gallons per bather. Evaporation loss will not remove contaminants and so make-up water for evaporation loss should not be counted as water drained and replaced.

Example

In this example, a pool is open 7 days a week and is averaging 30 bathers a day. During a week of normal operation 1725 gallons of make-up water is metered into the pool. The make-up water is added to replace water that is lost due to evaporative and non-evaporative (splash out, drag out, backwashing, etc.) losses.

The water drain and replacement rate for this pool is:

7 gals per bather x 30 bathers = 210 gallons per day, or 1470 gallons per week.

The estimated amount of evaporation loss for the week in this example is 900 gallons (based on 1.5 inches of evaporation loss in a week from a 1000 square-foot surface area pool). So the amount of water that was "drained" from the pool would be only 825 gallons:

1725 gallons make-up water
– 900 gallons added to replace evaporated water
825 gallons of water replaced due to non-evaporative losses.

An additional 645 gallons would need to be removed and replaced to reach the goal of 7 gallons a bather:

1470 gallons total to drain and replace
– 825 gallons drained and replaced due to normal operation
645 additional gallons of water that must be drained and replaced.

In summary, the loss due to evaporation should not be counted as water drained and replaced.

Explanation of water drain and replacement rate

Currently, for swimming pools in the U.S., water replacement is used as a method to correct for excessive levels of parameters such as calcium hardness, total dissolved solids (TDS), metals, cyanuric acid, and foam. However water replacement is not often mandated for public health. The European Community and FINA (Federation Internationale de Natation Amateur) have adopted the German DIN (Deutch Industrie Normen) Standard 19643-1, "Treatment and Disinfection of Swimming and Bathing Pool Water."[39] This standard specifies that each day 30 liters (approximately 8 gallons) of water per bather shall be drained and replaced with fresh water. This standard is based on treatment systems that can vary significantly from those used in the

[39] DIN 19643-1, *Treatment and Disinfection of Water Used in Bathing Facilities*, April 1997, Section 9.6 Filling water replacement: At least 30 l of pool water per bather shall be replaced by filling water, either continuously or once a day. The water replacement calculation may take into account the water replaced as a result of filter backwashing during filtration and possibly also the volume of water required to operate the chlorine or ozone feed plants, for example. In the case of hot whirlpool baths that have their own water treatment system, replacement of the filling water is unnecessary, since the facilities have to be drained every day.

U. S. These differences should be kept in mind when deciding what water replacement interval is appropriate for a particular facility.

The justification for the DIN standard has not been published. Therefore the following Drain and Replacement Rate for pools is adapted from the WRI for spas. However it can be seen below that the results produced from either DIN or the Drain and Replacement Rate for pools are similar although the rationale leading to the respective rates may be different.

In published studies the data show that each bather might excrete about half as much sweat and urine into a pool as into a spa. If this is true, the water replacement rate for a pool might reasonably seem to be half that for the spa in terms of gallons per bather. So if 3 gallons needs to be replaced for every bather that enters the spa (see spa section above), then half that amount, or 1.5 gallons, may need to be replaced for every bather that enters a pool.

Although this value may be appropriate if the entire pool could be drained on a regular basis, it is not appropriate for a pool where the water may be removed only in increments due to the time involved to drain and re-fill large quantities of water and the risk of shell damage caused by buoyancy of the pool shell in ground water.

There is one very important difference between the gradual water replacement described here for a pool and the total drain-and-replace schedule for a spa. Totally draining and replacing the water is far more efficient for diluting or eliminating contaminants.

Consider the following two scenarios:

Complete Drain:

Draining 297 of 300 gallons (99%) from a spa and refilling would dilute the bather waste to 1/100th of the pre-replacement concentration. (Assume that the retained 3 gallons might be trapped in plumbing, filter, etc.)

Gradual Water Replacement:

If a 10,000 gallon pool were drained in 100 gallon increments, this procedure could be conducted 100 times, for a total of 10,000 gallons, but the bather waste would only be diluted to 37% of the initial level. This is because the fresh water is mixed with the contaminated water, and the next 100 gallon increment that is withdrawn will have a lower concentration of contaminants than the original water. The mathematical expression of this is shown as follows:

$$\left(\frac{10{,}000 - 100}{10{,}000}\right)^{100} = 0.99^{100} = 37\%$$

This assumes all 100 replacements are back-to-back, with no new bathers introduced between partial water replacements.

These two examples show that 100 replacements of 1/100th of the water each time eliminates 63% of the contaminants whereas replacing 99% of the water all at once eliminates 99% of the contaminants (assuming the refill water contains none of the contaminants).

To eliminate 99% of the contaminants using 1% water replacements would take 458 such replacements in a row; thus it would take about 4.6 times as much replacement water to achieve the same level of dilution as with a single 99% water replacement.

Totally replacing the water all at once is therefore obviously more efficient, but not always possible with a pool, due to the greater water volumes. So a pool water replacement rate of 1.5 gallons per bather would not be enough since only partial draining and replacement is practiced and this is inefficient.

Multiplying the 1.5 gallons per bather by an efficiency factor of 4.6× gives a water replacement rate of 6.9 or about 7 gallons of water per bather.

As indicated previously, DIN standard 19643 gives a water replacement rate equivalent to 8 U.S. gallons per bather per day. This value is not far from the 7-gallon-per-bather replacement rate calculated above.

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Section A9 — Microbiological

A9.1 — Bacteria and other pathogens

Why regular bacteriological monitoring is not required

Although a variety of products are used in pools and spas, only those products that make public health claims (sanitizers) require registration with the U.S. Environmental Protection Agency (EPA). Once a sanitizer is registered by the EPA as a sanitizer under FIFRA (Federal Insecticide, Fungicide and Rodenticide Act), it becomes legal to say that the product kills disease-causing bacteria in pools and/or spas. Since sanitizers play a vital role in protecting swimmers and bathers from disease-causing organisms, the EPA's performance criteria for registration are challenging.

The EPA performance criteria are outlined in DIS/TSS-12, "Efficacy Data Requirements, Swimming Pool Water Disinfectants." In order to obtain FIFRA registration, the test product must be able to control bacteria in swimming pools during rigorous field studies. These studies last for 4 – 12 months and determine the test product's ability to control bacteria while people are swimming. A minimum of 144 samples are collected over four to twelve months for bacterial enumeration and water chemistry. Registration will be granted only if the following is true for at least 85% of the samples tested:

– The standard heterotrophic plate count (HPC; see below) does not exceed 200 cfu/ml,

– Total coliforms and fecal coliforms do not exceed one per 50 ml (see Coliforms below).

An additional test listed within DIS/TSS-12 is conducted under laboratory conditions to measure the rate at which sanitizers kill bacteria. Any sanitizer that kills 99.9999% (6-log reduction) of two bacterial species within 30 seconds may add a "disinfectant" claim on the sanitizer label.

Clearly, by obtaining EPA registration all sanitizers will have already demonstrated their ability to control bacteria under real-world conditions. Therefore, as long as a sanitizer is used according to label directions, routine microbiological testing of pool and spa water is not required and is redundant. However, frequently monitoring parameters such as sanitizer level, pH, etc., are critical to safeguard public health. In addition to the redundancy of routine microbiological testing, there are additional factors to consider. First, microbiological testing usually requires up to 48 hours in order to obtain the test results. Therefore, microbiological testing can provide only a history of water quality from up to two days prior to obtaining the test results. This time lag between sampling and obtaining results means that the data may no longer be indicative of current conditions. The interest of public health is better served by frequently monitoring and maintaining adequate levels of the sanitizer while monitoring other important parameters such as pH.

Intermittent monitoring for bacteria is not an effective way to gauge the microbiological water quality in a pool or spa. A single test can often give erroneous results (false positive or false negative) if the samples were not properly obtained or treated. Even if a sample is handled and tested properly, the results can still be ambiguous. A single test can be misleading; true evaluation requires that hundreds of samples be taken over an extended time period to evaluate the water quality.

Pathogenic microorganisms

Many types of microorganisms are capable of causing disease in humans. Relatively few of them have been identified as disease-causing agents (pathogens) in sanitized recreational water. When a sanitizer is under evaluation prior to EPA-registration, bacteria are the only microbes used to gauge performance. Although EPA does not require data against other microorganisms, all pool sanitizers have been shown to display a broad spectrum of antimicrobial activity.

While it would be desirable for all pools and spas to remain free of microorganisms at all times, the sanitizer levels required to eliminate all microorganisms in the pool or spa would be unsafe for bathers. Therefore, pool/spa water is not sterile, and microorganisms are present. In other words, the function of an EPA sanitizer isn't to completely kill all bacteria. Rather, it's to control their numbers and subsequently lessen the opportunity for them to cause diseases.

Descriptions of some common waterborne pathogens and pertinent microbiological terms are found below.

- **Heterotrophic Plate Counts (HPC)** — a means of enumerating bacteria that require an organic carbon source for survival (heterotrophs). HPC are expressed as colony forming units per milliliter (CFU/ml), where each CFU represents a single heterotrophic bacterium. The EPA requires that HPC values are obtained during the testing of sanitizers for FIFRA registrations.

- **Coliform Bacteria** — A very large group of various bacterial species. The group includes bacteria that occur naturally in the intestines of warm-blooded animals and these present the greatest concern in recreational waters. Since coliforms do not proliferate in aqueous environments, their presence in a pool is indicative of fecal contamination. Hence, coliforms are often referred to as indicator organisms. Fecal coliforms, such as *E. coli* 0157:H7, can cause severe gastrointestinal illness and renal failure if contaminated pool water is swallowed.

- **Protozoan Parasites** — Parasites require a living host in order to reproduce. Two of the more common parasites in recreational water are *Cryptosporidium* and *Giardia*. These organisms are protozoa and are more resistant to chlorine than most bacteria. These parasites enter pool water from fecal contamination.

- ***Norovirus*** — a group of related viruses that cause acute gastrointestinal illness. They were formerly known as Norwalk and Norwalk-like viruses. Like *E. coli* and the protozoan parasites, these viruses are highly contagious and are spread via the fecal-oral route.

- ***Legionella*** — This bacterium causes Pontiac fever and Legionnaire's disease. Pontiac fever causes flu-like symptoms that are usually resolved within a few days. Legionnaire's disease is potentially fatal, often striking immunocompromised individuals. In the realm of recreational water, these diseases are usually contracted by inhaling *Legionella*-containing aerosols generated by spas. Although *Legionella* is susceptible to traditional sanitizers, it is often found within biofilms (see below) thereby gaining greater resistance to biocides.

- ***Pseudomonas*** — A bacterium that can cause dermatitis (hot tub rash). While most reported outbreaks occur in spas and hot tubs, *Pseudomonas* has also been referred to as the causative agent of "swimmer's ear."

- **Biofilm** — A community of microorganisms usually found growing on a surface, as opposed to free floating (planktonic) in an aqueous environment. Biofilms can be bacterial, algal, fungal, or a combination thereof and are usually more resistant to sanitizers than planktonic organisms.

Since most disease outbreaks in pools result from swallowing water contaminated with feces, operators should refer to the CDC (U.S. Centers for Disease Control and Prevention) website when dealing with fecal accidents: http://www.cdc.gov/healthyswimming.

Operators should refer to the APSP Information Bulletin "Spa Decontamination Procedures", when dealing with contamination of spas.

References

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A9.2 — Algae

Algae are microscopic plant-like organisms that contain chlorophyll and often grow in visible colonies. While algae are not generally recognized as pathogens (see references) in treated water, they can adversely affect the health and safety of swimmers. The presence of algae can increase the sanitizer demand and algae can harbor disease-causing organisms. Algae growing on the pool floor can constitute a slip hazard that can result in injury. Moreover, if algae are floating feely they can raise turbidity throughout the pool. As a result, a swimmer in distress might not be seen quickly enough in order for trained personnel to render assistance.

If algae are visible, take immediate remedial action.

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Section A10 — Contaminants

"Contaminant" refers to any physical, chemical, or biological substance in the water that may adversely affect the health or safety of the bather or the quality of the water.

A10.1 — Combined chlorine

Combined Chlorine is the term generally used to refer to chloramines. These chloramines may be inorganic, in the cases of monochloramine (NH_2Cl), dichloramine ($NHCl_2$), and trichloramine (nitrogen trichloride, NCl_3), or organic. Combined chlorine is formed when free chlorine combines with amine-containing compounds (for example, proteins and ammonia from perspiration and urine). These compounds can cause eye, mucous membrane, and skin irritation, and have strong objectionable chlorine-type odors. In addition to these characteristics, nitrogen trichloride is a volatile substance (i.e., readily forms a gas). When formed, nitrogen trichloride can be especially irritating to swimmers and corrosive to structural components. Ideally, no combined chlorines should be present in the pool or spa.

If the local water treatment plant uses chloramination for drinking water disinfection, chloramines (predominantly monochloramine) may be present in the fill water.

According to White (1999):

> Tastes and odors from the application of chlorine are not likely to occur from the chlorine compounds themselves up to the limits listed below:

Free chlorine (HOCl)	20.0 mg/L
Monochloramine (NH_2Cl)	5.0 mg/L
Dichloramine ($NHCl_2$)	0.8 mg/L
Nitrogen trichloride (NCl_3)	0.02 mg/L

Chloramines are biocides, but are much less effective as sanitizers than free available chlorine. According to Block, "the killing time of chlorine is extended considerably in chloramines or N-chloro compounds, and the higher the concentration of ammonia or nitrogenous compounds, the greater the lag in bactericidal time." This statement is supported by work performed by Berman et al. Berman's work showed that for inactivation of coliform bacteria, the time required to achieve 99% (2 log) inactivation with monochloramine was approximately 50 times longer than the time required for the same amount of inactivation with a similar concentration of free chlorine.

The Maximum Residual Disinfectant Level (MRDL) for chloramines is 4 ppm (40 CFR). This level was established for drinking water treatment plants that perform chloramination. Chloramines are often used to disinfect public water supplies because the chloramination process is less likely to generate disinfection byproducts, and because a chloramine residual is less reactive, and therefore easier to maintain throughout the water distribution system.

Combined chlorine concentrations are obtained by subtracting the measured free available chlorine concentration from the measured total chlorine concentration. The maximum level for combined chlorine is 0.2 ppm.

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A10.2 — Foam

Persistent foam (foam remaining in a spa after the jets are turned off) may harbor microorganisms and make the microorganisms more difficult to kill. Foam can also decrease visibility below the water surface creating unsafe bather conditions.

Foam in a pool or spa may be caused by organic wastes, consumer personal care products (lotions, etc.), incomplete rinsing of a filter after cleaning, and quaternary algaecides. Low calcium hardness levels can also create ideal conditions for foam formation and may exacerbate an existing problem.

Defoamers are often used to temporarily suppress existing foam, but the causes of foam formation will still persist.

A10.3 — Metals

Heavy metals can be introduced into the pool or spa from the source water at the time of fill or through subsequent water replacements. Metals can also come from metal fixtures (i.e., copper heat exchangers) located inside the pool/spa or from some water treatment algaecides. Pool operators should test their source water prior to filling a pool or spa in order to determine initial levels of metals.

If excessive heavy metals are present in the water:

- Staining may be occurring and could worsen;
- Corrosion of metal parts (i.e. copper heat exchangers) may have occurred and could worsen;
- Water may discolor;
- Filter cycle may decrease and require more frequent back-washing; and
- pH may be too low.

Copper, iron, and manganese are the most typical metals found in pool and spa water. Their presence can lead to staining of pool/spa surfaces or water discoloration. Copper staining will typically be green or blue in color. Iron typically will stain with an orange-to-brown color. Manganese generally stains with a purple-to-black color. Additionally high copper, combined with high cyanuric acid, can sometimes leave a purple deposit on pool or spa surfaces.

The Environmental Protection Agency National Primary Drinking Water Standard for copper is 1.3 ppm. The Secondary Drinking Water Standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The Secondary limits for metals found in drinking water are as follows:

Copper	1.0 ppm
Iron	0.3 ppm
Manganese	0.05 ppm
Silver	0.10 ppm
Zinc	5.0 ppm

There is not sufficient justification for setting a limit for metals in pools or spas to protect public health.

Some algicidal or sanitization systems utilize metals for microbial control (see A5.5, Metal-Based Systems). These systems are typically designed to minimize any negative effects of heavy metals in the water by limiting the dosage of metals or chelating the metals to prevent staining.

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A10.4 — Nitrates

Nitrate ion is a nutrient for algae and a number of bacteria. Elevated algae and bacteria populations associated with elevated nitrate ion concentrations create a significant chlorine demand. This leads many to the incorrect conclusion that nitrate ion has a chlorine demand. Nitrate ion is at the highest oxidation state of nitrogen, thus it does not have a chlorine demand.

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A10.5 — Phosphate

Phosphate is an oxidized form of phosphorous. Phosphorous is a non-metallic element and an essential nutrient for all living organisms, including bacteria and algae. Phosphate does not create a chlorine demand since the phosphate ion does not react with free chlorine. However, inadequate maintenance and sanitization can allow algae and bacteria to reproduce rapidly and utilize phosphorous as a nutrient. Under these circumstances, the multiplying algae or bacterial populations will cause chlorine demand.

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U. S. Environmental Protection Agency (EPA). Phosphoric acid; toxic chemical release reporting; community right to know, OPPTS-400056; FRL-5762-2, *Federal Register*, vol. 63, no. 15, 23 January 1998 / Notices.

U. S. Environmental Protectin Agency (EPA). Terms of environment: glossary, abbreviations and acronyms http://www.epa.gov/OCEPAterms/.

Vollenweider, R.A., 1968, The Scientific Basis of Lake and Stream Eutrophication with Particular Reference to Phosphorus and Nitrogen as Eutrophication Factors. OECD.DAS/CSI/68.27, Paris.

Appendix B — General references

This appendix is not part of the American National Standard and is included for information only.

U. S. Centers for Disease Control and Prevention (CDC)
Recreational water illness. CDC healthy swimming website: http://www.cdc.gov/healthyswimming/.

U. S. Environmental Protection Agency
Drinking water limits. U.S. EPA safewater website: http://www.epa.gov/safewater/contaminants/index.html.

U.S. EPA registration. U.S. EPA microbial pesticides website: http://www.epa.gov/oppad001/.

EPA label. U.S. EPA website: http://oaspub.epa.gov/pestlabl/ppls.home.

World Health Organization (WHO)
Guidelines for pools: http://www.who.int/water_sanitation_health/bathing/en/.

Appendix C — Glossary

Definitions

Acid: A liquid or dry chemical used to lower the pH and/or alkalinity of pool or spa water.

Acid Demand: A measure of the amount of acid required to lower the pH to a desired level.

Acid Demand Test: Acid of known strength is added in increments to a measured water sample to determine the amount of acid necessary to make an adjustment in a pool to achieve the desired pH.

Acidic: Having a pH below 7.0. Opposite of basic.

Acid Wash: A procedure using an acid solution to clean an interior surface of a pool with subsequent neutralization of the acid.

AF: See *Alkalinity Factor*.

Aggressive Water: Water that is corrosive because it is low in pH, and/or calcium hardness, and/or alkalinity.

Algae: Microscopic plant-like organisms that contain chlorophyll.

Algicide: Any chemical or material that kills algae. ALGAECIDE.

Algistatic: Able to inhibit the growth of algae.

Alkali: A term applied to bases, usually carbonates, bicarbonates, and hydroxides, that raise the pH and alkalinity when added to water.

Alkaline: Having a pH above 7.0.

Alkalinity: See *Total Alkalinity*.

Alkalinity Factor (AF): Used to calculate the saturation index of water.

Alum (Aluminum Sulfate) ($Al_2(SO_4)_3$): A compound used to cause suspended solids in the water to form filterable masses (flocculate).

Ammonia (NH_3): A chemical compound of hydrogen and nitrogen that combines with free chlorine in pools to form chloramines or combined chlorine. It also combines with free bromine to form bromamines.

Amphoteric: Having the ability to serve as either an acid or a base. AMPHIPROTIC

Available Chlorine: A rating of a chemical's total chlorine content based on a comparison to elemental (gaseous) chlorine having 100% available chlorine.

Back Pressure: Resistance to flow, normally expressed in pounds per square inch (kilograms per square centimeter.

Backwash: The process of cleansing the filter medium and/or elements by the reverse flow of water through the filter.

Backwash Cycle: The time required to backwash the filter medium and/or elements and to remove debris in the filter vessel.

Bacteria: Single-celled microorganisms of various forms, some of which cause infections or disease.

Bactericide: Any chemical or material that kills bacteria.

Balance: In pools and spas, used to refer to a condition of the water that is neither scaling nor corrosive.

Base: A chemical used to raise pH and/or total alkalinity of pool or spa water.

Base Demand: A measure of the amount of alkaline material required to raise pH to a predetermined level. This can be accomplished by use of a base demand test, whereby a standard base is added by drop to the pH test solution until the desired pH is reached.

Basic: Having a pH above 7.0. Opposite of acidic.

Bather: Any person using a pool, spa, or hot tub and adjoining deck area for the purpose of water sports, recreation, therapy or related activities. USER.

Bather Load: The number of persons in the pool/spa water at any given moment or during any stated period of time. SWIMMER LOAD.

BCDMH (Bromo Chloro-Dimethyl Hydantoin, $C_5H_6N_2O_2BrCl$) Products: Sanitizer product that is used to generate available bromine. Contains available bromine and available chlorine.

Biofilm: A community of microorganisms such as bacteria, algae, or fungi that are encased in a gelatinous matrix and usually attached to surfaces. The matrix protects the microorganisms from harsh environmental conditions and confers greater resistance to sanitizers and algicides. SLIME.

Bleach (NaOCl): Sodium hypochlorite. A chlorine source that typically has between 5% and 16% available chlorine. LIQUID CHLORINE.

Breakpoint Chlorination: The addition of a sufficient amount of chlorine to water to destroy the combined inorganic chlorine present. Normally, the amount added is equal to ten times or more the combined chlorine concentration.

Bromamines: Bromine-ammonia compounds exhibiting sanitizing properties similar to hypobromous acid.

Bromide: A salt that contains a bromide (Br^-) ion. Bromide becomes hypobromous acid when it reacts with oxidizers such as chlorine, ozone, or persulfates.

Bromine : *See BCDMH, DBDMH, Bromide and Bromine Generators.*

Bromine Feeder: A device to add or deliver bromine sanitizer at a controlled rate.

Bromine Generator: See *Electrolytic Chlorine/Bromine Generator*.

Buffer: Chemical that when dissolved in water will resist pH change. (See total alkalinity.) Also a chemical solution used to calibrate pH instrument.

Calcification: Formation of calcium carbonate on walls of pools or pipes, or in a filter or heater, due to low solubility of calcium salts.

Calcium Carbonate ($CaCO_3$): An insoluble calcium compound that is the major component of scale. $CaCO_3$ occurs normally in limestone, marble, various eggshells, seashells, etc.

Calcium Chloride ($CaCl_2$): A soluble white salt used to raise the calcium hardness of pool and spa water.

Calcium Hardness: A measure of the amount of calcium dissolved in water and expressed in parts per million (ppm) or milligrams per liter (mg/L) as calcium carbonate.

Calcium Hardness Factor (CF): Used to calculate the saturation index of water.

Calcium Hypochlorite ($Ca(OCl)_2$): A solid white form of chlorine found in both granular and tablet forms (65% - 78% available chlorine).

Carbon Dioxide (CO_2): Common gas found in air. Can be used to lower pH in a pool.

Caustic Soda (**NaOH**)**:** Sometimes called caustic sodium hydroxide or lye. A highly alkaline substance sometimes used to raise pH.

Caution: See *Signal Word.*

CF: See *Calcium Hardness Factor*.

CFU (colony forming units): Used to express the concentration of microorganisms per unit of volume, most often as CFU per ml of bacteria in water.

Chelating Agent: A chemical used to bind (sequester) metals dissolved in water, to prevent them from precipitating and staining pool surfaces. CHELANT.

Chemical Feeder: A device (floating or mechanical) for adding a chemical to pool or spa water.

Chemical Feeder Output Rate: Amount of chemical or active ingredient delivered by a feeder per unit time (for example, pounds of chlorine per hour). One pound per hour is equivalent to 0.45 kilograms per hour.

Chloramines: They are formed when free chlorine combines with nitrogen-containing compounds (for example: perspiration, ammonia). These compounds can cause eye and skin irritation, have strong objectionable chlorine-type odors, and low sanitizing capability. COMBINED CHLORINE.

Chlorinated Isocyanurates (**ISOS**)**:** Sanitizer products that are self-stabilizing due to release of free available chlorine and cyanuric acid when they dissolve. *See Sodium Dichlor and Trichloro-Isocyanurate.*

Chlorinator: A device to add or deliver a chlorine sanitizer at a controllable rate.

Chlorine: See *Calcium Hypochlorite, Sodium Dichlor,Chlorinated Isocyanurates, Sodium Hypochlorite,* and *Trichloro-Iso-Cyanurate.*

Chlorine Demand: The amount of chlorine that will be consumed by readily oxidizable impurities in pool or spa water.

Chlorine Gas (Cl_2): A gaseous form of chlorine used to sanitize pools and spas; contains 100% available chlorine.

Chlorine Generator: See *Electrolytic Chlorine/Bromine Generator.*

Chlorine Neutralizer: A chemical used to reduce chlorine residuals. *See Sodium Thiosulfate.*

Chlorine Residual: See *Residual.*

Circulation System: The mechanical components that are a part of a re-circulation system on a pool or spa. Circulation equipment may be, but is not limited to, categories of pumps, hair and lint strainers, filters, valves, gauges, meters, heaters, surface skimmers, inlet/outlet fittings, and chemical feeding devices. The components have separate functions, but when connected to each other by piping, perform as a coordinated system for purposes of maintaining pool or spa water in a clear and sanitary condition.

Clarifier: A chemical that causes fine suspended solids in water to combine into filterable clusters. See *Flocculant.*

Clarity: The degree of transparency of pool water. Characterized by the ease with which an object can be seen through a given depth of water.

Coliform Bacteria: Bacteria found in the intestines and fecal matter of warm-blooded animals. The detection of coliforms is used to indicate the possibility of disease-causing bacteria.

Combined Chlorine: COMBINED AVAILABLE CHLORINE. See *Chloramines*.

Commercial/Public Pool: Any pool, other than a residential pool, that is intended to be used for swimming or bathing and is operated by an owner, lessee, operator, licensee, or concessionaire, regardless of whether a fee is charged for use. (Refer to ANSI/NSPI-1 2003, *Standard for public swimming pools*).

Commercial/public pools shall be further classified and defined as follows:

Class A, Competition Pool: Any pool intended for use for accredited competitive aquatic events such as La Federation Internationale De Natation Amateur (FINA), U.S. Swimming, U.S. Diving, National Collegiate Athletic Association (NCAA), National Federation of State High School Associations (NFSHSA), etc. The use of the pool is not limited to competitive events.

Class B, Public Pool: Any pool intended for public recreational use.

Class C, Semi-Public Pool: Any pool operated solely for and in conjunction with lodgings such as hotels, motels, apartments, condominiums, etc.

Class D, Other Pool: Any pool operated for medical treatment, therapy, exercise, lap swimming, recreational play, and other special purposes, including, but not limited to, wave or surf action pools, activity pools, splasher pools, kiddie pools, and play areas.

Class D-1, Wave Action Pools: Wave action pools include any pool designed to simulate breaking or cyclic waves for purposes of general play or surfing.

Class D-2, Activity Pools: Activity pools are those pools designed for casual water play ranging from simple splashing activity to the use of attractions placed in the pool for recreation.

Class D-3, Catch Pools: Catch pools are bodies of water located at the termination of a manufactured waterslide attraction provided for the purpose of terminating the slide action and providing a means for exit to a deck or walkway area.

Class D-4, Leisure Rivers: Manufactured streams of near-constant depth in which the water is moved by pumps or other means of propulsion to provide a river-like flow that transports bathers over a defined path that may include water features and play devices.

Class D-5, Vortex Pools: Circular pools equipped with a method of transporting water in the pool for the purpose of propelling riders at speeds dictated by the velocity of the moving stream.

Class D-6, Sand Bottom Pools: Pools that use sand as an interior floor finish over an impervious surface and are equipped to treat and filter the water in the sand areas to maintain a healthful sand condition.

Class D-7, Interactive Play Attractions: Manufactured devices using sprayed, jetted, or other water sources contacting the bathers and do not incorporate standing or captured water as part of the bather activity area.

Class D-8, Amusement Park Attractions: Manufactured features designed for bather interaction or incidental contact with static, splashing, or flowing water.

Class D-9, Natural Bodies of Water: Those natural or man-made aquatic play areas normally regarded as oceans, lakes, ponds, streams, quarries, or bodies of water that the local jurisdiction has designated as Natural Bodies of Water. (The design or construction of these facilities is not included in the scope of ANSI/IAF standards.)

Class E: Pools used for instruction, play or therapy and with temperatures above 86° F.

Public pools may be diving or non-diving. If diving, they shall be further classified into types as an indication of the suitability of a pool for use with diving equipment.

Type VI-IX: Public pools suitable for the installation of diving equipment by type.

Type N: A non-diving public pool. (No diving allowed.)

Copper Sulfate ($CuSO_4$): A blue inorganic salt, sometimes used as an algicide. BLUESTONE.

Cyanuric Acid: A chemical that reduces the loss of chlorine in water due to the ultraviolet rays of the sun. STABILIZER, ISOCYANURIC ACID, CONDITIONER, TRIAZINETRIONE.

Danger: See *Signal Word.*

Dichlor: See *Sodium Dichlor*.

Diethylphenylene Diamine (**DPD**)**:** A chemical testing reagent that measures bromine or free available and total chlorine; produces a series of colors from pale pink to dark red.

Dry Acid (**$NaHSO_4$**)**:** See *Sodium Bisulfate*.

Effluent: The outflow of water from a filter, pump, or pool.

Electrolytic Chlorinator: See *Electrolytic Chlorine/Bromine Generator*.

Electrolytic Chlorine/Bromine Generator: An electrolytic device used to generate free available chlorine or total bromine from either chloride or bromide salts.

EPA-Registered Product: A product bearing the EPA stamp indicating that it meets EPA standards for efficacy, human health and safety, environmental impact, use instructions, and product labeling. All products that claim to kill or control bacteria, algae, etc., are required to be registered.

Erosion Feeder: A device that dispenses a sanitizer by directing a flow of water past tablets, briquettes, or pellets.

Etching: Corrosion on the surface; the pitting or eating away of a material such as the surface of plaster.

Evaporation: Conversion of liquid molecules into vapor.

Fecal Streptococci: The fecal streptococcus group of microorganisms includes, but is not limited to, the organisms S. faecalis, and S. faecium, which inhabit the gastrointestinal tract of warm blooded animals. These organisms are indicators of contamination in water. The ingestion of the fecal streptococci can cause illness.

Ferric Iron ($Fe+^3$ or Iron III): Generally insoluble in water, commonly precipitating as rust.

Ferrous Iron ($Fe+^2$ or Iron II): Found in groundwater. It is soluble in water and will generally impart a pale green color. In the presence of oxidizers, it will convert to Iron III.

Filter: A vessel that removes undissolved particles from water by recirculating the water through a porous substance (a filter medium or elements).

Cartridge Filter: A filter that utilizes a porous element that acts as a filter medium.

Diatomaceous Earth Filter: A filter that utilizes a thin coating of diatomaceous earth (DE) or other filter aid over a porous fabric as its filter medium.

Permanent Medium Filter: A filter that utilizes a filter medium (sand).

Filter Aid: Usually refers to powder-like substances such as diatomaceous earth or volcanic ash used to coat a septum type filter. Also used as an aid to sand filters. Finely divided medium (diatomaceous earth, processed perlite, etc.) used to coat a septum of a diatomite-type filter.

Filter Cartridge: A filtering element, usually of fibrous material.

Filter Cycle: The operating time between cleaning or backwash cycles.

Filter Element: A device within a filter tank designed to entrap solids and conduct water to a manifold, collection header, pipe, or similar conduit and return it to the pool, spa, or hot tub. A filter element usually consists of a septum and septum support, or a cartridge.

Filter Medium: A finely graded material (such as sand, diatomaceous earth, polyester fabric, anthracite, etc.) that removes solid particles from the water.

Filter Sand: A hard silica-like material free of carbonates or other foreign material used in sand filters as the media.

Filtration: The process of removing undissolved particles from water by recirculating the water through a porous substance (a filter medium or elements).

Flocculant (floc): A chemical that causes fine suspended solids in water to combine into large clusters that settle out.

Flow: The rate of the movement of water, typically in gallons per minute. One U.S. gallon per minute is equivalent to 3.79 liters per minute.

Free Available Chlorine: That portion of the total chlorine that is not combined chlorine and is available as a sanitizer.

Gallonage: A specific quantity of fluid in terms of gallons. One U.S. gallon is equivalent to 3.79 liters.

Galvanic Action: The creation of electrical current by the process of electro-chemical action of dissimilar metals in a liquid.

Galvanic Corrosion: The deterioration of metal produced when two dissimilar metals are exposed to the electrical current produced by electrochemical action.

GPD: Gallons per day. One U.S. gallon per day is equivalent to 3.79 liters per day.

GPH: Gallons per hour. One U.S. gallon per hour is equivalent to 3.79 liters per hour.

GPM: Gallons per minute. One U.S. gallon per minute is equivalent to 3.79 liters per minute.

Gunite: A pneumatically applied (sprayed) concrete that is a dry mixture of cement, aggregate, and/or sand. Water is applied to the mix at the hose nozzle.

Halogen: Any of the family of chemical elements including fluorine, chlorine, bromine, and iodine. Chlorine and bromine are commonly used as sanitizers or oxidizers in recreational water.

Hardness: The amount of calcium and magnesium dissolved in water; measured by a test kit and expressed as parts per million (ppm) of equivalent calcium carbonate.

Hazard: A condition or set of circumstances that has the potential of causing or contributing to injury or death.

Heat Exchanger: A device with coils, tubes, and plates that takes heat from any liquid, or air, and transfers that heat to another fluid without intermixing the fluids.

Hot Tub/Spa: A warm water reservoir with hydromassage jets that are manufactured from prefabricated materials at a factory. Hot tubs/spas may be "self-contained," or "non-self-contained." (Refer to ANSI/NSPI-6 1999, *Standard for portable spas*.)

> *Self-Contained Hot Tub/Spa*: A hot tub/spa that has a cabinet that houses the controls, the pump, heater, and filter. Most "portable hot tubs/spas" are made of an acrylic thermoplastic shell and are surrounded by a cabinet made of wood, alternative wood, or thermoplastic. A "self-contained hot tub/spa" can be moved to another location and reinstalled. A "self-contained hot tub/spa" has all control, water heating and water circulating equipment as an integral part of the product. A "self-contained hot tub/spa" may be permanently wired or cord connected. Also known as a "portable hot tub/spa."
>
> *Non-Self-Contained Hot Tub/Spa:* A hot tub/spa that is made of an acrylic or thermoplastic shell molded at the factory to comfortably fit the body's contours. A "non-self-contained hot tub/spa" does not

have water heating and circulating equipment as an integral part of the product. "Non-self-contained hot tubs/spas" may employ separate components such as an individual filter, pump, heater and controls, or they may employ assembled combinations of various components.

Hydrochloric Acid (HCl): Also called muriatic acid when diluted. A very strong acid used in pools or spas for pH control and for certain specific cleaning needs. A by-product of the addition of chlorine gas to water. Use extreme caution in handling.

Hypochlorous Acid (HOCl): Formed when any chlorinating product is dissolved in water. This is the most active sanitizing form of chlorine. Its dissociation in water into H^+ and OCl^- is pH dependent.

Hydrogen Peroxide (H_2O_2): Compound consisting of hydrogen and oxygen supplied in an aqueous solution, used as an oxidizer. Will neutralize halogen sanitizer in water.

Hypobromous Acid (HOBr): A chemical compound that acts as a sanitizer and algicide in water.

Hypochlorinator: A chemical feeder through which liquid solutions of chlorine-bearing chemicals are fed into the pool water at a controlled rate. See *Chlorinator*.

Hypochlorite: A family of chemical compounds including calcium hypochlorite, lithium hypochlorite, sodium hypochlorite, etc., found in various forms for use as a chlorine carrier in pool/spa water.

Hypochlorite Ion (OCl^-): The anion from ionization of hypochlorous acid.

Hypochlorous Acid (HOCl): A chemical compound that acts as an algicide. The most powerful sanitizer of chlorine in water.

Influent: The water entering a filter or other device.

Iodine (I_2): A chemical element that exists as a grayish-black granule in its normal state or as a part of a chemical compound that is a biocidal agent.

Ionization: The process whereby a compound in solution separates into positive ions (cations) and negative ions (anions).

Ionizer: A device that electro-chemically generates metal ions such as silver and/or copper ions from anodes of these metals.

Iron: See *Ferric Iron* and *Ferrous Iron*.

Isocyanurates: See *Chlorinated Isocyanurates*.

Langelier Index: A numerical calculation, based on the Langelier water balance equation, that indicates whether the water may be corrosive or scale forming. See *Saturation Index*.

Leaching: The extracting of a soluble substance from some material, commonly tannic acid from redwood or cedar in hot tubs or a mineral extracted from plaster.

Liquid Acid (HCl): Chemical used to lower pH and total alkalinity, most commonly muriatic acid.

Liquid Chlorine: See *Sodium Hypochlorite*.

Lithium Hypochlorite (LiOCl): A white solid used as a sanitizer and oxidizer in pools and spas that has a pH of approximately 9 and that typically contains 35% available chlorine.

Magnesium Hardness: A measure of the amount of magnesium dissolved in water and expressed in parts per million (ppm) or milligrams per liter (mg/L) as calcium carbonate.

Main Drain: An outlet located at the bottom of a pool or spa to conduct water to the recirculating pump.

Make-Up Water: Water used to fill or refill a pool/spa. SOURCE WATER.

Micron: One millionth of a meter. Used to describe the size of particles that filters are capable of trapping.

Microorganism: A microscopic plant or animal life. Usually refers to bacteria, protozoa, and algae in the water.

Muriatic Acid (HCl): A commercial name for hydrochloric acid.

National Sanitation Foundation (NSF International): An independent, nonprofit organization of scientists, engineers, educators, and others engaged in research and testing and in the development of standards in selected public health and environmental areas.

Natural Gas: Admixture of gaseous hydrocarbons, chiefly methane, occurring naturally under-ground, often in association with petroleum products.

Nitrogen (N_2): An element present in ammonia, sweat, urine, fertilizers, and a variety of personal care products and environmental sources. When inadvertently introduced into pools or spas it readily reacts with chlorine to form chloramines.

Non-Toxic: Generally having no adverse physiological effect on human beings or other living organisms.

Organic Matter: Carbon-based substances, generally originating from living organisms, often introduced to pools or spas by bathers and the environment. For example, perspiration, urine, saliva, suntan oil, cosmetics, lotions, and dead skin.

Organisms: Plant or animal life. Usually refers to algae or bacteria-like growth in pool water.

ORP: See *Oxidation Reduction Potential.*

Orthotolidine (**OTO**)**:** A colorless reagent that reacts with chlorine or bromine to produce yellow-to-orange colors that indicate the amount of total chlorine or bromine in water. OTO measures total chlorine. Because OTO is a suspected carcinogen and very acidic, use caution when handling this chemical.

Oxidation-Reduction Potential (ORP): A measure of the oxidation-reduction potential of chemicals in water. It is generally measured in millivolts by means of an electronic meter and depends upon the types and concentrations of oxidizing and reducing chemicals in the water.

Oxidizers: Products used to destroy organic and inorganic contaminants in water.

Ozone (O_3): A gaseous molecule composed of three (3) atoms of oxygen that is generated on site and used for oxidation of water contaminants. It can also be used to regenerate bromine from bromide ions and as a supplemental contact sanitizer in conjunction with an EPA-registered sanitizer that provides a constant residual.

Ozone Contact Concentration: The amount of ozone that is dissolved in pool/spa water.

Ozone Generator: A device that produces ozone, generally exposing oxygen or air to corona discharge or ultraviolet light.

Ozone, **Low Output Generating Equipment (Ozonator):** Refers to units that will produce ozone in air at a concentration less than 500 ppm. Usually this term will refer to ultraviolet (UV) generators.

Parts Per Million (PPM): The unit of measurement used in chemical testing that indicates the parts by weight in relation to one million parts by weight of water. It is essentially identical to the term milligrams per liter (mg/L) in pool water.

Pathogens: Disease-causing microorganisms.

Pathological Agents: Toxins, microbes, etc. capable of causing diseases.

Permanently Installed Swimming Pool*:* A pool that is constructed in the ground or in a building in such a manner that it cannot be readily disassembled for storage.

pH: A value used to express acidity of a substance. Expressed as a number on a scale of 0 to 14, with 7.0 being neutral; values less than 7.0 are acidic and values greater than 7.0 are basic.

Phenol Red: A pH indicator used in water analysis in the range between 6.8 and 8.4 The color changes from yellow to red to purple as pH increases.

pH Meter: An electronic device that measures pH by means of a pH electrode immersed in the water to be tested.

Pool: A body of water contained in a reservoir used for recreational purposes. See *Residential Pool.* See *Commercial/Public Pool.*

Pool User: Any person using a pool and adjoining deck area for the purpose of water activities or other related activities.

Potable Water: Water that is safe and satisfactory for drinking.

Potassium Monopersulfate ($KHSO_5$): A solid oxidizer used to prevent the build-up of contaminants in pool and spa water. POTASSIUM PEROXYMONOSULFATE.

Precipitate: A substance separating out in the form of solid particles from a liquid. A result of a chemical or physical change that settles out or remains as a haze in suspension (turbidity).

Public Pool: See *Commercial/Public Pool*.

Pump: A mechanical device, usually powered by an electric motor, that causes hydraulic flow and pressure for the purpose of filtration, heating, and circulation of the pool or spa water. Typically, a centrifugal pump design is used for pools, spas, or hot tubs.

Quaternary Ammonium (QUAT): Organic compound of ammonia used as an algistat and an algicide.

Reagents: The chemical used to test various aspects of water quality.

Recirculation System: See *Circulation System.*

Residual: The measurable sanitizer present in water.

Risk: The possibility of suffering harm or loss.

Salinity: The salt content of water.

Sand Filter: A filter using sand or sand and gravel as a filter medium.

Saturation Index: A number that indicates whether water will have a tendency to deposit calcium carbonate from a solution, or whether it will be potentially corrosive. Five factors are used in the computation: pH, total alkalinity, calcium hardness, temperature, and TDS. When correctly balanced, the water will be neither scale-forming nor corrosive.

Scale: The precipitate that forms on surfaces in contact with water when the calcium hardness, pH, or total alkalinity levels are too high.

Sequestering Agent: A chemical that combines with metals keeping them in solution and preventing them from depositing on and staining pool surfaces. Some sequestering agents are chelating agents.

Shock: Product used to treat microbial infestations as well as destroy non-living organic and inorganic contaminants in water. Because shock products are used to kill bacteria and algae, they must be registered by EPA. *See EPA Registered Product.*

Shock-oxidizer: Product used to destroy non-living organic and inorganic contaminants in water. This product is neither a sanitizer nor algicide. For control of microorganisms in pool, spa, or hot tub water, or algae control, use an EPA registered product.

Shock Treatment: The practice of adding a shock product to the water.

Shock-Oxidizer Treatment: The practice of adding a shock-oxidizer product to the water.

Signal Word: A visual alerting device in the form of a decal or label placard or other marking such as an embossing, stamping, etching, or other process that advises the observer of the nature and degree of the potential hazard(s) that can cause property damage, injury, or death. It can also provide safety precautions or evasive actions to take, or provide other directions to eliminate or reduce the hazard. Aquatic safety signage shall conform to specifications as described in the ANSI Z-535 series of standards on product safety signs and labels.

Signal word: to convey the gravity of the risk

Consequences: what are likely to happen if the warning is not heeded

Instructions: appropriate behavior to reduce or eliminate the hazard

> *CAUTION:* Indicates a potentially hazardous situation that, if not avoided, could result in minor or moderate injury. It may also be used to alert against unsafe practices.
>
> *DANGER:* Danger indicates an imminently hazardous situation that, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.
>
> *WARNING:* Warning indicates a potentially hazardous situation that, if not avoided, could result in death or serious injury.

Skimmer: A device installed in the pool or spa that permits the removal of floating debris and surface water to the filter.

Skimmer Weir: Part of a skimmer that adjusts automatically to small changes in water level to ensure a continuous flow of water to the skimmer.

Soda Ash: See *Sodium Carbonate*.

Sodium Bicarbonate (**$NaHCO_3$**)**:** Also baking soda or sodium hydrogen carbonate. A white powder (pH = 8.3) used to raise total alkalinity in water.

Sodium Bisulfate (**$NaHSO_4$**)**:** Also known as dry acid. A granule used to lower pH and/or total alkalinity in water.

Sodium Carbonate (**Na_2CO_3**)**:** A white powder used to raise pH of the water.

Sodium Dichlor (Sodium Dichloro-Isocyanurate) ($C_3N_3O_3Cl_2Na$): Contains between 56% and 64% available chlorine. Sanitizer product that is self-stabilizing due to release of free available chlorine and cyanuric acid when they dissolves. SODIUM DICHLORO-S-TRIAZINETRIONE.

Sodium Hypochlorite (**NaCl**)**:** A clear liquid form of an inorganic chlorine compound obtainable in concentrations of 5% to 16% available chlorine. LIQUID CHLORINE, BLEACH.

Sodium Thiosulfate ($Na_2S_2O_3$): A chemical used to neutralize chlorine.

Soft Water: Water that has a low calcium and magnesium content.

Spa: A product intended for the immersion of persons in heated water circulated in a closed system, and not intended to be drained and filled with each use. A spa usually includes a filter, a heater (electric, solar, or gas), a pump or pumps, and a control, and may include other equipment, such as lights, blowers, and water sanitizing equipment.

> **Public Spa -** Any spa other than a permanent residential spa or residential portable spa which is intended to be used for bathing and is operated by an owner, licensee, concessionaire, regardless of whether a fee is charged for use. (Refer to ANSI/NSPI-2 1999 Standard for Public Spas.)
>
> charged for use. (Refer to ANSI/NSPI-2 1999, *Standard for public spas*.)

Spalling (Concrete or Plaster): The separation of the top layer of cement-rich material, exposing the underlying aggregate layer.

Spa User: Any person using a spa and adjoining deck area for the purpose of water activity or other related activity.

Special Purpose Pool*:* A pool intended to be used exclusively for a specific activity, such as instruction diving, competition, or medical treatment.

Splash Pool: A pool having a water depth not exceeding 18 inches (18") (0.46 meters) that has as its intended primary use random play by small children. The pool could include constructed play devices including small flume type water slides and other play devices. CHILDREN'S ACTIVITY POOL. See *Catch Pool*.

Splasher (Wader) Pools: A splasher pool shall have a maximum water depth of thirty-six inches (36") (0.91 meters). These pools are not intended to be covered within the scope of IAF standards.

Stabilizer: See *Cyanuric Acid*.

Superchlorination: The practice of adding a sufficient amount of a chlorinating compound to reduce cloudy water, slime formation, musty odors, algae and bacteria counts, and/or improve the ability to maintain sanitizer residuals.

Surface Skimming System: A device or system installed in the pool/spa that permits the removal of floating debris and surface water to the filter.

Swimmer Load: See *Bather Load*.

Swimming Area: Area of pool in excess of three feet (3') (0.91 meters) in depth that is devoted to swimming.

Temperature Factor (TF): Used when determining the saturation index.

Test Kit: Equipment used to determine specific chemical residual and physical properties of water.

Titration: A method for measuring alkalinity, hardness, available chlorine or other such chemical parameters by measured addition of reagents that yield a foreseeable end point as indicated by a change in color.

Total Alkalinity: A measure of the pH buffering capacity of water. Alkalinity is generally expressed in terms of the equivalent concentration of calcium carbonate in mg/L (or ppm).

Total Alkalinity (TA) Factor: Used when determining the saturation index.

Total Chlorine: The sum of both the free available and combined chlorines.

Total Dissolved Solids (TDS): The measure of the total amount of dissolved matter in water.

Toxic: A substance having an adverse physiological effect on human beings or other living organisms.

Trichloro: A form of organic chlorine, most commonly found in compressed form (tablets or sticks). See Trichloro-Iso-Cyanurate.

Trichloro-Iso-Cyanurate ($C_3N_3O_3Cl_3$): Sanitizer product that is self-stabilizing due to release of free available chlorine and cyanuric acid when it dissolves. A form of organic chlorine that reacts with water to form 90% available chlorine and cyanuric acid. TRICHLORO-S-TRIAZINETRIONE. See *Chlorinated Isocyanurates.*

Turbidity: Cloudy condition of water due to the presence of extremely fine particulate materials in suspension that interfere with the passage of light.

Turnover Rate: The period of time (usually in hours) required to circulate a volume of water equal to the pool or spa capacity.

Ultra-Violet Light: A component of sunlight and can be generated artificially. Ultra-violet light stimulates many types of organic molecules to become chemically reactive and can decompose a variety of chemical species. UV light-generating devices may be used as a supplemental sanitizer to inactivate microorganisms. UV light is often characterized as UV-A, UV-B, or UV-C, indicating wave lengths of 315 – 400 nanometers (nm), 290 – 315 nm, and 220 – 290 nm, respectively.

User: Any person engaging in water activities or related activities at a pool, spa, or hot tub, including the adjoining deck.

User Load: The total number of persons permitted in the pool/spa complex at any given time. See *Bather Load*.

Volume: The capacity of a specified container (e.g., a pool or spa) expressed in gallons or liters. One U.S. gallon is equivalent to 3.79 liters.

Wading Pool: A pool that has a shallow depth used for wading.

Warning: See *Signal Word.*

Weir: See *Skimmer Weir.*

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