Section 6: Pool Water Quality Management

Rationale:

Essential components of effective pool water management include water source, managing pool water clarity to minimize injury hazard, managing water quality to prevent the transmission of infectious disease, and managing potential hazards from disinfection by-products that can be found in the water and air.[58] These challenges can be met through a combination of the following factors:

- treatment to remove particulates, pollutants, and microorganisms including filtration and disinfection to remove/inactivate infectious microorganisms
- pool hydraulics to ensure effective distribution of disinfectant throughout the pool, good mixing, and removal of contaminated water
- frequent addition of fresh water to dilute substances that cannot be removed from the water by treatment
- cleaning to remove biofilms from surfaces, sediments from the pool floor, and particulates adsorbed to filter materials
- ventilation of indoor pools to remove volatile disinfection by-products and radon[59]
- education and encouraging good patron hygiene

[58] WHO.(2006). Guidelines for safe recreational waters. Retrieved February 2011, from WHO Water Sanitation and Health: http://www.who.int/water_sanitation_health/bathing/srwe2chap5.pdf

[59] http://www.who.int/water_sanitation_health/bathing/srwe2chap5.pdf p. 80

Section 6: Pool Water Quality Management

6.1 Water source – source water

Rationale:
Water used in an aquatic facility includes drinking water, pool fill water, make-up water, and pool waste water. Each water system can contribute to the health safety of employees and patrons.

Recommendations:

- Drinking water: Any water supply serving the pool and used for drinking water and other purposes shall be potable and meet the requirements of the latest edition of the Canadian Drinking Water Guidelines for bacteriological and chemical quality. This includes water provided at plumbing fixtures used for drinking, cooking, dishwashing, hand washing, and showering as well as the pool water. Once the water is in the pool and the recirculation system, it is no longer potable and should not be ingested.
- Backflow protection: All portions of the potable water supply system serving the pool(s) and auxiliary facilities shall be protected from backflow with a backflow prevention device.
- Fill/make-up water:
  - shall be tested for water quality as part of the Aquatic Safety Plan to ensure effective overall water treatment and to ensure fill water does not contribute to pool water contamination (e.g., some municipal water treatment use chloromated chlorine, which increases the level of chloramines in the pool water and affect water quality and air quality).
  - shall be from a potable water supply.

6.2 Water Replacement / Make-Up Water [60,61]

Rationale:
Water loss is common at aquatic venues due to evaporation, user splash out, plumbing, shell leaks, and planned dilution (adding fresh water to decrease the concentration of disinfection by-products not removed by the water treatment system). Planned dilution also helps control levels of total dissolved solids and other chemical used in pools (e.g., cyanuric acid).

Recommendations:
Calculating how much and how often pool water replacement shall occur during the aquatic safety planning stage involves, at a minimum

- removal of water from the pool and replacement with make-up water will occur as needed to maintain water quality
- recommended use of a dilution rate of 30 litres of fresh water per bather to decrease the concentration of bather-generated contaminants [WHO 2006]
- daily recording of water replacement rates shall be part of record keeping
- make-up water (fresh water) shall be from an uncontaminated potable water supply

(See also Section 5.1, Aquatic Play Feature General Recommendations)

[60] Toronto Public Health Swimming Pool Operator's Manual p 14
[61] WHO.(2006). Guidelines for safe recreational waters. Retrieved February 2011, from WHO Water Sanitation and Health: http://www.who.int/water_sanitation_health/bathing/srwe2chap5.pdf?ua=1 p 12

6.2.1 Spa water replacement

Rationale:
Spas, hot tubs, and therapeutic spas have higher contamination loads due to lower volume of water per patron (bather) and higher water temperatures. Both these factors increase disinfection use and contribute to the challenge of maintaining clean water. Complete water replacement, cleaning, scrubbing, and inspection prior to refilling are effective operational tools to prevent recreational water-related illnesses in these settings.

Recommendations: [62]
For spa water volumes exceeding 4000 litres

- 30 litres/day of water shall be replaced per bather to a maximum of 20% of total spa water volume

For spa water volume less than 4000 litres

- drain the water to waste and refill to the total volume of water in the public spa when[63]
  - total dissolved solids (TDS) have increased to 1500 ppm greater than TDS at spa start-up (start-up TDS includes source water TDS and any other inorganic salt added at start-up)
  - water replacement interval (WRI) is less than or equal to the number of days from the last replacement, calculated as WRI = V ÷ 10 x U
    WRI = maximum number of operating days between drainings, rounded up to a whole number
    V = total volume of the spa in litres
    U = total estimated number of bather uses per operating day

Prior to refilling of spa pools the following shall be performed along with any other identified operational procedures identified in the Aquatic Safety Plan:

- inspection of all parts including, but not limited to, drain covers, suction fittings, and all emergency equipment to ensure they are properly secured and operational according to standards and the manufacturer's operational instructions
- inspection of surfaces for biofilm, and the cleaning and scrubbing of all surfaces

6.3 Overflow Water/ Backwash Water

- Overflow water shall return to the filter system or shall be discharged to a sewer system approved by Nova Scotia Environment. Where overflow gutter water discharges into a sanitary sewer, a suitable air gap of not less than the diameter of the drainpipe shall be provided to create a gravity drip into the sewer without direct mechanical connection.
- Backwash water shall be discharged into a sanitary sewer with an approved gap or by other means advised by NSE.

[62] Toronto Public Health Swimming Pool Operator's Manual
[63] ANSI/APSP 11 2009 p. 4

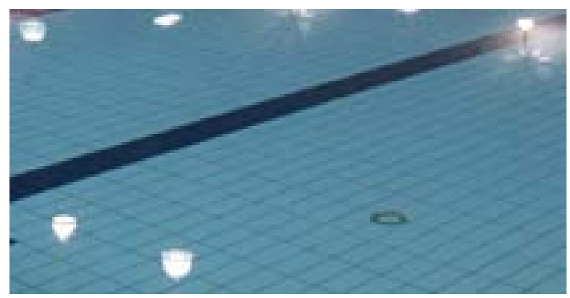
6.4 Water Clarity (Turbidity)

Rationale:
Poor water clarity in a pool can be a significant health hazard. When the water clarity is so poor as to obscure view of swimmers under the water or the bottom of the pool, immediate closure of the pool is required. Excessive turbidity can hinder lifeguard visibility of patrons who may be in distress under the water and interfere with patrons' visibility of other swimmers, the pool walls, and floor, which could result in impact injury and even death.

Poor water clarity indicates high turbidity. Turbidity is a measure of the density of particles suspended in water. High numbers of suspended particles (>1,000,000/mL) reduces water clarity (i.e., the water appears cloudy, green-coloured, or dull). High turbidity (poor clarity) usually results from

- poor water circulation and filtration
- poor operation, leading to build-up of algae and environmental dirt
- poor water balance (high pH, high total alkalinity, or high calcium hardness)
- no or ineffective disinfection/oxidation
- improper product addition
- improper ventilation

Poor water clarity

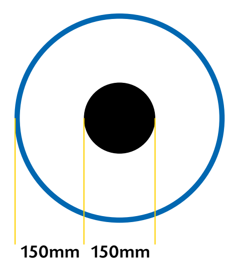


Good water clarity

Recommendations: [64, 65]

1. Maintain effective pool clarity

- The aquatic venue bottom shall be visible at all times.
- The bottom drain (at the deepest part of the pool) shall be clearly visible from the lifeguard stand and from the side of the pool at all times.
- Water shall pass the black disc test.
  - A black disc measuring 150 millimetres in diameter on a 450 mm white background is affixed to the bottom of the pool at the deepest point and shall be clearly visible from any point on the deck nine metres away from the disc.



Hint: The black colour will turn to grey as the water becomes cloudy.

[64] Adapted with permission from Toronto Public Health, Pool Guidelines
[65] ANSI/apsp-11 2009 p. 3

Spas/Hot Tub Clarity
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).[66]

2. Establish preventative and troubleshooting policies
An Aquatic Safety Plan shall

- include operational procedures to prevent, identify, and rectify high turbidity (low visibility) that shall include
  - effective water quality management
  - effective filtration and water circulation
- identify when to backwash filters, change filter mediums, and ensure the filtration and circulation systems operate 24 hours a day
- identify chemicals that can be used to assist in turbidity prevention and reduction (e.g., flocculants, clarifiers, ultraviolet, ozone, and monopersulfate use)
- include closure procedures and protocols
  - make sure a staff member with authority to close the pool when the pool fails the clarity test is on duty during all operation hours
  - implement and train staff on pool closure protocol

6.5 Pool Water Glare

Rationale:
Not all pools will experience a glare issue but glare can obstruct the ability of the patron and staff to see the bottom of the pool and therefore interfere with lifeguards' ability to see patrons in distress. It will interfere with the pool operator from seeing the early signs of algae growth and it also may prevent the patron from seeing the bottom of the pool, leading to impact injuries.

Recommendations:
- Windows and lighting equipment shall be adjusted to minimize glare and excessive reflection on the pool water surface.
- In lifeguarded facilities, the operator shall assess glare conditions frequently during operating hours to ensure the bottom and objects in the pool are visible. The operator may consider adjusting guard positions to improve visibility as a result of glare interference.
- The operator shall supply lifeguards with polarized sunglasses while conducting patron surveillance when it is necessary to reduce glare. (See also Section 8.2, Aquatic Facilities with Supervision and Lifeguards.)

[66] ANSI/apsp-11 2009 p. 4

6.6 Disinfection of Pool Water

Rationale:
"Strictly, disinfection means removing the risk of infection, and is achieved primarily by maintaining the correct concentration of disinfectant in the water. Primary disinfection means a treatment that will kill bacteria, viruses, parasites and provide a residual. Secondary disinfection (UV or ozone) increases the kill of infectious organisms, especially Cryptosporidium and is recommended for increased risk venues; Oxidation by disinfectants and non-chlorine oxidizers breaks down soluble dirt and other organic contamination introduced by bathers." [67]

6.6.1 Primary disinfection

Choosing the type of primary disinfectant depends on pool design, pool type, chemical storage space, pool intended use, intended bather load, potential for increased contamination burden, source water quality, and how it will be introduced, maintained, and monitored, and if secondary disinfection will be utilized. A primary disinfectant shall have the ability to leave a measurable disinfectant residual.

The choice of primary disinfection shall carefully consider the range of source water parameters, as disinfection can be affected by other chemicals and contaminants.

6.6.1.1 Chlorine

Chlorine is the most common primary disinfectant used in the treatment of swimming pool/spa water. Chlorine exists as gas, solid, and liquid. Each has advantages and disadvantages in its use and different ways of introduction to the water, which also plays a role in the management of chlorine and its effectiveness.

The chemical reaction that occurs upon introduction of chlorine to pool water is important to understand to ensure proper water management and to reduce risk of recreational water illness.

When chlorine is added to pool water, some of the chlorine reacts with organic materials and metals in the water, and will not be available for further disinfection. This is called the chlorine demand of the water. The remaining chlorine concentration is termed total chlorine.

$$TC = CC + FAC$$

Total chlorine (TC) consists of combined chlorine and free available chlorine (FAC; the chlorine available to inactivate disease-causing organisms).[68,69]

6.6.1.1.1 Testing and FAC Minimum Level Recommendations

Daily frequent monitoring and adjusting of chlorine residuals and other water parameters (pH) is necessary to ensure optimum chlorine effectiveness. (Table 5, next page).

[67] Pool Water Treatment Advisory Group (PWTAG), *Code of Practice The Management And Treatment Of Swimming Pool Water(2013)*, http://www.pwtag.org/documents/CodeofPractice1.13v5_000.pdf p 16
[68] http://www.cdc.gov/safewater/publications_pages/chlorineresidual.pdf
[69] http://www.ncceh.ca/en/professional_development/practice_questions/pool_chlorination

Table 5. FAC Minimum Level Recommendations [70]

Pool type	Free Available Chlorine	
	Un-stabilized	Stabilized or used with cyanuric acid (outdoor pools)
Public Pool (and play features)	1.0 mg/1 (ppm)	2.0 mg/1 (ppm)
Hot tub/Therapy/Spa	3.0 mg/1 (ppm)	Not recommended
*Hypochlorous acid is approximately 80 times more effective than the hypochlorite ion as a disinfectant. It is important to maintain the pH below 7.8 to avoid disease transmission.[71]		

*Effect of pH on Chlorine

- at pH 8.0, only 20% of the FAC is immediately available as hypochlorous acid thereby making any measurable free available chlorine (FAC) less effective
- at pH 7.5, about 50% of the FAC is immediately available as hypochlorous acid making the FAC more effective

6.6.1.1.2 Combined chlorine (CC; chloramines)[72]

Rationale:
CC forms when chlorine chemically bonds to material containing nitrogen including, but not limited to, urine (ammonia), dead algae, skin and sweat. This reduces the chlorine available for disinfection, which reduces disinfection power. CC can be determined using an appropriate test kit and utilizing this formula:

CC = TC – FAC.

High CC levels

Levels above 0.4 mg/L (ppm) can indicate that the bathing load or contaminant load (from swimmers) is high. High CC can cause complaints of a strong chlorine smell, eye and possible breathing irritation after exposure to pool water and air, particularly for indoor pools. These complaints are further exacerbated when water becomes agitated from patron activity, pool features (wave pools, spray features), or hot tubs as all of these by nature aerosolize the water and corresponding CC into the aquatic venue's air.[73] High levels of CC, poorly positioned air vents, and inadequately designed and maintained ventilation systems increase potential health effects and equipment corrosion.[74]

[70] The USA Centre for Disease and Prevention. (2014) Model Aquatic Health Code-First Edition The Code
[71] ANSI/APSP 11 – 2009 p. 8
[72] CDC's Healthy Swimming Recommendations and the MAHC; The WHO Guidelines for safe recreational water environments Vol 2, Swimming Pools and Similar Environments; NSW Ministry of Health Australia; The National Swimming Pool Foundation, Pool & Spa Operator Handbook
[73] World Aquatic Conference Session, International Conference on Swimming Pool & Spa, Rome 2013: Key Advances in Disinfection By-Products and Microbiology, *Laura Suppes, R.S., M.P.H.,*
[74] NIOSH. 2008. Health Hazard Investigate Report: Investigation of Employee Symptoms at an Indoor Waterpark, Mason, OH. Cincinnati, OH: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institutes for Occupational Safety and Health, NIOSH HETA No. 2007-0163-3062 http://www.cdc.gov/niosh/hhe/reports/pdfs/2007-0163-3062.pdf, ANSI/APSP 11 -2009 p. 4

CC and Ventilation

- The CC value found in water does not take into account how ventilation systems and air movement affect the chloramine levels in the air. An indoor pool with normal combined chlorine levels can have high air trichloramine levels if there is insufficient intake of fresh air. Conversely, an indoor pool (water) with relatively high combined chlorine levels can have normal air trichloramine levels if the ventilation system is highly efficient. Therefore, interpretation of combined chlorine results needs to take into account ventilation efficacy. Proper air movement and distribution are crucial in reducing chloramine concentrations and health effects.
- Chloramine compounds are heavier than air and are more likely to concentrate closer to the pool surface and deck level, and some airflow is required to move them towards an air return. Adequate airflow rates at deck and pool surfaces are necessary to move the contaminants from the pool to the return ducts so they can be exhausted from the building.

Combined Chlorine Reduction Recommendation[75]

Removing and/or reducing CC in pool water is an operational challenge. Pool operators and patrons must strive to reduce formation of CC in the water and from evaporating into the air. It is recommended to

- maintain CC below 0.4 ppm (mg/L) in pools
- test CC levels daily and maintain a record of results
- utilize techniques to reduce CC, such as
  - education of bathers on their role in pool contamination
  - utilization of tools like break point chlorination to reduce combined chlorine BPC = (CC-FC) x 10
  - UV technology to help degrade CC
  - ensuring a ventilation system is designed, positioned, and maintained to provide adequate withdrawal, and that dilution is good industry practice and meets at a minimum the Ashrae 62.1- 2007 standards for indoor pool ventilation. Note: This may not be possible for existing pools. These pools should at least have the ventilation system cleaned and evaluated. They should also consider poor ventilation as an obstacle for adding new pool features. (See also Section 6.13, Ventilation, Air Circulation, and Moisture Control.)

6.6.1.1.3 Effects of Cyanuric Acid on Chlorine[76]

Rationale:
Cyanuric acid is a weak acid that is marketed as a chlorine stabilizer for swimming pools exposed to natural UV light (outdoor pools). Other terms used by the pool supply industry are isocyanurates, conditioner, and CYA.

Cyanuric acid forms a weak bond with the free available chlorine in the pool water, effectively trapping the FAC from escaping and protecting it from the sun's UV rays. Properly managed, cyanuric acid reduces the amount of chlorine that needs to be added to maintain the minimum residual in an outdoor pool. In a small pool with a moderate bather load, cyanuric acid can significantly reduce the costs spent on chemical disinfectants.

[75] The Association of Pool and Spa Professionals, American National Standards for Water Quality in Public Pools and Spas, ANSI/APSP-11 2009

[76] Based on the CDC's Healthy Swimming Recommendations and the MAHC; The WHO Guidelines for safe recreational water environments vol 2, Swimming Pools and Similar Environments; NSW Ministry of Health Australia; The National Swimming Pool Foundation, Pool & Spa Operator Handbook

However, the temporary bonds cyanuric acid forms with the free chlorine may reduce the overall effectiveness of the FAC. The time required to kill bacteria in a pool can be significantly increased with the use of cyanuric acid and low levels of FAC. As the level of cyanuric acid rises in the pool water, the killing power of the FAC residual weakens. At above 50 ppm of cyanuric acid, the time it takes to kill bacteria in the water is longer compared to swimming pool water without cyanuric acid. As the level of cyanuric acid accumulates, the chlorine will become increasingly less effective in keeping the water clean and problems such as increased cloudiness in the pool water, and abundant growth of bacteria and algae, can occur.

- Unlike chlorine, cyanuric acid is never exhausted. Once added to the pool water, it remains. Adding more cyanuric acid will increase the level, not replace exhausted chemical.
- The best way to reduce cyanuric acid is to partially drain the pool and add fresh water.
- A pool shall be tested for cyanuric acid before any is added.
- Dichlor and trichlor are two solid chlorine compounds that are widely used as disinfectants in swimming pools. Both are often marketed as stabilized chlorine because they release cyanuric acid into the pool water. If either of these is used as the primary disinfectant then it may not be necessary to also add cyanuric acid to a pool. Testing levels is always the best policy to ensure sufficient, but not excess, quantity.

Recommendations:
- Cyanuric acid levels shall be tested at least once a week and before any additional cyanuric acid is added.
- Cyanuric acid levels shall not exceed 100 ppm, with the ideal concentration being 30-50 ppm.
- If levels rise above 100 ppm, a portion of the pool water shall be removed and fresh water added. There is no other means to reduce cyanuric acid levels in pools except by dilution with fresh water that contains no cyanuric acid.
- Pools that use cyanuric acid or stabilized chlorine shall at a minimum maintain a free chlorine residual of 2 ppm (mg/L).
- ORP readings decline as cyanuric acid levels increase, which reduces chlorine oxidation potential.
- Stabilized chlorine should not be used to hyper-chlorinate as it will raise cyanuric levels to unacceptable levels. (see the Diarrheal Release Response Recommendations Fact Sheet)
- Cyanuric acid should not be used with bromine or ozone.

6.6.1.2 Bromine Disinfection (Primary Disinfectant)[77]

A second form of primary disinfection is bromine. When bromine is dissolved in the water it produces hypobromous acid, a moderately powerful oxidizer and a good disinfectant. It is used more often in spas than pools due to the high contamination load and higher water temperatures found in spas (therapeutic pools and hot tubs). Bromine is more effective at higher pH values compared to chlorine. However, its use continually decreases pH and alkalinity levels, and bromine is not used with ozone or cyanuric acid. There is no known bromine stabilizer so this product is less effective in outdoor pools.

[77] National Swimming Pool Foundation (NSPF), Pool & Spa Operator Handbook (2011)

Table 6. Recommendations [78,79]

Pool type	Minimum bromine residual
Public swimming pool	3.0 mg/L (ppm)
Spa/Hot tub/Therapy pool	4 to 6.0 mg/L (ppm) High water temperature and heavy use may require operation at maximum levels[80]
With an N diethyl-p-phenylene test kit, the chlorine reading should be multiplied by 2.25 to obtain the bromine concentration.	

6.6.2 Secondary (supplemental) disinfection – Ultraviolet (UV) Light and Ozone

Secondary disinfection can be used in combination with the primary disinfection. In some instances, including increased risk venues (wading-toddler and therapeutic pools where accidental release is more common), it is highly recommended to use with primary disinfection.

Secondary disinfection is not a substitute for a residual disinfectant (primary disinfection) as it does not carry its disinfection properties into the pool.

6.6.2.1 UV light recommendation

- UV systems shall only operate while the recirculation system is operating.
- An operational manual is to be available onsite and staff shall be properly trained in the operation and maintenance of all equipment.
- UV systems shall be operated and maintained according to manufacturer's instructions.
- UV systems shall be designed and installed so lamps can be readily cleaned and maintained.
- UV systems shall be operated and maintained to meet or exceed the minimum validated output intensity needed to achieve the required dose for a 3-log inactivation of Cryptosporidium.
- UV sensors shall be calibrated at a frequency in accordance to the manufacturer's instructions and all calibration shall be maintained onsite.
- UV systems shall be operated not to exceed the maximum validated flow rate and shall meet no less than the minimum validated output intensity.

[78] The USA Centre for Disease and Prevention. (2014) Model Aquatic Health Code-First Edition The Code
[79] Toronto Public Health, Spa Operations Manual, p. 53
[80] ANSI/APSP 1 2009 p. 9

6.6.2.2 Ozone [81]

- An operational manual is to be available onsite and staff shall be properly trained in the operation and maintenance of all equipment.
- Ozone systems shall be operated and maintained according to manufacturer's instructions.
- Ozone is toxic at high concentration and an irritant at low concentrations. When used indoors, air monitoring devices shall be utilized and the ozone concentration in the air shall not exceed the 8-hour Time Weighted Average in any 8-hour work shift of a 40-hour work week.[82]
- Residual ozone concentration shall remain below a minimum of 0.1 ppm (mg/L)
- Ozone systems shall be operated and maintained to meet or exceed the minimum validated output intensity needed to achieve the required dose for a 3-log inactivation of Cryptosporidium.

6.6.3 Salt Water Generation Disinfection Systems

Rationale:
These are part of a new wave of disinfection delivery. These systems produce chlorine (sodium hypochlorite) onsite and it is used as a disinfectant for the pool water. Therefore water management and disinfectant parameter testing is the same as for chlorine.

Resource:
Salt water generators use a low voltage electric current to convert chloride salt in water into chlorine (sodium hypochlorite) via electrolysis. A timer or an automatic sensor and control system can control the operation of a salt chlorinator. Chlorinator output is related to the size or number of electrode plates. As this output is fixed, bather loads and chlorine consumption should be considered before installing the system.

Scaling of the electrode plate may occur if there is too much calcium hardness in the water. Electrodes require periodic cleaning with acid in accordance to manufacturer's directions. Cells will require replacing with age.

Recommendations:

- Use only pool grade salt.
- Maintain salt in the pool water at approximately 2500 ppm or as indicated by the manufacturer's instructions.
- Pool chemistry parameter levels like FAC, CC, and pH will have the same effect and require the same attention as a non-salt generated pool, and require the same frequency of testing.
- Fecal release remediation may require super or hyper chlorination with a secondary source of chlorine to allow a quick response to a fecal accident. This shall be clearly identified and outlined in the facility specific Aquatic Safety Plan.
- A warning device (visual and/or audible) shall be programmed to warn operators when the cell voltage is not working or not within the manufacturer's recommended range.
- An automatic shut-off mechanism shall be in place to shut off the chlorinator's electric power to the electrolytic cell in the event of[83]
  - loss of electric power
  - interruption in water flow through the cell

[81] The USA Centre for Disease and Prevention. (2014) Model Aquatic Health Code-First Edition The Code
[82] ANSI/APSP -11 2009 p. 2
[83] NSF/ANSI 50-2009a

6.6.4 Disinfection dosing (disinfection and chemical addition methods)[84,85]

Rationale:
How disinfectants and chemicals are added to the pool influences the disinfectant's effectiveness. Chemical dosing can occur pre- or post-filtration, and is dependent on the individual disinfectants and pool design. It is important to respond quickly to changes in disinfectant demand in busy pools. Automation allows this to be done with less effort and with more precision and has been proven to save money by reducing chemical costs.

Hand dosing or broadcasting delivers disinfectant (chemicals) to the pool water manually (by hand or by manually adding to an erosion feed system). It is not the recommended method to be used in "larger"pools due to several drawbacks that include, but are not limited to

- the potential for human error
- ineffective response times to an increase in disinfection demands
- increased worker safety risk

Hand dosing requires strong pool management of operations, training, and monitoring and shall not be done when patrons are in the pool or pool area.

Automatic dosing system is the preferred method of dosing as it will deliver disinfectant to the pool in a controlled continuous and steady rate in response to the disinfection demand. There are various forms of automatic dosing systems including systems that collect information via probes that feed the information back to a controller that automatically adjusts the dose rate of the continuous metered dosing system. In some cases it can also monitor pH and oxidation-reduction potential. Examples include salt water generators (see Section 6.6.3, Salt Water Generation Disinfection Systems), dry chemical feeders, or a pump that delivers liquid chlorine at a particular rate, or erosion feeders.

An automatic dosing system enables a quick and effective response to pool water disinfection and pH demands. It is intended to prevent the disinfectant residual to drop below the set level and prevents pH from moving out of the required range.

Recommendations:
- Swimming pools and spas shall have, or strive to have, automatic dosing equipment that meets NSF/ANSI Standard 50, to effectively manage pool water.
- A maintenance and inspection plan shall be developed and implemented as outlined in all the necessary equipment and chemical manufacturer's manuals and any engineering instructions.
- The system
  - shall operate 24 hours a day
  - ensures dosing pumps are in good working order and will automatically shut off when circulation system is turned off or if there is a failure (If chemical dosing continues with no water, a chemical build-up will occur that could result in a chlorine gas build-up that would be dangerous to the patrons and pool environment).
  - having automatic controllers shall be monitored by visual observation and as indicated in the manufacturer's instructions at the start of each operating day to ensure functioning
  - ensures chemical levels and equipment are routinely checked

[84] http://www.health.nsw.gov.au/environment/factsheets/Pages/disinfectant-dosing.aspx
[85] WHO, http://www.who.int/water_sanitation_health/bathing/srwe2chap5.pdf p87

- Hand dosing, broadcasting, or floating devices are not continuous-metered disinfectant dosing systems. An erosion feeder is not a continuous-metered disinfectant dosing system unless it can deliver the disinfectant at a constant continuous rate instead of at a diminishing rate.

6.7 Oxidation-Reduction Potential (ORP)[86]

ORP is the potential of a disinfectant to inactivate germs and oxidizing organic material.

- It senses the oxidation potential of the water (chlorine is a strong oxidizer, so ORP inadvertently measures the disinfectant's oxidation capability). It is not a replacement for testing FAC but can be an effective system to assist in water quality management.
- OPR does not measure disinfection level, such as FAC.
- ORP and disinfectant level do not have a linear relationship. Low free available chlorine level in a pool does not mean that the ORP will also be low.

The ORP measure is in millivolts using probes. The higher the millivolt reading, the more powerfully the swimming pool water is able to oxidize and disinfect. It will require calibration and training on its use, including potential interferences, which all shall be outlined in a facility-specific Aquatic Safety Plan. For additional information see manufacturer's instructions.

ORP Recommendations[87]

- In swimming pools and spas, an ORP of 650 to 720 mV allows quick disinfection and breakpoint chlorination (destruction of chloramines) where conditions permit.
- Ensure probes are calibrated every day to a known standard as described in the manufacturer's operation manual.
- Since some chemicals used in public pools including cyanuric acid and potassium monopersulfate can interfere with the ORP test results, ensure an Aquatic Safety Plan identifies any potential interference in testing and monitoring of all water parameters.
- Ensure that probes are cleaned at a frequency that ensures they will always effectively respond to pool demands (Note: Some probes come with an automatic cleaning feature).
- Free available chlorine levels shall be checked daily as described in this guideline and as determined in the facilities Aquatic Safety Plan.
- Perform appropriate (refer to operations and maintenance instructions) verification tests that will verify that the ORP sensor is operating properly.

[86] CDC's Healthy Swimming Recommendations and the MAHC; The National Swimming Pool Foundation, Pool & Spa Operator Handbook (2011) p. 93
[87] CDC's Healthy Swimming Recommendations and the MAHC; The National Swimming Pool Foundation, Pool & Spa Operator Handbook (2011)

6.8 Non-chlorinating oxidizing products – potassium monopersulfate

Non-chlorinated oxidizing products like potassium monopersulfate can be used as a non-chlorine oxidizing shock instead of chlorine shock or when super-chlorinating. These compounds are used in addition to disinfectants. They do not replace disinfection but instead assist primary disinfectants. They cannot be used to hyper-chlorinate when an incident release has occurred.

6.9 Water Balance

Water balance includes pH, alkalinity, calcium hardness, total dissolved solids (TDS), and Langelier Saturation Index (LSI).

6.9.1 pH[88]

Rationale: Correct pH is essential for water balance (equipment protection), bather comfort, and disinfection efficiency. Understanding what affects pH and how pH affects water quality (including disinfection efficacy) are essential for a pool operator to know.

pH is a measure of the relative acid/alkali strength of a solution. pH is measured on a scale from 1 to 14, with 7.0 being neutral. Pool water shall be maintained between 7.2 and 7.8 with the ideal level between 7.4-7.6 (Table 7, below).

Table 7. Consequences of pH

When pH is too high	When pH is too low
water is more likely to have scale-forming properties creating higher equipment maintenance and shortening equipment lifespan	water will be corrosive to pool equipment and surfaces
pH will affect chlorine disinfection ability • as pH increases, free chlorine loses its oxidative ability • at a pH of 8.0, only 20% of free chlorine is immediately available as hypochlorous acid, which is the compound that kills germs • at a pH of 7.5, about 50% is immediately available	water will irritate the eyes and skin, and cause bathing suit wear

What affects pH

Knowing what affects pH will aid in maintaining a satisfactory pH level in the aquatic water. pH is affected by

- addition of disinfectants that are strongly acidic or alkaline, which will lower or increase pH
- aeration (exposure to the air, such as by wave action), which increases pH by removing acidic gases
- pH of source water
- patron waste and personal hygiene including urine, fecal matter, and cosmetics

[88] http://www.who.int/water_sanitation_health/bathing/srwe2chap5.pdf

Recommendations [89]

- The ideal range for pool/spa water is 7.4 to 7.6.
- The acceptable range is 7.2 to 7.8.
- pH shall be tested prior to opening to adjust pool chemistry if necessary before opening and every 2 to 4 hours depending on the pool chemical addition method and bather load (see Table 8, Frequency of Water Parameter Testing, page 76).

6.9.2 Alkalinity (Carbonate/Biocarbonate)

Alkalinity measures the amount of salts present in the water. Alkalinity works as a buffer to prevent pH fluctuation or pH bounce. Conversely, total alkalinity above 200 ppm can make any necessary pH adjustment difficult (i.e., pH lock). Both of these extremes affects water chemistry and the ability of chlorine to kill bacteria and will cause corrosion, staining, scaling, cloudy water, or eye/skin irritation.

Recommendations:

- 60 to 180 ppm (mg/L) [90]
- ideal range 80 to 100 ppm when calcium hyperchlorite, lithium hypochlorite, and sodium hypochlorite are used, which increase the pH
- ideal range 100 to 120 ppm when dichlor, trichhlor, chlorine gas, and bromine are used (these cause pH to fall)

6.9.3 Calcium hardness [91]

Calcium hardness measures the amount of calcium salts present in the water. Relative to the other water balance parameters, if calcium hardness is too high, scaling of heaters and pool finishes may occur. If calcium hardness is too low, etching of cement and tiles and corrosion of heating and circulation components may occur. Calcium behaves differently from most chemicals, in that it becomes less soluble as temperatures rise, which is an important factor for pools with higher water temperatures. In areas of high calcium source water, specialist advice shall be sought before establishing recommended water balance parameters and choice of disinfectant and pH chemicals.

Recommendation:

Pools and Water Parks	150 - 400 mg/L
Spas	100 - 250 mg/L

6.9.4 Total Dissolved Solids (TDS)

TDS measures all solids and salts dissolved in pool water. TDS is increased by the addition of chemicals and salts from pool users and then concentrated further by the evaporation of water. TDS has also been described as a measure of the age of the water. Water replacement ensures lower TDS levels, water freshness, and water health.

Recommendations:

- The level of TDS shall be a maximum of 1500 ppm above fill water TDS.
- For salt-chlorinated pools, the TDS should be measured after the addition of salt to determine the acceptable base TDS. The salt in salt-chlorinated pools constitutes the bulk of TDS and shall be accounted for when measuring TDS.

[89] http://www.who.int/water_sanitation_health/bathing/srwe2chap5.pdf, CDC MOHC, Disinfection, ANSI/APSP-11 2009 p. 14
[90] ANSI/APSP-11 2009,Vore, Roy, RWI, NSPF
[91] ANSI/APSP-11 2009

6.9.5 Langelier Index (Saturation Index, SI)

Rationale:

Water balance describes the scale or corrosion activity of pool water. Water balance is affected by five factors: pH, total alkalinity, calcium hardness, temperature, and TDS. When balanced, these factors increase disinfection efficacy, maintain bather comfort and protect the pool equipment and pool surfaces from corrosion and scaling. Maintaining water balance takes knowledge, time, and precision.

Water balance can be calculated using a number of indexes and tables. The SI is the most universally accepted method and is calculated as:

SI = pH + TF+ AF+ CF– 12.1
TF = temperature factor
AF = alkalinity factor
CF = calcium factor

pH and specific tables are used to establish the factor of temperature, alkalinity, calcium, and then use the constant -12.1 for TDS. If the sum of these factors is too low, water will be corrosive to fittings and finish. These corrosive conditions occur when SI is less than –0.5 (for heated water, SI should not be less than –0.2). When the sum of these factors is too high, water will cause deposits to form on fittings and finishes. These scale-forming conditions occur when SI is more than +0.5.

Recommendation $-0.3 < SI > +0.3$

6.9.6 Water temperature

Monitoring and ensuring the appropriate pool water temperature is dependent on, and important for, several reasons including, but not limited to these factors:

- At higher water temperatures, the primary disinfectant is used up more rapidly increasing the risk of no or reduced primary disinfection residual levels, which leads to microbial growth.
- The activity level expected of the patrons may have an effect on what temperature the water shall be maintained. Typically, competition pools are maintained at a lower temperature than wading (toddler) pools.
- Human health can be affected by water temperature that is too high or too low.
- The higher the temperature, the more likely scaling is to occur because calcium solubility is lowered as temperature increases.
- At a lower temperature, the water can absorb more calcium. Concrete, marble sheen, or tiled pool surfaces may become etched.

Recommendations:[92]

- Pool temperature depends on the intended user/type of pool, but typically is between 26 to 32°C[93]
- Spa (hot tub, therapy) pool water temperature shall not exceed 104°F (40°C) due to health concerns.
  - The length of time a patron stays in a higher temperature pool is dependent on age and health conditions. Restricted and warning signs shall be clearly displayed in the direct area of the pool. See also Section 5.2.3, Timing Device.

6.10 Other

Clarifiers, flocculants, and defoamers shall be used per manufacturer's instructions.

[92] The USA Centre for Disease and Prevention. (2014) Model Aquatic Health Code-First Edition The Code
[93] ANSI/APSP-1 2009 p. 27

6.11 Monitoring Water Quality Parameters [94,95]

Rationale:
Accurate test results allow the operator to verify that the pool chemistry is effective and allows the operator to take corrective action as necessary to ensure effective disinfection, reduce operation costs, and prevent equipment/surface corrosion and scaling. To ensure accurate results, testing shall be done using appropriate equipment and following the manufacturer's instructions. Good record keeping helps to reveal and resolve problems, track chemicals used, and troubleshoot unexpected results. For example, identifying through testing that the free available chlorine residual is zero will indicate a need of immediate corrective action. Good record keeping can be helpful to determine the exact amounts of chemical required to effect a particular amount of change in pool chemistry.

Water Quality Testing Equipment (WQTE) Recommendations [96,97]

- Suitable testing equipment is to be provided for the reliable determination of primary disinfectant residuals including free available chlorine, total chlorine, pH, total alkalinity, calcium hardness, cyanuric acid, total dissolved solids, oxidation-reduction potential, salt, and any other parameter identified in the Aquatic Safety Plan.
- Testing equipment shall come with [98]
  - detailed instructions including calibration methods, if applicable
  - maintenance of WQTE components, if applicable
  - proper storage instructions and replacement instructions
    - Test kits are best kept in a cool and dark place to prevent deterioration of the chemicals. Chemicals and reagents are to be replaced frequently as per the manufacturer's recommendations (in many cases, annually). Test kit and chemical operational instructions on storage, handling, and replacement shall be consulted when developing standard operating procedures.
- Titration testing is recommended over colorimetric test kits as they are accurate to 0.2 mg/L (ppm) with easily recognizable start and end points.
- Tests need to be conducted according to manufacturer's instructions and recommendations, and shall be undertaken by individuals trained to do the testing and familiar with test result response. Testing equipment needs proper maintenance.
- Chemical controllers shall be maintained and calibrated according to manufacturer's recommendations.
- If automatic sensing devices are used to determine the ORP, pH, and disinfectant residuals, manual testing shall be conducted at least once a day to ensure that the automated sensing device is maintaining proper control.
- Test kits that use the diethyl-p-phenylenediamine (DPD) method or FAS-DPD are recommended for testing free and combined chlorine.
- Test kits using the orthotolidine (OTO) method are not recommended as they present health hazard risks to the user, can test only for total chlorine, and do not differentiate between free and combined chlorine.

[94] Adapted with permission from the BC Guidelines for Swimming Pools 2012
[95] CDC's Healthy Swimming Recommendations and the MAHC; The WHO Guidelines for safe recreational water environments Vol 2, Swimming Pools and Similar Environments; NSW Ministry of Health Australia; The National Swimming Pool Foundation, Pool & Spa Operator Handbook
[96] B.C. Guidelines for Swimming Pool Operations
[97] ANSI/APSP-1 2009 p. 27, p. 30
[98] NSF/ANSI 50-2012 p. 59

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Potential water test interferences shall be accounted for and steps to reduce interference shall be developed. For example, potassium monopersulfate will cause a false positive (more intense pink colour) for combined chlorine at any level and for free chlorine at high levels (over 25 ppm) when using a DPD test kit.[99]

Table 8. Frequency of water parameter testing[100]

Parameter	Frequency of testing during periods of use All Aquatic Venues	
Sanitizer (disinfectant) and pH	Manual feed system	Prior to opening, then every 2 hours
	Automatic Feed	Prior to opening, then every 4 hours
	In-Line ORP	Prior to opening, then every 4 hours or once a day
Clarity	Daily	
Temperature	Daily	
Alkalinity	Once per week	
Hardness	Every two weeks	
Cyanuric Acid	24 hours after addition then once per month. If stabilized chlorine is used, then once every 2 weeks	
Salt	Weekly or as per manufacturer's instructions	

99 CDC's Healthy Swimming Recommendations and the MAHC; The WHO Guidelines for Safe Recreational Water Environments Vol. 2, Swimming Pools and Similar Environments; NSW Ministry of Health Australia; The National Swimming Pool Foundation, Pool & Spa Operator Handbook

100 ANSI/NPSP 11-2009 p. 31

6.12 Water Microbiological Testing

Recommendations:[101,102]

- Provided minimum disinfection levels and other parameters are consistently maintained, monitored, and recorded as described in this guideline, routine microbiological testing is not necessary, unless the Aquatic Safety Plan has established reasons, except
  - before a pool is used for the first time
  - before the pool is put back into use after it has been shut down for repairs or cleaning
  - if there are difficulties with the treatment system
  - as part of any investigation into possible adverse effects on bather and worker health
- When sampling is performed it shall be conducted
  - from the point near an outlet or from any other location necessary to give an accurate representation of the water in the pool
  - between 200 and 400 millimetres below the surface of the water
  - using standard operating procedure and appropriate sampling technique
- Algae shall not be visible in the pool or spa when it is open for public use.

6.13 Ventilation, Air Circulation, and Moisture Control [103,104,105]

Rationale:

Ventilation and air circulation systems provide fresh air exchange and air circulation. For indoor facilities it is also an essential tool used, in combination with good water chemistry control, to remove disinfectant by-products (DBP) from the air breathed (when such by-products exist). Proper ventilation and circulation also ensures relative humidity levels are maintained at a level that is comfortable for the patrons. Humidity should also be maintained at a level that prevents damage to the equipment and structural integrity of the facility.

Biological and chemical by-products in pool water that are released to the air can affect patron health and pool equipment. This is especially problematic for indoor water parks and indoor aquatic facilities with many play features. When urine and sweat are introduced into the pool water the nitrogen will combine with the chlorine to form monochloramines, dichloromethanes, and eventually trichloromethanes (chloramines). Dichloromethanes and trihalomethanes can easily move from water to air. Aquatic play features will aid in this transfer from water to air. The levels of di- and trichloromethane will increase with high bather loads, poor water chemistry control, poor water feature maintenance, and poor ventilation.[106]

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[101] WHO

[102] Vore, Roy Ph.D., Recreational Water Illness, Aquatic Management Series, The National Swimming Pool Foundation.

[103] The USA Centre for Disese and Prevention. (2014) Model Aquatic Health Code-First Edition The Code

[104] National Swimming Pool Foundation, Pool Operator Handbook 2011 , p. 158-159

[105] NSPF Aquatic Facility Environmental Health Leader Symposium Live Streamed from WAHC, Indoor Air Quality Franceen Gonzales, Vice President, Risk Management at Great Wolf Resorts, Inc., October 15, 2013

[106] National Institute for Occupational Safety and Health (NIOSH) (2010). Workplace Safety Report: Reducing Illnesses at Indoor Waterparks. DHHS NIOSH Publication No. 2010-138 retrieved from the www on March1, 2014 at http://www.cdc.gov/niosh/docs/wp-solutions/2010-138/pdfs/2010-138.pdf

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Recommendations:

1. General

- Air handling systems shall be maintained and operated to comply with all requirements of the original system design, construction and installation.
- The air handling system shall operate continuously, including providing the required amount of outdoor air. The exception is that the amount of outdoor air may be reduced by no more than 50% during non-use periods as long as acceptable air quality is maintained.
- Develop and implement a ventilation/circulation system program of standard operating, maintenance, testing, and inspection procedures with detailed instructions and provide the required training to ensure effective ongoing maintenance and monitoring and cleaning.
- Implement a ventilation cleaning program including replacement or cleaning, where appropriate, of ventilation air filters.
- Monitor, log, and maintain ventilation set points and other operational parameters as intended according to the engineering and manufacturer's specifications.

2. Facility Modification

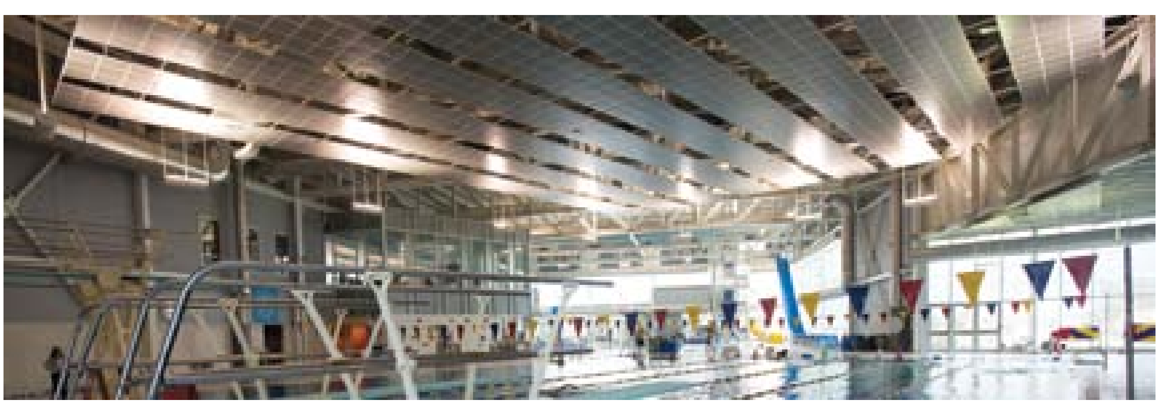
- ensure ventilation and circulation needs are evaluated, including vent positioning, when an aquatic venue is modified, which would include, but not be limited to
  - addition of aquatic features, such as spray pads/elements, wave, and slide features
  - increase in size or number of pools and spas
  - modification of ceiling height

3. Troubleshooting could include

- ensuring that air exhaust ducts are exhausted outside and are not exhausted to another area of the building (such as change rooms)
- ensuring that low-level exhausts are used close to the water or water feature to help exhaust air from surface water
- ensuring that relative humidity levels are maintained below recommended levels (higher levels encourage corrosion and occupant discomfort)
- developing and implementing an operational plan for reducing combined chlorine compounds and an educational campaign on the role patrons play

4. Emergency Planning

- Develop an air quality action plan with procedures for purging the indoor aquatic facility for chemical emergencies or other indicators of poor air quality.



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6.14 Facility Heating

Recommendations:

- Maintenance, repairs, and alterations to facility-heating equipment shall preserve compliance with applicable codes.
- Air temperature shall be controlled to the original specifications or in the absence of such, the dew point of the interior space should be maintained at less than the dew point of the interior walls at all times so as to prevent damage to structural members and to prevent biological growth on walls.

6.15 Water Heating

Recommendations:

- Maintenance, repairs, and alterations to pool-water heating equipment shall preserve compliance with applicable codes.