Contents

Chapter 14—Residential Swimming Pools and Spas

"Most people assume if their young child falls into the pool, there will be lots of splashing and screaming, and plenty of time to react. In reality, a child slips into the water and often goes under the surface. These drownings can happen quickly and silently-without warning."

Hal Stratton, Chair
U.S. Consumer Product Safety Commission,
2002–Present

Introduction

Swimming is one of the best forms of exercise available and having a residential swimming pool also can provide much pleasure. Nevertheless, it takes a great deal of work and expense to make and keep the pool water clean and free of floating debris. Without a doubt, a properly maintained and operated pool is quite rewarding. Home pools, however, are sometimes referred to as attractive nuisances or hazards. It is essential to be able to evaluate the risks associated with a pool. A regulatory agent or consultant must understand the total engineered pool system and be capable of identifying all equipment, valves, and piping systems. The piping system for a pool should be color-coded to assist the pool operator or the owner to determine the correct way to operate the swimming pool. The specific goal is to protect the owners, their families, and others who may be attracted to a residential pool.

Residential pools and spas should provide clean, clear water; water free of disease agents; and a safe recreational environment. In addition, residential pools and spas should have effective, properly operating equipment and effective maintenance and operation.

Childproofing

Although it seems obvious, close supervision of young children is vital for families with a residential pool. A common scenario is a young child leaving the house without the parent or caregiver realizing it. Children are drawn to water, and they can drown even if they know how to swim. All children should be supervised at all times while in and around a pool.

The key to preventing pool tragedies is to provide layers of protection. These layers include limiting pool access, using pool alarms, closely supervising children, and being prepared in case of an emergency. The U.S. Consumer Product Safety Commission (CPSC) offers these tips to prevent drowning:

- Fences and walls should be at least 4 feet high and installed completely around the pool. The fence should be no more than 2 inches above grade. Openings in the fence should be a maximum of 4 inches. A fence should be difficult to climb over.

- Fence gates should be self-closing and self-latching. The latch should be out of a small child's reach. The gate should open away from the pool; the latch should face the pool.

- Any doors with direct pool access should have an audible alarm that sounds for 30 seconds. The alarm control must be a minimum of 54 inches high and reset automatically.

- If the house forms one side of the barrier to the pool, then doors leading from the house to the pool should be protected with alarms that produce a sound when a door is opened.

- Young children who have taken swimming lessons should not be considered "drown proof"; young children should always be watched carefully while swimming.

- A power safety cover-a motor-powered barrier that can be placed over the water area-can be used when the pool is not in use.

- Rescue equipment and a telephone should be kept by the pool; emergency numbers should be posted. Knowing cardiopulmonary resuscitation (CPR) can be a lifesaver.

- For aboveground pools, steps and ladders should be secured and locked or removed when the pool is not in use.

- Babysitters should be instructed about potential hazards to young children in and around swimming pools and their need for constant supervision.

- If a child is missing, the pool should always be checked first. Seconds count in preventing death or disability.

- Pool alarms can be used as an added precaution. Underwater pool alarms can be used in conjunction with power safety covers. CPSC advises consumers to use remote alarm receivers so the alarm can be heard inside the house or in other places away from the pool area.

- Toys and flotation devices should be used in pools only under supervision; they should not be used in place of supervision.

- Well-maintained rescue equipment (including a ring buoy with an attached line and/or a shepherd's crook rescue pole should be kept by the pool.

- Emergency procedures should be clearly written and posted in the pool area.

- All caregivers must know how to swim, know how to get emergency help, and know CPR.

- Children should be taught to swim (swimming classes are not recommended for children under the age of 4 years) and should always swim with a buddy.

- Alcohol should not be consumed during or just before swimming or while supervising children.

- To prevent choking, chewing gum and eating should be avoided while swimming, diving, or playing in water.

- Water depth should be checked before entering a pool. The American Red Cross recommends 9 feet as a minimum depth for diving and jumping.

- Rules should be posted in easily seen areas. Rules should state "no running," "no pushing," no drinking," and "never swim alone." Be sure to enforce the rules.

- Tables, chairs, and other objects should be placed well away from the pool fence to prevent children from using them to climb into the pool area.

- When the pool is not in use, all toys should be removed to prevent children from playing with or reaching for them and unintentionally falling into the water.

- A clear view of the pool from the house should be ensured by removing vegetation and other obstacles that block the view.

Hazards

Numerous issues need to be considered before building residential pools: location of overhead power lines, installation and maintenance of ground fault circuit interruptors, electrical system grounding, electrical wiring sizing, location of the pool, and type of vegetation near the pool. The commonly used solar covers that rest on the surface of the pool and amplify sunlight do an excellent job of increasing the pool temperature, and they also increase the risk for drowning. If children or pets fall in and sink below the cover, it can be nearly impenetrable if they attempt to surface under it.

Winterizing the pool also can be hazardous. The pool water in most belowground pools is seldom drained because of groundwater pressure that can damage the structure of the pool. Therefore, water in most home pools is only lowered below the frost line for winter protection. In these cases, a pool cover is installed to keep debris and leaves from filling the pool in the winter months. The pool cover becomes an excellent mosquito-breeding area before the pool is reopened in the spring because of the decomposing vegetation that is on the pool cover, the rain that accumulates on the top of the pool cover during the winter, and the eggs laid on the pool cover in early fall and early spring. The cover also provides ideal conditions for mosquitoes to breed: stagnant water, protection from wind that can sink floating eggs, the near absence of predators, and warm water created by the pool cover collecting heat just below the surface (Figure 14.1).

Public Health Issues

Current epidemiologic evidence indicates that correctly constructed and operated swimming pools are not a

Figure 14.1. Pool Cover

major public health problem. They are preferable to bathing beaches because of the engineered controls designed into pools. Poorly designed or operated pools, however, can be major public health hazards. Data from CDC between 1999 and 2000 show that 59 disease outbreaks from 23 states were attributed to recreational water exposure and affected an estimated 2,093 people. Of the 59 recreational outbreaks, 44 (74.6%) were of known infectious etiology. Of the 36 outbreaks involving gastroenteritis, 17 (47.2%) were caused by parasites; 9 (25.0%) by bacteria; 3 (8.3%) by viruses; 1 (2.8%) by a combination of parasites and bacteria, and the remaining 6 (16.7%) were of unknown cause. Of the 23 nongastroenteritis-related recreational outbreaks, seven were attributed to *Pseudomonas aeruginosa*, four to free-living amoebae, one to *Leptospira* species, one to *Legionella* species, and one to bromide. Sixteen of the 17 parasitic recreational water outbreaks involving gastroenteritis; nine (24.3%) were outbreaks of dermatitis; and six (16.2%) were caused by *Cryptosporidium parvum*. The seventeenth outbreak was caused by *Giardia lamblia* (intestinalis). In 1999, an outbreak of *Campylobacter jejuni* was associated with a private pool that did not have continuous chlorine disinfection and reportedly had ducks swimming in the pool [1].

Diseases

- **Intestinal diseases:** *Escherichia coli* O157:H7, typhoid fever, paratyphoid fever, amoebic dysentery, leptospirosis, cryptosporidiosis (highly chlorine resistant), and bacillary dysentery can be a problem where water is polluted by domestic or animal sewage or waste. Swimming pools have also been implicated in outbreaks of leptospirosis.

- **Respiratory diseases:** Colds, sinusitis, and septic sore throat can spread more readily in swimming areas as a result of close contact, or improperly treated pool water, coupled with lowered resistance because of exertion.

- **Eye, ear, nose, throat, and skin infections:** The exposure of delicate mucous membranes, the movement of harmful organisms into ear and nasal passages, the excessive use of water-treatment chemicals, and the presence of harmful agents in water can contribute to eye, ear, nose, throat, and skin infections. Close physical contact and the presence of fomites (such as towels) also help to spread athlete's foot, impetigo, and dermatitis.

Injuries

Injuries and drowning deaths are by far the greatest problem at swimming pools. Lack of bather supervision is a prime cause, as is the improper construction, use, and maintenance of equipment. Injuries include evisceration, electrocution, entrapment, and entanglement. Some particular problem areas include the following:

- lose or poorly located diving board,
- slippery decks or pool bottoms,
- poorly designed or located water slides,
- projecting or ungrated pipes and drains that can catch hair or body parts,
- drain grates of inadequate size,
- improperly installed or maintained electrical equipment, and
- improperly vented chlorinators and mishandled chlorine materials.

Water Testing Equipment

It is essential that correct equipment be used and maintained for assessing the water quality of both swimming pools and spas. The operators of pool and spas need to monitor a wide range of chemicals that influence pool operations and water quality. Their equipment should test for chlorine, bromine, pH, alkalinity, hardness, and cyanuric acid build up. The chlorine should be measurable at a range of 0 to 10 parts per million (ppm). Water pH levels should be accurately measured with an acid or base test. A kit to check pool chemical levels usually includes N,N-diethyl-p-phenylene-diamine (DPD) tablet tests for free and total chlorine, and other one-step tablet tests for pH, total alkalinity, calcium hardness, and cyanuric acids. The homeowner should determine acid or base demand using an already reacted pH sample in dropper bottles. Paper test strips with multiple tests (including chlorine, bromine, and pH) are also available, but the reliability of these tests varies greatly. If used, they should be kept fresh, protected from heat and moisture, and checked against other test systems periodically if water quality problems persist.

Swimming pools are engineered systems, with demanding safety and sanitary requirements that result in rather sophisticated design standards and water treatment systems. The size, shape, and operating system of the pool is based on the following considerations:

- the intended use of the pool and the maximum expected bather loading;

- the selection of skimmers, scuppers, or gutters, depending on the purpose, size, and shape of the pool;

- the recirculation pump, whose horsepower and impeller configuration are based on the distance, volume, and height of the water to be pumped;

- the filters, which are sized on the volume of water to be treated and the maximum gallons (liters) of water per minute that can be delivered by the pump and the type of filter media selected; and

- the chemical feeder sizes and types, which are based on the chemicals used, total quantity of the water in the system, expected use rates, and external environmental factors, such as quantity of sunlight and wind that affect the system.

Disinfection

The length of time it takes to disinfect a pool depends, for example, on the type of fecal accident and the chlorine levels chosen to disinfect the pool. If a fecal accident is a formed stool, the faollowing chlorine levels will determine the times needed to inactivate *Giardia*:

Chlorine Levels (ppm)	Disinfection Time
1.0	45 minutes
2.0	25 minutes
3.0	19 minutes

These times are based on a 99.9% inactivation of *Giardia* cysts by chlorine, pH 7.5, and 77°F (25°C). The times were derived from the EPA *LT1ESWTR Disinfection Profiling and Benchmarking Technical Guidance Manual* [2]. These times do not take into account "dead spots" and other areas of poor pool water mixing.

If the fecal accident is diarrhea, the following chlorine levels will determine the times needed to inactivate *Cryptosporidia*:

Chlorine Levels (ppm)	Disinfection Time
1.0	6.7 days
10.0	16 hours
20.0	8 hours

A CT value is the concentration (C) of free available chlorine in parts per million (ppm) multiplied by the time (T) in minutes (CT value = C×T). The CT value for *Giardia* is 45 and the value for *Cryptosporidia* is 9,600. If a different chlorine concentration or inactivation time is used, CT values must remain the same. For example, to determine the length of time needed to disinfect a pool at 15 ppm after a diarrheal accident, the following formula is used: C×T = 9,600. Solve for time: T= 9,600÷15 ppm = 10.7 hours. It would, thus, take 10.7 hours to inactivate *Cryptosporidia* at 15 ppm. You can do the same for *Giardia* by using the CT of 45.

CDC has Web sites that contain excellent information about safe swimming recommendations, recreational water diseases, and disinfection procedures for fecal accidents [3,4].

Content Turnover Rate

The number of times a pool's contents can be filtered though its filtration equipment in a 24-hour period is the turnover rate of the pool. Because the filtered water is diluted with the nonfiltered water of the pool, the turbidity continually decreases. Once the pool water has reached equilibrium with the sources of contamination, a 6-hour turnover rate will result in 98% clarification if the pool is properly designed. A typical-use pool should have a pump and filtration system capable of pumping the entire contents of the pool though the filters every 6 hours. To determine compliance with this 6-hour turnover standard, the following formula is used:

Turnover rate = pool volume (gallons)/
flow rate×60 (minutes in hour)

Following is a sample calculation of the pool content turnover rate using the rate of flow reading from the flow meter:

Turnover rate = 90,000 (gallons in pool)/
180 gallons per minute×60 (minutes in hour)

8.3-hour turnover rate = 90,000 (pool volume in gallons)/10,800

The above pool would not meet the required turnover rate of 6 hours. The cause could be improperly sized piping or restrictions in the piping, an undersized pump, or undersized or clogged filters. This turnover rate would probably result in cloudy water if the pool is used at the normal bather load. The decreased circulation would also make it difficult for the disinfecting equipment to meet the required levels.

Filters

Pool filters are not designed to remove bacteria, but to make the water in the pool clear. Normal tap water looks quite dingy if used to fill a pool and, in some cases, the bottom of the pool is not visible. The maximum turbidity level of a pool should be less than 0.5 nephelometric turbidity units. Pool filters should be sized to ensure that the complete contents of the pool pass through the filter once every 6 hours. Home pools typically use one of three types of filters.

High-rate Sand Filters

High-rate sand filters were introduced more than 30 years ago and reduced the size of the conventional sand filter by 80%. The sand filter is the most popular filter on the market. High-rate sand filters use a silica sand that has been strained to give it a uniform size. It is referred to as pool-grade sand #20 silica. The sand is normally 0.45 millimeters (mm) to 0.55 mm in diameter. As water passes through the filter, the sharp edges of the sand trap the dirt from the pool water. When the backpressure of the filter increases to 3 to 5 psi, the filter needs to be cleaned. This is usually accomplished by reversing the flow of the water through the filter and flushing the dirt out the waste pipe until the water being discharged appears clear. These filters perform best when used at pressure levels below 15 to 20 gallons per minute, depending on the manufacturer of the filter.

Cartridge Filters

Cartridge filters have been around for many years, but only recently have gained in popularity in the pool industry. They are similar to the filter on a car engine. The water is passed through the cartridge and returned to the pool. When the pressure of a cartridge filter increases approximately 5 psi, the pump is turned off; and the top of the filter is removed. The cartridge is removed and either discarded and replaced or, in some cases, washed.

Diatomaceous Earth

Diatomaceous earth (DE) is a porous powder made from the skeletons of billions of microscopic animals that were buried millions of years ago. There are two primary types of DE filters, but they both work the same way. Water comes into the filter, passes through the DE, and is returned to the pool. If properly sized and operated, DE filters are considered by some to provide the highest quality of water. They are capable of filtering the smallest particle size of all the filter types. It is usually adequate to change the DE once every 30 days. However, if your pool water is very dirty, it is not uncommon to change it 3–4 times a day until the water is clear. The frequency of backwashing will depend on many factors, including the size of your filter, flow rate of your plumbing, and the bather load in your pool. When the pressure reading on the filter reaches the level set by the manufacturer's manual, it will be ready for backwashing.

Filter Loading Rates

The specification plate on the side of approved residential or commercial swimming pool filters contains such information as the manufacturer, type of filter, serial number, surface area, and designed loading rate. Knowing the surface area of the filter permits calculation of the number of gallons flowing through the filter per minute. An excessive flow rate can push the media into the pool or force pool solids and materials thought the media, resulting in turbid water. Figure 14.2 shows a typical home pool treatment system. Regulations typically specify how much water can be filtered through the various types of pool filtration systems.

Disinfectants

Many disinfectants are used in pools and spas around the world, including halogen-based compounds (chlorine, bromine, iodine), ozone, and ultraviolet light with hydrogen peroxide. Those used most often are chlorine, bromine, and iodine, and each has advantages and limitations.

Figure 14.2. Typical Home Pool Equipment System

Chlorine—Pools can be disinfected with chlorine-releasing compounds, including hypochlorite salt compounds. Calcium hypochlorite is inexpensive and popular for cold-water pools, but not suitable for hot pools and spas because it will promote scaling on heat exchangers and piping. Chlorine levels can be rapidly reduced with high use and regular checks should be made to ensure maintenance of disinfection. Some adjustment of pH is required for most forms of chlorine disinfection. When chlorine gas is used, a fairly high alkalinity needs to be maintained to remove the acid formed during dosing [5]. Sodium hypochlorite is a liquid chlorine, and has a pH of 13, causing a slight increase in the pH of the pool water, which should be adjusted with an acidic mixture. The sun's rays will degrade sodium hypochlorite. Chlorinated isocyanate is available in three forms-granular, tablet, and stick. The granular form contains 55%–62% available chlorine and the stick and tablet form contain 89% available chlorine [6].

Bromine—Bromine needs to be used at levels twice those of chlorine to achieve similar disinfection. Bromine is available as the sodium or potassium salts. In the presence of ammonia, bromine rapidly forms relatively unstable ammonia bromamines that possess disinfection efficiencies comparable to that of free bromine. It is also unnecessary to destroy ammonia bromamines because they do not produce irritating odors [5].

Iodine—Potassium iodide is a white, crystal chemical. This chemical needs an oxidizer, such as hypochlorite, to react with organic debris and bacteria. Iodine does not react with ammonia, hair, or bathing suits, or cause eye irritation, but it can react with metals, producing greenish-colored pool water [6].

Ozone—Ozone is a very powerful oxidant and is effective against viruses. It can only be generated at the point of use and commercial generation units are safe for use. Ozone dosing is only practical where there is water circulating off-pool because adequate ozone-water mixing is essential for maximum oxidation. Ozone generators may be of the ultraviolet lamp or corona discharge type. The ultraviolet lamp efficiency reduces with time and the lamp and associated activated charcoal filter will need replacement [5].

Ultraviolet Light—Ultraviolet light, like ozone, is sometimes used for off-pool water disinfection. Ultraviolet light has no effect on pH or color and has little effect on the chemical composition of the water. However, color, turbidity, and chemical composition of the water can interfere with ultraviolet light transmission. The water must be adequately treated before ultraviolet light exposure. Hydrogen peroxide is often used for this purpose as it is relatively safe in low concentrations, is nonflammable, and produces oxygen and water as end products. For the ultraviolet light plus hydrogen peroxide system to be effective, it must operate 24 hours a day. Ultraviolet light disinfection is not pH dependent, but the addition of hydrogen peroxide results in slightly acidic conditions [5].

Silver-copper Ionization—Sanitizing can be accomplished by using an ionizing unit that introduces silver and copper ions into the water by electrolysis, or by passing an electric current through a silver and copper electrode. The limiting factors in using this system in the pool and spa are cost, slow bactericidal action, and potentially high contaminant levels caused by bather loads. Also, black spots can form on pool surfaces if the proper parameters of water chemistry are not maintained. An approved chemical disinfectant must be used with an ionizing unit [6].

The effective use of halogen disinfectants is based on the pH, hardness, and alkalinity of the water. Improper pH, hardness, and alkalinity levels in the pool can render high levels of disinfectant useless in killing disease-causing organisms. Table 14.1 summarizes water-quality problems that affect pools and suggests corrective actions.

Effect of pH

The ideal pH to avoid eye irritation is 7.3. Bacteria- or algae-killing effectiveness is improved with an even lower pH. National standards typically recommend a range of 7.2 to 7.6, which is cost-effective. Table 14.2 demonstrates the loss of disinfection as pH increases:

Chlorine Disinfectants

The options for selecting the form of chlorine disinfectant to use in pools are quite varied, and the choices are complex. Table 14.3 gives the properties of each form. Gas chlorine costs the least, and the relative cost of each form of chlorine increases as you move right across the table. The cost of the disinfectant tends to be less the higher the concentration of available chlorine. The safety issues are more complex than they might appear. The hazards of gas chlorine are well known. The solid forms of chlorine, such as calcium hypochlorite, are quite reactive. When exposed to organic compounds, they can generate a great deal of heat and are potentially explosive. Because solid chlorine seems inert to the untrained worker, it is often stored beside motor oil or gasoline or left in where

Water Quality Issue (Symptoms)	Potential Problems (Root Causes)	Corrective Approaches (Actions)
Air bubbles coming from inlets	1. Air in filter shell (easy fix) 2. Leak in hair and lint strainer, pipe, valves, or fittings on suction side of pump (may be difficult to fix)	1. Bleed air off of top of filter shell. 2. Check seal around opening of hair and lint strainer. Locate leaking fitting and seal.
Foam on water, around floating objects, and on sides of pool	1. Low hardness of water (easy fix) 2. Effect of algaecides (do not need) 3. Spillage of detergent into pool	1. Maintain minimum of 200 ppm calcium hardness, but less than 400 ppm. 2. Do not use algaecides, but maintain 1 ppm of free chlorine at minimum and a pH of 7.2–7.3. (pH of 7.2 is preferable) for algae-free water. 3. Backwash filters for extended time and add makeup water. If foam is still a problem, add defoaming agent.
Cloudy water	1. Inadequate turnover rate 2. Filter media corrupted, channeled, or creviced. 3. Excessive filter pressure. 4. High pH or alkalinity above 150 ppm.	1. Check pump capacity and flow rate. 2. If sand, clean filter and replace media, if necessary. If diatomaceous earth (DE) filter, wash filter bags in weak acid solution. 3. Backwash filter, bleed air pressure from filter shell, check pump for proper sizing. 4. Reduce pH to maximum of 7.6 and alkalinity to less than 150 ppm.
Milky water (uniform water color with white, opaque appearance)	DE entering pool from DE filter leakage	Check filter bags for tears or holes and the mounting of the bags on the filter septa. Expect 24-hour minimum filtering to clear water.
Dull green color, varying density	Algae growth	Super-chlorinate, then maintain pH at 7.6 (preferably 7.2) and disinfectant level of 1 ppm or higher.
Bright green color	Dissolved iron	Adjust pH to between 7.2 and 7.6, adjust disinfectant level to between 1 and 1.5 ppm. Iron should precipitate to ferrous state (brown); backwash repeatedly to remove. Expect 24 to 46 hours of filtering to clear water.
Bluish green color	Copper damage from low pH	Raise pH to 7.6, increase hardness to 200 ppm and alkalinity to at least 150 ppm. Perform a saturation index calculation. Adjust water to slightly above +0.5 to achieve scale-forming water to isolate before equipment damage.
Reddish brown water, uniform in color and texture	Precipitated iron (ferrous)	Adjust pH and disinfectant level and backwash filter as needed until clear.

Table 14.1. Pool Water Quality Problem Solving [7]

HoCl ⟷	H +	OCl -
Hypochlorous Acid—More Increases Effectiveness [Percent of Chlorine as HOCl]	Hydrogen Ion [pH]	Hypochlorite Ion—More Reduces Effectiveness [Percent of Chlorine as OCl]
90	6.5	10
73	7.0	27
66	7.2—IDEAL	34
45	7.6—IDEAL	55
21	8.0	79
10	8.5	90

Table 14.2. pH Effect on Chlorine Disinfection [7]

	Gas Chlorine	Sodium Hypochlorite	Calcium Hypochlorite	Dichloro	Trichloro
Percent Chlorine	100	10–15	65–70	56–62	90
Effect on pH	Lowers pH	Raises pH	Raises pH	Neutral	Lowers pH
Sunlight Effects	Considerable	Yes	Yes	Little loss	Little loss
Physical Form	Gas	Liquid	Granular or tablets	Granular only	Granular or tablets

Table 14.3. Chlorine Use in Swimming Pools

moisture can start a chemical reaction. Even a pencil with a graphite core that drops from a shirt pocket into a container of calcium hypochlorite could result in a chemical reaction leading to a fire that would release free chlorine gas [7].

The following chemical reactions produce chlorine by-products that reduce the effectiveness of chlorine and cause most eye irritation.

$Cl_2 + H_2O = HCl + HOCl$
Chlorine + Water = Hydrochloric Acid + Hypochlorous Acid

$HOCl + NH_3 = H_2O + NH_2Cl$
Hypochlorous Acid + Ammonia = Water + Monochloramine

$HOCl + NH_2Cl = H_2O + NHCl_2$
Hypochlorous Acid + Monochloramine = Water + Dichloramine

$HOCl + NHCl_2 = H_2O + NCl_3$
Hypochlorous Acid + Dichloramine = Water + Nitrogen Trichloride

Tables 14.1–14.4 serve as a quick problem-solving reference for the home pool owner and operator. The CDC Web site (www.cdc.gov/healthyswimming) provides a great deal of useful information for both the inspector and the homeowner.

Pool Water Hardness and Alkalinity

The ideal range of water hardness for a plaster pool is 200 to 275 ppm. The ideal range for a vinyl, painted, or fiberglass surface is 175 to 225 ppm. Excess hardness causes scaling, discoloration, and filter inefficiency. Less than recommended hardness results in corrosion of most contact surfaces.

Alkalinity should be 80 to 120 ppm. High alkaline levels cause scale and high chlorine demand. Low levels cause unstable pH. Sodium bicarbonate will raise the alkalinity level. The pool water will be cloudy if alkalinity is over 200 ppm.

	Minimum	Ideal	Maximum	Comments
Water Clarity				
Crystal-clear water at all times is the goal	Main drain visible	Crystal clear, object the size of a dime easily seen from pool deck at main drain, water sparkles	None	Lack of clarity is often due to malfunctioning or undersized filters. Other problems may be improperly sized pump, air collecting in the filter shell, or operator not running filter 24 hours per day.
Disinfectant Levels				
Free chlorine				
Standard pool	4	4	4	Continuous levels at 1 to 1.5 ppm minimum.
Wading or shallow pool for children	3	5	7	Super-chlorinate indicators: high chlorine level, eye irritation, or algae growth. Super-chlorinate indicators: High chlorine levels, eye irritation or algae growth. Continuous levels.
Combined chlorine	None	None	0.5	
Bromine	2	5	10	
Wading or shallow pool for children	4	7	10	
Iodine ppm	Consult product manufacturer	–	–	—
Chemical Values				
Hardness, $CaCO_3$	150	200–400	500 +	If difficult to control, use a different disinfectant.
Heavy metals	None	None	None	Check algaecide for heavy metal presence or by-products of corrosion (partial water replacement may be recommended).
Stabilizer, cyanuric acid	10	30–50	100	If level exceeds 100 ppm, partial water replacement recommended.
Algae, bacteria	None	None	None	Shock treat and maintain required levels of disinfectant and 7.2 to 7.6 pH.

Table 14.4. Swimming Pool Operating Parameters [7]

Liquid Chemical Feeders

Positive Displacement Pump

A positive displacement pump is preferable to erosion disinfectant feeders. Positive displacement pumps can be set to administer varied and specific chemical dosage rates to ensure that a pool does not become contaminated with harmful microorganisms. A positive displacement pump does need routine cleaning, descaling, and servicing. Running a weak muriatic acid or vinegar solution through the pump weekly can minimize most major servicing of the pump. Most service on the pump involves one of four areas:

1. the check valves are scaled, their springs are weak, or valves are no longer flexible;
2. the diaphragm is cracked, leaking, or not flexible;
3. the drive cam needs replacement or requires adjustment; or
4. the motor requires replacement.

Erosion and Flow-through Disinfectant Feeders

These feeders work by the action of water moving around a solid cake of chlorine and eroding the cake. The feeders work quite well for smaller pools, but require considerable care and maintenance. The variables that affect the effectiveness of erosion feeders are

1. solubility of the chlorine cake or tablet;
2. surface area of the cake or tablet;
3. amount of water flowing around the cake or tablet;
4. concentration of chlorine in the cake or tablet; and
5. number of cakes or tablets in the feeder.

Note: For safety reasons, the disinfectant cake must not be accessible.

Spas and Hot Tubs

Hot tubs (large tubs filled with hot water for one or more people) or spas (a tub with aerating or swirling water) are used for pleasure and are increasingly being recommended for therapy. The complexity of these devices increases with each new model manufactured. Newer models often have both ozone and ultraviolet light emitters for enhanced disinfection (see Disinfectants section earlier in this chapter). However, the environment of the spa and hot tub, if not cleaned and operated correctly, can become a culture medium for microorganisms. Because the warm water is at the ideal temperature for growth of microorganisms, good disinfection is critical. Table 14.5 provides suggested hot tub and spa operating parameters. It is essential that all equipment works properly and that the units are cleaned and disinfected on a routine basis. Monitoring the water temperature is very important and, depending on the health of the user, can be a matter of life and death. Time in the heated water should be limited, and the temperature for pregnant users should be below 103°F (39°C) to protect the unborn baby.

References

1. Lee HL, Levy DA, Craun GF, Beach MJ, Calderon RL. Surveillance for waterborne-disease outbreaks—United States, 1999–2000. MMWR 2002; 51(SS08):1–28. Available from URL: http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5108a1.htm.
2. US Environmental Protection Agency. LT1ESWTR Disinfection profiling and benchmarking: technical guidance manual. Washington, DC: US Environmental Protection Agency; 2003. Available from URL: http://www.epa.gov/safewater/mdbp/pdf/profile/lt1profiling.pdf.
3. Centers for Disease Control and Prevention. Healthy swimming. Atlanta: US Department of Health and Human Services; no date. Available from URL: http://www.cdc.gov/healthyswimming/.
4. Centers for Disease Control and Prevention. Fecal accidents response recommendations for aquatics staff. Atlanta: US Department of Health and Human Services; no date. Available from URL: http://www.cdc.gov/healthyswimming/fecalacc.htm.
5. Broadbent C. Guidance on water quality for heated spas. Rundle Mall, South Australia, Australia: Public Environmental Health Service; 1996. Available from URL: http://www.dh.sa.gov.au/pehs/publications/monograph-heated-spas.pdf.
6. Michigan State University Pesticide Education Program. Swimming pool pest management: category 5A, a training guide for commercial pesticide applicators and swimming pool operators. Chapter 3: pool disinfectants and pH. East Lansing, MI: Michigan State University; no date. Available from URL: http://www.pested.msu.edu/BullSlideNews/bulletins/pdf/2621/E2621chap3.pdf.
7. National Swimming Pool Foundation. Certified pool-spa operator handbook, 2004. Colorado Springs, CO: National Swimming Pool Foundation; 2004. Available from URL: http://nspf.org.

Additional Sources of Information

American Academy of Pediatrics. Available from URL: www.aap.org.

American National Standards Institute. Available from URL: http://www.ansi.org.

American Red Cross. Available from URL: www.redcross.org.

	Minimum (ppm)	Ideal (ppm)	Maximum (ppm)	Comments
Disinfectant Levels				
Free chlorine	3	4	10	Continuous levels. Super-chlorinate when combined level exceeds 0.2.
Combined chlorine	None	None	0.5	Super-chlorinate indicators: High chlorine levels, eye irritation or algae growth.
Bromine	4	5	10	Continuous levels.
Iodine ppm	Consult product manufacturer			
Ozone, ultraviolet light, hydrogen peroxide, and others	Consult product manufacturer			Use also requires a disinfectant in most health jurisdictions.
Chemical Values				
pH	7.2	7.3	7.6	Ideal range: 7.2–7.6.
Total alkalinity, $CaCO_3$	60	80–100	180	
Dissolved solids	300	NA	2,000	Excess solids many lead to hazy water and corrosion of fixtures (may need partial water replacement).
Hardness, $CaCO_3$	150	200–400	500 +	If difficult to control, use a different disinfectant.
Heavy metals	None	None	None	Check algaecide for heavy metal presence or by-products of corrosion (partial water replacement may be required).
Stabilizer, cyanuric acid	10	30–50	100	If level exceeds 100 ppm, partial water replacement may be required.
Algae, bacteria	None	None	None	If observed, shock treat and maintain required levels of disinfectant and the appropriate pH.

Table 14.5. Spa and Hot Tub Operating Parameters [7]

American Trauma Society. Available from URL: www.amtrauma.org.

Association of Pool and Spa Professionals. Available from URL: http://www.nspi.org/.

Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Available from URL: www.cdc.gov/ncipc/factsheets/drown.htm.

For more information about the CDC fecal accident recommendations, go to URL: http://www.cdc.gov/healthyswimming/fecal_response.htm.

For additional information about cryptosporidiosis, go to URL: http://www.cdc.gov/healthyswimming/cryptofacts.htm.

See also Web-based Injury Statistics Query and Reporting System (WISQARS) [Online]. (2002). National Center for Injury Prevention and Control, Centers for Disease Control and Prevention. Available from URL: www.cdc.gov/ncipc/wisqars.

Children's Safety Network. Available from URL: http://www.childrenssafetynetwork.org.

Chlorine Institute, Inc. Available from URL: http://www.cl2.com.

National Safe Kids Campaign. Available from URL: http://www.safekids.org.

National Safety Council. Available from URL: http://www.nsc.org/.

National Swimming Pool Foundation. Available from URL: http://www.nspf.com/.

Think First National Injury Foundation. Available from URL: http://www.thinkfirst.org.

US Consumer Product Safety Commission. Available from URL: http://www.cpsc.gov.