Frequent Testing of Combined Chlorine Makes Sense

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Publications:

Presented paper at Pool Asia Expo March 2011 titled Healthy Pool Water and Cyanuric Acid Phuket, Thailand

Co-authored paper titled New Field Test for Lead (Pb+2) in Soil published International Journal of Soil, Sediment and Water 2010, Vol 3, Issue 2, Article 10

Presented paper New Field Test For Lead (Pb+2) in Soil, October 2008, 24th Annual International Conference on Soils, Sediments, and Water, held at the University of Massachusetts, Amherst, MA.

Presented paper at Pittsburgh Conference, Feb 2007, Chicago, IL., titled Evaluation of Field Test Kits for Detection of Arsenic in Drinking Water.

Co-authored paper presented at Mid-Atlantic Association of Forensic Scientists conference titled Dept of the Navy Military Working Dog Drug Detection Program.

Presented paper at American Academy of Forensic Sciences titled Suggested Guidelines for the Collection and Analysis of Gunshot Residue.

Co-authored paper titled Incubation Temperature Effects on Cocaine Volatile Headspace Sampling by Solid Phase Microextration / Gas Chromatography / Mass Spectrometry presented at Mid-Atlantic Association of Forensic Scientists annual conference.

Co-authored paper presented at Mid-Atlantic Association of Forensic Scientists conference titled Dept of the Navy Military Working Dog Drug Detection Program.

Other qualifications:

Professional Membership:
The South River Federation, Inc., (a Chapter of the Chesapeake Bay)
American Chemical Society
Mid Atlantic Association of Forensic Scientists
American Board of Criminalists (ABC) Certificate (Diplomate 1999)
High School Science Fair Judge: Anne Arundel County, MD. Loudoun County, VA.; Cape May County, NJ.

Awards: Lincoln University General Physics Award, Norman Gaskin Memorial Prize in Organic Chemistry, American Chemical Society Scholastic Achievement Award, Who's Who Among American Colleges and Universities. Received numerous job performance awards. MFS Graduate Research Advisory Honorarium from George Washington University.

Abstract

A review of recently published articles and research supports more then ever that Combined Chlorine (CC, also referred to as chloramines, monochloramines) needs to be carefully monitored in swimming pools. This presentation will review the chemistry that occurs in chlorinated pools: Chlorine and the

interaction of sweat, urine, skin cells of swimmers form the many chlorinated compounds know as Combined Chlorine (CC). Many of these compounds are mutagenic at typical concentrations found in pool environments. Clear association of CC in pools to health effects such as asthma has been substantiated. Combined Chlorine can be a serious health risk for swimmers especially in indoor pools. A review of currently available CC test methods will be covered in detail.

Frequent Testing of Combined Chlorine Makes Sense

Maris Jaunakais, Consultant
Industrial Test Systems, Inc.

World Aquatic Health™ Conference • October 13, 2011

OVERVIEW

- Water Balance for a Healthy Pool Water
- Chlorination of Pools/Spas
- Formation of Chloramines
- Chloramines associated health problems
- Eliminating Chloramines - Shocking a pool
- Testing for Chloramines

WATER BALANCE

- **Healthy Water = Balanced Water**

- For Balanced Water must consider 5 things
- Components of Langelier Saturation Index (LSI)
  - pH
  - Total Alkalinity
  - Calcium Hardness
  - Total Dissolved Solids (TDS)
  - Temperature

HEALTHY POOL WATER

- Start with Balanced Water but other chemicals introduced that affect pH, Total Alk, Ca Hardness, TDS:
- Sanitizer / oxidizer used to disinfect affects pH
- Chlorine Stabilizer such as Cyanuric acid
- And chemicals needed to address other pool water problems, such as cloudy water, algae, mold, stains, etc.
- Rain Water

Why Need for Balanced Pool Water

- Protect bathers health – prevent the transmission of infectious disease, prevent skin irritation, respiratory problems, eye irritation; etc.
- Protect the Pool or Spa and Equipment from corrosion and/ or scale-formation, and discoloration
- To minimize potential hazards from disinfection by-products.

POOL WATER BALANCE

- Defined as water that will neither scale nor corrode pool or spa surfaces and / or equipment
- **Corrosion** involves the dissolving or wearing-away of a material
- **Scale** is the white deposit or precipitate that builds up on fixtures, surfaces, and equipment
- Balanced water is non-irritating to the eyes and skin of bathers, and allows the sanitizer to work effectively.

SOURCES OF CHEMICALS IN POOL WATER

- Chemicals used to treat source water, including disinfection by-products, lime and alkalis, phosphates and, for chlorine treated systems, monochloramines
- Bather's sweat, urine, dirt, lotions, sunscreen, cosmetics, soap residues, deodorant, hair spray, etc.
- Items introduced from environment such as debris, dirt, leaves , vegetation, etc. that also contribute chemicals
- Chemicals used to treat pool water - pH correction chemicals, sanitizers, oxidizers, stabilizer, chemicals for treating algae, mold, etc.
- Disinfection by-products - trihalomethanes, haloacetic acids, chlorate, nitrogen trichloride, etc.

WATER BALANCE - pH

- pH is most important factor
- Affects all other chemical / balance parameters
- pH in the ideal range between 7.2 - 7.8 will be comfortable for the human eye
- High pH reduces Chlorine's effectiveness

TOTAL ALKALINITY (AL)

- The ability of the water to resist a change in pH
- "buffering capacity"
- The sum of bicarbonates, carbonates, and hydroxide in the water
- Water with an appropriate amount of AL will resist wide and rapid fluctuations in pH (called pH bounce)
- Proper AL stabilizes pH
- Bicarbonate buffers essentially neutralize acids and alkaline before they can affect the pH

TOTAL ALKALINITY (AL)

- If AL is low, pH will be readily affected by anything introduced into the pool
- If AL is high, pH will be difficult to adjust (water will scale)
- Total Alkalinity is **the key to water balance** and it is recommended that it **should be adjusted FIRST**, even before pH
- Anytime you add acid or alkaline to adjust the pool or spa AL, you will also be changing the pH, and vice versa

TOTAL ALKALINITY (AL)

Low Alkalinity can cause:

- Wide and rapid pH fluctuations
- Corrosion of pool or spa and equipment
- Skin / Eye Irritation
- Low pH
- Adding acid like Muriatic Acid will lower AL

TOTAL ALKALINITY (AL)

- The Sanitizer used influences Alkalinity
- Different sanitizers have different pHs
- The ideal level is 80-100 PPM with sanitizers like Sodium, Calcium, or Lithium Hypochlorite
- The ideal level is 100-120 PPM with sanitizers like Dichlor, Trichlor, Bromine, or Chlorine Gas

- Primary unit of measurement for concentration is **mg/L** or as commonly used parts per million (**PPM**)

CALCIUM HARDNESS (CA)

- Defined as the amount of Calcium Salts in the water (reported as Calcium Carbonate)
- Term Calcium Hardness used because hardness in tap water is due to Calcium
- Magnesium, barium and sulfate also can contribute to the Hardness
- The water used to fill the pool will vary in its calcium content depending on region of the country and city or well water used
- Ideal range is 200-400 PPM

CALCIUM HARDNESS (CA)

Low Calcium Hardness Causes	IDEAL RANGE	High Calcium Hardness Causes
1. Etching of plaster, concrete, and grout 2. Corrosive water 3. Pitting of surfaces	**200 ppm TO 400 ppm**	1. Scale formation 2. Filter calcification 3. Cloudy water 4. Decrease in heater efficiency 5. Reduced circulation 6. Rough pool surfaces 7. Eye Irritation

CALCIUM HARDNESS (CA)

- Should be tested regularly.
- Pool and spa water must have a certain amount of Calcium
- Calcium Hardness, when outside the optimal range, can either allow corrosion to occur or cause scaling.
- Make-up water with high calcium is "hard water"
- Make-up water with low calcium is "soft water".
- Low water hardness allows corrosion or pitting of calcium rich surfaces such as concrete, plaster, and grout.

TOTAL DISSOLVED SOLIDS (TDS)

- TDS is the total of all the dissolved material in the water.
- TDS value is contributed and influenced by ions of calcium, magnesium, sulfate, chloride, sodium, potassium, phosphate, nitrate, and all other ions; Alkalinity; Cyanuric Acid; and other chemicals present in the water.
- Anything dissolved in the water is part of TDS.

TOTAL DISSOLVED SOLIDS (TDS)

Potable Water	100-1000 ppm
Sea Water	35,000 ppm

Total Dissolved Solids are added into the pool water by:

CALCIUM HARDNESS	ALGICIDES	TOTAL ALKALINITY
SOURCE WATER	WIND BLOWN DUST & DIRT	EVAPORATION
DISINFECTANTS	BATHERS	BODY OILS
BALANCE CHEMICALS	ANYTHING ADDED	

TOTAL DISSOLVED SOLIDS (TDS)

- High TDS levels may increase undesirable events:
  1. Algae growth despite adequate sanitizer
  2. Corrosion despite the water being otherwise balanced
  3. Cloudy water despite adequate filtration
  4. Eye and skin irritation
  5. Deposits on the pool wall

TOTAL DISSOLVED SOLIDS (TDS)

- Over time, TDS will increase in a pool
- TDS may actually double in a year
- Why? - chemicals are added, debris and dirt blow or wash in, & water evaporation
- If TDS exceeds 1500 ppm of initial level, drain and replace at least some of water
- TDS maximum 3000 ppm ??

TEMPERATURE

- Temperature is an important water balance factor but difficult to control
- Pool water is usually held at between 78 - 82◦ F
- Spa water is held much higher at from 96 - 104◦ F

SANITIZER AND DISINFECTANTS

- A disinfectant kills disease-causing organisms
- A sanitizer kills all microorganisms with impunity, (USA EPA 99.9% effective) i.e., chlorine
- Oxidation refers to the "chemical reaction" that organic contaminants or waste products undergo

Because the pool environment is constantly exposed to new contaminants, two important considerations:

1. Sanitize the water to kill microorganisms
2. Oxidize organic contaminants

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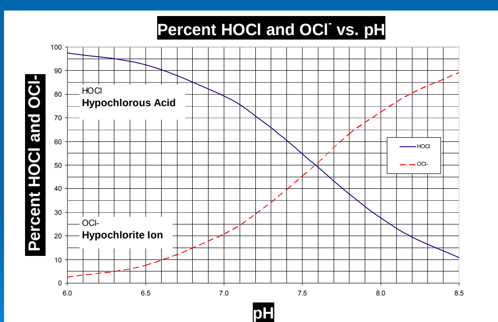
CHLORINE

- Chlorine is most popular sanitizer, disinfectant, algae killer, and oxidizer in the world
- Inexpensive, safe when used properly, and effective.
- In a pool or a spa, chlorine pulls double-duty as a sanitizer and oxidizer
- Chlorine is most effective under certain conditions. The single most important factor is pH. The pH must be in the optimal range in order for chlorine to be effective

pH VERSUS CHLORINE SPECIES



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CHLORINE

- Effective against a broad range of microorganisms
- More than 79,000 tons per year are used in the United States and Canada to treat water
- Monitoring chlorine concentrations is very important
- Used in pools to protect bathers health, water clarity and equipment
- Several pathogens can be transmitted in water
- Inactivation of pathogens depends on contact time
- In USA Public Health Departments require public pools be routinely tested for chlorine concentration

GERM INACTIVATION TIME IN 1 PPM CHLORINATED WATER

GERM	INACTIVATION TIME
E. Coli O157:H7 Bacterium	Less than 1 minute
Hepatitis A Virus	About 16 minutes
Giardia Parasite	About 45 minutes
Cryptosporidium Parasite	About 15300 minutes (10.6 days)

pH 7.5, 77 °F

SOURCES OF CHLORINE

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Chemical Name	Chemical Formula	Form	% Chlorine
Chlorine Gas	Cl_2	Gas	100%
Calcium Hypochlorite	$Ca(OCl)_2$	Solid	65-70%
Sodium Hypochlorite	NaOCl	Liquid	~12%

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ABOUT THE SOURCES OF CHLORINE

- Despite chemical & physical differences among Chlorine sanitizer, all form hypochlorous acid
- Change occurs when form of sanitizer is added to water
- Hypochlorous acid (HOCl) is effective disinfecting agent

CHLORINE AMMONIA REACTION

- **Chlorine (as HOCl) reacts with ammonia (NH_3) and organic nitrogen compounds such as proteins and amino acids in pool**
- **A series of reactions can occur that form various chloramines**
- **1. $HOCl + NH_3 = NH_2Cl + H_2O$**
  hypochlorous acid + ammonia = monochloramine + water
- **2. $NH_2Cl + NH_3 = NHCl_2 + H_2O$**
  monochloramine + ammonia = dichloramine + water
- **3. $NHCl_2 + NH_3 = NCl_3 + H_2O$**
  dichloramine + ammonia = trichloramine + water
- **The three species of chloramines constantly and rapidly shift from one form to another. The species that predominates is dependent on pH, temperature, turbulence, and the chlorine to ammonia ratio.**

Chloramines / Combined Chlorine

- Chloramines – chemical compounds formed by free chlorine reacting with nitrogen containing contaminates in pool water
- Chloramines form because of insufficient free chlorine
- Chloramines have disinfectant properties but considerably (from 40 to 60 times) less effective than free chlorine
- Contaminates come from swimmer wastes such as sweat, urine, body oil, etc.
- The pool smell of “chlorine” is actually smell of combined chlorine, i.e., trichloramines
- Ideally, Chloramine levels should be as close to zero as possible.
- 20% Drinking water in US is Monochloramine disinfected water and may be used as pool source water

Chloramines / Combined Chlorine

- Chloramines are all respiratory irritants with trichloramine being the most toxic (order of toxicity: monochloramine < dichloramine < trichloramine-most severe.)
- Disinfection byproducts are chemicals formed when a disinfectant combines with organic matter or other chemicals present in water.
- Trihalomethanes (THMs) are disinfection byproducts that are formed when organic matter in the water combines with chlorine.
- THMs are also formed with chloramine disinfection but at a lower concentration-- (approximately 1/3 less) than chlorine.
- THMs may be possible but not proven cancer causing byproducts.

Chloramines / Combined Chlorine

- **While Chlorine and its disinfection byproducts have been studied extensively for years, disinfection byproducts of chloramine have not been studied extensively.**
- **EPA has very limited dermal (skin) and inhalant (respiratory) studies on chloramine as disinfectant for drinking water.**
- **EPA has limited cancer studies on humans or animals.**
- **In one study mononuclear cancer was detected in female rats.**
- **Another study shows reproductive toxicity and reduced reproductivity in mice and hamsters.**
- **Research to date only explores oral (such as drinking tap water) exposure. Limited info about exposure through bathing or inhaling indoor vapors.**

Chloramines / Combined Chlorine

- Combined chlorine is calculated from these values as follows:
- **Combined chlorine = Total chlorine - Free chlorine**

- ***Combined chlorine (CC) or chloramines* - chlorine in the water that has reacted and combined with ammonia, nitrogen-containing contaminants and other organics**
- ***Total chlorine* - sum of both the free available and combined chlorines**
- ***Free chlorine (FC)* - chlorine remaining that has not reacted with contaminants and is therefore "free" to disinfect**

Chloramines / Combined Chlorine

- Chloramines (combined chlorine) are poor sanitizers & have a gaseous tendency. Presence of chloramines (and dichloramines/trichloramines in particular) cause following physical symptoms:

- Red, burning eyes
- Burning sensation in nose, throat and lungs
- Dry, itchy skin and dry hair
- Chloramines can cause and/or aggravate respiratory problems, cause breathing difficulty leading to "swimmers' asthma" particularly in young children
- In addition, pools have tendency to discolor, becoming milky or green with algae due to the low sanitizing ability of combined chlorine.

Chloramines / Combined Chlorine

- **Chloramine fumes can cause lung congested** (Lifeguard Lung.") **& cause sneezing, sinus congestion, coughing, choking, wheezing, shortness of breath, and asthma**
- **Cause increase in asthma due to exposure from chloramines in indoor swimming pool areas**
- **Chloramine damages mucous membranes. Lung damage in those exposed to chloramines in indoor pool air is similar to that seen in regular smokers**
- **Chloraminated vapor from showers, baths, hot tubs, dishwashers, and other household appliances contains volatilized chemicals that can be inhaled and cause irritation to the respiratory tract.**
- **Toxic exposure to chemicals (like chloramine) in water is greater from taking a shower than from drinking the same water**
- **An individual can experience long term effects from repeated exposures to a chemical (like chloramine) at levels not high enough to make them immediately sick**
- **Likelihood of becoming sick from a chemical increases with exposure time and concentration**
- **One study found that there was an increase in deaths from influenza and pneumonia in the communities that used chloramine**
- **Chloramine exposure damages lung mucosa, making lungs more susceptible to allergens and infections.**

Source:

- Substances Fact Sheet for Chloramine, New Jersey Department of Health and Senior Services
- Belgium study from the Catholic University of Louvain
- Health24 News article
- Toxic Showers and Baths article
- Hazardous Substances Fact Sheet for Chloramine
- Zierler, et al

Chloramines / Combined Chlorine

Skin Problems - at high levels & long exposure times, Chloramines can cause severe skin reactions:

- Rash, dry skin, itching, flaking, welting, blistering, chapping, burning sensation, cracking, scarring, bleeding, pigmentation
- Can aggravate other skin conditions such as eczema and psoriasis.
- Can cause bleeding lips, dry mouth and dry throat.
- Can cause burning, red, and dry eyes.
- Skin exposure to ammonia "breaks down cell structural proteins, extracts water from the cells and initiates an inflammatory response, which further damages the surrounding tissues."

Chloramines / Combined Chlorine

Digestive and Gastric Problems

- Chloramines can damages digestive mucosa.
- Can aggravate digestive disorders.
- One research suggests that monochloramine is responsible for gastric cancer. (Journal of Gastroenterology, 1997, "Enhancement by Monochloramine of the Development of Gastric Cancers in Rats; a possible mechanism of Helicobacter, pylori-associated gastric carcinogenesis.

Health Departments Enforce rules because swimmers leave behind:

- Up to 50 ml of urine per swimmer
  (mostly by children)
- 100 ml of sweat per swimmer each hour
- Up to 100,000,000 bacteria per swimmer
- Organics like sunscreen, deodorant, hair spray, etc
- Greatest concern is a fecal or diarrhea accident (resulting in release of Ecoli, cryptosporidium)

ENVIRONMENTAL HEALTH PERSPECTIVES

- In the November, 2010 issue of EHP (ehponline.org) Environmental Health Perspectives several articles discuss the health issues involving swimming pools. Several statistics and comments in them are worth noting carefully because they will result in changes in the near future.

ENVIRONMENTAL HEALTH PERSPECTIVES

- The Nov. 2010 article in EHP entitled "*What's in the Pool? A Comprehensive Identification of Disinfection By-products (DBP) and Assessment of Mutagenicity of Chlorinated and Brominated Swimming Pool Water*" concluded:
  1. Many new DBP's not identified previously in swimming pool or drinking water are found to be mutagenic at typical levels detected.
  2. DBP's formed from chlorine interaction with sweat, urine and skin cells of swimmers.
  3. These DBP's are part of the Combined Chlorine

Center for Disease Control and Prevention (CDC)

- CDC review: 12.1% pools inspected (of 111,000 in 13 states) were immediately closed for serious health or safety violations
- Current laws for pool health and safety are regulated at State and local levels and vary widely
- CDC recommends that Swimmers can and should take more control of their public bathing choices
- CDC developing science-based **Model Aquatic Health Code (MAHC)** guide for local and state agencies needing guidance to update or implement standards governing the design, construction, operation, and maintenance of swimming pools (Steering Committee completed two reviews Disinfection & Water Quality module but Technical Committee & public comment pending.

ENVIRONMENTAL HEALTH PERSPECTIVES

- **CDC recommends these points to swimmers:**
  1. **Do not swallow pool water or get it in your mouth**
  2. **Observe odor at pool since well maintained pools should have NO disinfectant odor and water should not cause eye irritation or coughing.**
  3. **Pool side should not feel slimy or sticky.**
  4. **Ask management if pool is frequently tested for pH and disinfectant. What were the last results?**
  5. **SWIMMERS SHOULD BRING THEIR OWN TEST STRIPS! To confirm chlorine level is 1-3 PPM or Bromine is 2-5 PPM and pH is 7.2-7.8.**
  6. **Notify management if your testing shows problem and do not swim in the pool until problem is corrected.**
  7. **Asthma sufferers benefit from swimming but if symptoms worsen on swim days then disinfection by-products may be the trigger. Talk to management about pool and the symptoms.**

Chloramines / Combined Chlorine

State Regulations - Chloramine maximum allowable amount public outdoor pools, e.g.,

Pennsylvania: 0.2 ppm max. tested & logged 2X daily, Weekly superchlorination for pools, achieved by increasing the free chlorine residual to ten times the combined chlorine level FC 0.4 min., 2 – 4, 5 max.

New Jersey: 0.2 ppm FC: 1 – 4 outdoor 1- 3 indoor

Maryland: 0.2 ppm FC: 1.5 – 10 ppm

Massachusetts 0.2 ppm FC: 1.0 - 3.0

Some states do not address max. allowable CC levels

Suggested Standards for Swimming Pools

Association of Pool & Spa Professionals (APSP):

- Free chlorine: 2.0 - 4.0 ppm
- Combined chlorine: **None**
- pH 7.2 - 7.8 (ideal range of 7.4 - 7.6)
- Total alkalinity:
  - Liquid chlorine, cal hypo, lithium hypo 80 - 100 ppm
  - Gas chlorine, dichlor, trichlor and bromine compounds 100 – 120 ppm
- Total dissolved solids (TDS): Not to exceed 1500 ppm greater than at pool start-up
- Calcium hardness: 200 – 400 ppm
- Cyanuric acid: 30 – 50 ppm

EUROPEAN DIN REGULATION

- To overcome CC issues, the German DIN regulation requires pools be drained:
  1. Once a month or
  2. ¼ every week or
  3. 1/30 every day
- Fresh water is added routinely which removes or dilutes chloramines (organic & ammonia) and other contaminates
- Universal use of ozone and / or UV for pools and free chlorine levels are maintained at 0.4 to 0.6 ppm

Break Point Chlorination

- Breakpoint chlorination with chlorine or super oxidation with a non chlorine oxidizer eliminates chloramines
- Ultraviolet & ozone systems can also reduce chloramines in pools
- Break Point Chlorination is the point at which enough Free Chlorine is added to eliminate all the combined chlorine, ammonia and nitrogen compounds

Break Point Chlorination

- To achieve breakpoint, chlorine added must be about ten times the amount of combined chlorine (CC) for 1 to 4 hours
- If too much chlorine is added, it may take a long time to drop to safe levels before bathing can be resumed
- Chlorine levels should return to acceptable levels (i.e. <5 mg/l) before bathing permitted in the pool
- This is an "all or nothing" process
- Insufficient chlorine will worsen the problem resulting in more chloramines formed
- Repeated "shocking" without reaching breakpoint will result in the pool reaching a point of no return
- Partial or complete draining of the pool water and refilling with fresh water may then be necessary

Tested Four Pools

March 2 and 3, 2011

Pool	#1	#2	#3	#4
Alkalinity (80 – 120)	27	38	78	100
pH (7.2 – 7.8)	6.9	7.1	8.0	8.0
Phosphate	0.55	0.48	0.46	0.85
Ca Hardness (200-400)	<10	<10	85	76
Chloride Salt	485	565	133	222
Free Cl (2 – 4)	1.12	6.81	1.12	0.22
Combined CL (0)	**0.11**	**0.04**	**0.08**	**0.12**
Cyanuric Acid (30 – 50)	27	15	3	0

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CHLORINE TEST

- Acceptable or compliant (uses DPD **(N,N diethyl-p-phenylene diamine)**)
- Appropriate for the staff technical ability
- Robust, reagents and equipment are reliable & stable
- Unaffected by interferences
- Accurate when performed correctly

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DPD CHLORINE TESTING

- DPD methods are preferred for chlorine measurement
- DPD methods determine concentration by color formed when chlorine & DPD react
- DPD-FAS Titration method determines chlorine by measuring the amount of FAS Titrant needed to bleach out DPD-chlorine color formed
- Most state & local health departments recommend or approve DPD tests because they are quick, enjoy wide acceptance and also have US EPA approval

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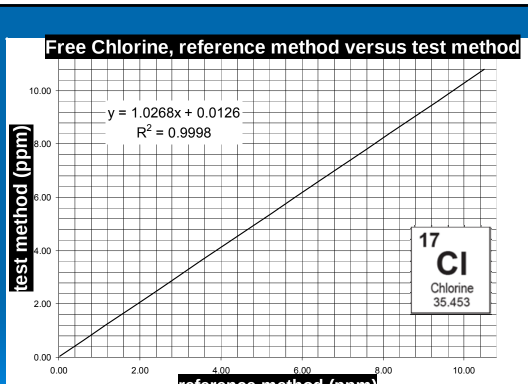

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DPD DELIVERY METHODS

- DPD-1, DPD-2, DPD-3 Liquid reagents
- DPD-1, DPD-3, DPD-4 Tablets
- DPD-1, DPD-4 Powder pillows
- DPD-1, DPD-3, DPD-4 Reagent delivery test strips

(All meet 4500-CL G reportable method)

- DPD is used for colorimetric or the DPD-FAS Titration methods to determine the chlorine concentration

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COLORIMETER + LIQUID DPD POOLSIDE TESTING PROCEDURE

1. Rinse out photocell 3 times with pool water
2. Fill to 10 ml line with pool water sample
3. Cap cell, wipe cell wall
4. Place cell in colorimeter and zero meter
5. Remove cell and uncap
6. Add five drops of buffer DPD-1 solution
7. Add five drops of indicator DPD-2 solution
8. Cap cell and mix for a few seconds
9. Wipe cell wall
10. Place in colorimeter and read chlorine result

COLORIMETER + DPD-1 POWDER PILLOW POOLSIDE TESTING PROCEDURE

1. Rinse out photocell 3 times with pool water sample
2. Fill to 10 ml line with pool water sample
3. Cap cell, wipe cell wall
4. Place cell in colorimeter and zero meter
5. Remove cell and uncap
6. Tear open powder pillow and add DPD-1
7. Cap cell and mix for 20 seconds
8. Wipe cell wall
9. Place in colorimeter and read chlorine result

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COLORIMETER + DPD-1 TABLET POOLSIDE TESTING PROCEDURE

1. Rinse out photocell 3 times with pool water sample
2. Fill cell to 10 ml line with pool water sample
3. Cap cell, wipe cell wall
4. Place cell in colorimeter and zero meter
5. Remove cell, uncap cell,
6. Pour out water except for a few drops
7. Add DPD-1 Tablet and crush with tablet crusher
8. Add pool water back to 10 ml line
9. Cap cell and mix for about 20 seconds
10. Wipe cell wall
11. Place in colorimeter and read chlorine result

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COLORIMETER + DPD-1 TEST STRIP POOLSIDE TESTING PROCEDURE

1. Rinse out photocell 3 times with pool water
2. Fill meter cell to capacity with pool water
3. Turn meter on and Zero
4. Dip DPD-1 Test Strip into sample for 20 seconds with back and forth motion (Press **"READ"** button that begins countdown timer)
5. Read chlorine result

NOTE: This is a recent development in DPD testing

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NEW DPD-1 TEST STRIP METHODOLGY DETECTS FREE & COMBINED CHLORINE

Step 1 and Step 2

Rinse out photocell 3 times with pool water

Fill meter cell to capacity with pool water

NEW DPD-1 TEST STRIP METHODOLGY DETECTS FREE & COMBINED CHLORINE

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Step 3

Turn meter on and Zero

NEW DPD-1 TEST STRIP METHODOLGY DETECTS FREE & COMBINED CHLORINE

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Step 4

Dip DPD-1 Test Strip into cell and press **READ** starting the 20 second countdown timer. During this time move the strip in a gentle back and forth motion.

Remove and discard the strip after “1” on display disappears.

NEW DPD-1 TEST STRIP METHODOLGY DETECTS FREE & COMBINED CHLORINE

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Step 5

Read chlorine result

Free Chlorine = 1.58 ppm

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NEW DPD-1 TEST STRIP METHODOLGY DETECTS FREE & COMBINED CHLORINE

Step 6

- Determine **Combined Chlorine** concentration: Press **“ZERO,”** then press **“READ”** button & simultaneously dip eXact® Strip Micro DPD-3 into water sample for 20 second count down.

  (During 20 seconds constantly move strip back & forth, which releases the Potassium Iodide reagent from the strip & mixes the sample)

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NEW DPD-1 TEST STRIP METHODOLGY DETECTS FREE & COMBINED CHLORINE

Step 7

- At end of 20 seconds meter will display “1” at which time remove & discard strip. Meter automatically reads & displays the **combined chlorine** concentration, & stores & test result in memory.
- Discard sample & rinse with water before storage. This DPD test method is compliant with US EPA & health department requirements for Free & Combined Chlorine.

Combined Chlorine = 0.31 ppm

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TOTAL CHLORINE (TC) = FREE CHLORINE (FC) + COMBINED CHLORINE (CC)

- Total chlorine = FC + CC
- Free chlorine = 1.58 ppm (FC)
- Combined chlorine = 0.31 ppm (CC)
- Total chlorine is = 1.58 + 0.31 = 1.89 ppm
  In this example the Combined chlorine is above the recommend level of 0.20 ppm and this pool needs to be shocked: in this example (10 X 0.31 = 3.1). This pool should be shocked by increasing the pool chlorine level by 3.1 ppm; therefore final chlorine level will be about 5 ppm

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FAS DPD POOLSIDE TESTING PROCEDURE

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Chlorine
35.453

1. Rinse out cell 3 times with Pool water sample
2. Fill to 25 ml line with pool water sample
3. Add five drops of buffer DPD-1 solution
4. Add five drops of indicator DPD-2 solution (or one scoop of DPD Powder)
5. Swirl to mix for a few seconds
6. Add one drop of FAS reagent, swirl to mix and observe color
7. Add next drop of FAS Reagent, swirl to mix and observe color *(Repeated for a total of 14 drops)*
8. When pink color disappears Multiple 0.2 by number of drops you have used to make color disappear This sample has (0.2 X 14 drops) 2.8 PPM Chlorine

Note: This procedure has 20 steps

Two "A" Resort Pools and Tap Water Tested

March 2, 2011

Pool	#1	#2	Tap Water
Alkalinity (80 – 120)	27	38	56
pH (7.2 – 7.8)	6.9	7.1	6.4
Phosphate	0.55	0.48	0.49
Ca Hardness (200-400)	<10	<10	16
Chloride Salt	485	565	365
Free Cl (2 – 4)	1.12	6.81	0.01
Combined CL (0)	**0.11**	**0.04**	**0.03**
Cyanuric Acid (30 – 50)	27	15	-

Two "B" Resort Pools and Tap Water Tested

March 3, 2011

Pool	#3	#4	Tap Water
Alkalinity (80 – 120) 78	100	82	-
pH (7.2 – 7.8)	8.0	8.0	7.4
Phosphate	0.46	0.85	0.22
Ca Hardness (200-400)	85	76	80
Chloride Salt	133	222	230
Free Cl (2 – 4)	1.12	0.22	0.01
Combined CL (0)	0.08	0.12	0.03
Cyanuric Acid (30 – 50)	3	0	-

eXact Micro 10

Engineered by Industrial Test Systems, Inc.
Was used for this Project

- 525 nm LED Spectrophotometer
- **USEPA, DIN, & ISO Compliant for Free, Combined, & Total Chlorine Testing**
- Factory Calibrated
- 20 mm cell path
- Built in sealed 4 milliliter cell
- Waterproof, buoyant
- Uses patented reagent strip technology

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eXact Micro 10 Specifications

eXact® Micro 10 Direct Read Specifications
No Look-up Tables Required

Menu	Tests for	Range	Resolution	+/- Accuracy
AL1	**Total Alkalinity**	20 - 180 ppm	1	25
PH2	**pH**	6.2 - 8.4 pH	0.1	0.3
CL3	**Free Chlorine (DPD-1) & Combined Chlorine (DPD-3)†**	0.00 - 11.0 ppm	0.01 (0.00 - 5.99 ppm)	0.02
			0.1 (6.0 - 11.0 ppm)	0.1, or 10%
CL3	**Ozone (DPD-4)**	0.00 - 11.0 ppm	0.01 (0.00 - 5.99 ppm)	0.02
			0.1 (6.0 - 11.0 ppm)	0.1, or 10%
PO4	**Phosphate**	0.04 - 3.20 ppm	0.01	0.02
CA5	**Calcium as $CaCO_3$**	20 - 990 ppm	10	20 or 7%
CH6	**Chloride / Salt (as NaCl)**	1000 - 9990 ppm	100	5%
CY7	**Cyanuric Acid**	3 - 90 ppm	1	5%
TR8	**Transmission** (30 other test parameters)	99.9 - 0.01 %T	0.1 (99.9 - 10.0 %T)	0.1
			0.01 (9.99 - 0.01 %T)	0.01

†Bromine easily obtained by multiplication factor using CL3 menu

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MAINTAINING HEALTHY POOLS and SPAS REQUIRE

1. Circulation
2. Filtration
3. Routine Cleaning and Maintenance
4. Testing of pool water
5. Testing of make-up water

HELPFUL RESOURCES

- **Book: Pool Chlorination Facts by Robert W. Lowry**
- Book: Intermediate Training Manual Part 1-Chemicals by Robert W. Lowry
- Book: The Ultimate Guide to Pool Maintenance by Terry Tamminen
- Book: The Pool Maintenance Manual by Terry Tamminen
- Internet: Florida Health Dept: http://www.doh.state.fl.us/Environment/water/swim/index.html
- Internet: CDC http://www.cdc.gov/healthyswimming/

STRIVE FOR BEST RESULTS

- Customers expect it
- Health Departments require it
- Liability issues for bad results

Questions?

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