NATIONAL ENVIRONMENTAL HEALTH ASSOCIATION
CEHA California Educational Symposium - Monterey, CA - April 12, 1990
NEHA National Educational Conference - Charlotte, NC - June 24, 1990

ORP TESTING AND CHEMICAL AUTOMATION FOR SWIMMING POOLS AND SPAS

by
Jacques M. Steininger, D. Sc.[1]

Improper water testing and chemical treatment can cause serious health problems to users of commercial pools and spas. Fortunately, these can now be avoided with ORP testing and Chemical Automation, a modern technology that is both scientifically sound and cost-effective.

In 1984, an investigation of 30 commercial spas by the State Health Department in Portland, Oregon revealed that more than half of the spas (16 spas) were contaminated, as shown by high Standard Plate Counts, high Coliform levels and/or high Pseudomonas aeruginosa levels. In addition, over 90% of the spas were in violation of the chemical maintenance parameters for chlorine level, pH and/or cyanuric acid level.

In 1987, a severe outbreak of gastroenteritis affected 48 persons attending a hockey tournament in Wilmington, ND. Because of the large number of people involved, investigators were able to trace the infection to a pool/spa facility at a local motel. Since the pool and spa had a common filtration system and were reportedly chlorinated at the time, the contamination was attributed to bather overloading, resulting in insufficient chlorination.

In 1987 again, two confirmed fatalities were linked by the Vermont Department of Health to Legionnaire's disease from a contaminated whirlpool spa in a Vermont inn.

In 1989, renewed outbreaks of infectious diseases related to spas and hot tubs led the Vermont Health Department to issue a bulletin warning to all innkeepers and to require strict enforcement of hourly testing requirements. An exception was made specifically for spas equipped with chemical automation equipment.

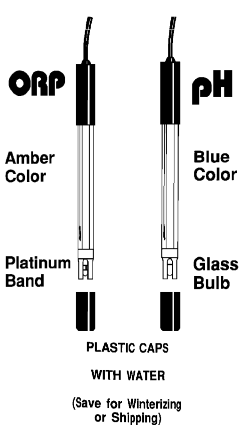

Figure 1 - ORP and pH Sensors.

These are just a few examples picked in a rapid survey of medical and environmental health journals. It must be realized, of course, that most infectious incidents go unreported because the persons involved are usually travelling and the public is not generally aware of the source of infection. These incidents are also normally not reported in trade publications for fear of alarming anyone. Residential pools and spas, which are not subject to Health Department supervision, probably fare even worse.

Table I - **HISTORY OF ORP**

1936	HARVARD UNIVERSITY Studies of ORP in Water Chlorination.
1968	GERMAN FEDERAL HEALTH DEPARTMENT Study of ORP in Swimming Pools.
1971	WORLD HEALTH ORGANIZATION Standard for Drinking Water.
1982	German DIN Standard for Swimming Pools.
1984	German DIN Standard for Hot Spas.
1985	Use of ORP for Ozone Monitoring.
1985	OREGON HEALTH DEPARTMENT Study of ORP in 30 Commercial Spas.
1988	NATIONAL SPA AND POOL INSTITUTE (NSPI) ORP Standard for Commercial Spas.

The bad news about these tragic cases is that they all result from improper water testing and chemical maintenance, caused by the use of legally acceptable but technologically obsolete equipment. The good news is that reliable and cost-effective technology is now available, i.e. ORP testing and Chemical Automation.

THE HISTORY OF ORP

The term OXIDATION-REDUCTION POTENTIAL (ORP or Redox) refers to the property of sanitizers - chlorine and bromine - to be also strong oxidizers. This means that they literally burn off germs, bacteria and other organic material in water (leaves, sweat, urine, etc).

Over 50 years ago, a research team of biochemists at Harvard University studied the oxidizing power of chlorine by monitoring it with a special sensor, called an ORP electrode, such as the one shown in Figure 1. They showed that the ORP readings were highly correlated with the bactericidal activity of chlorine for many germs and bacteria, and therefore with the bacteriological quality of the water.

This initial finding was subsequently confirmed by additional studies on drinking water and on swimming pools in different countries. This led to the recognition of ORP testing in many international and national health standards (Table I).

Figure 1 also shows a pH glass electrode that is used to measure the pH of the water. The ORP and pH sensors are quite similar in appearance and in operation and are normally used together in modern chemical automation equipment.

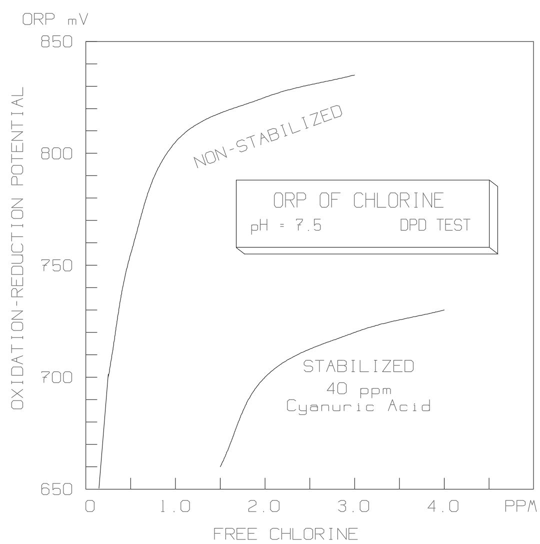

Figure2 - Oxidation-Reduction Potential of Chlorine.

THE ORP STANDARD FOR DRINKING WATER

ORP testing proved to be so reliable that it was adopted in 1971 as the standard for drinking water by the WORLD HEALTH ORGANIZATION (WHO).

Any lingering doubts about the effectiveness of chlorine and the validity of ORP testing should be dispelled by reading the following excerpts from the INTERNATIONAL STANDARDS FOR DRINKING WATER (Third Edition, Geneva, 1971).

"An exponential relationship exists between the rate of virus inactivation and ORP. An ORP of 650 mV (measured with a platinum/calomel electrode) will cause ***almost instantaneous inactivation of even high concentration of viruses****.*

Such a potential can be obtained with ***even a low concentration of free chlorine****, but only with an extremely high concentration of combined chlorine. This oxidative inactivation may be achieved with a number of other oxidants also, e.g. iodine, ozone and potassium permanganate.*

In a water, in which free chlorine is present, active viruses will generally be absent if coliform organisms are absent. In contrast, it cannot be assumed that the absence of viable coliforms implies absence from active viruses."

The following notes are pertinent to pool and spa applications.

NOTE # 1. WHO refers to a platinum/calomel electrode which reads about 45 to 50 mV lower than the standard silver chloride electrode used for water treatment. The WHO-recommended level for a silver chloride electrode is therefore 700 mV.

NOTE # 2. There is no mention of pH. This means that, contrary to a widespread myth, the same ORP standard applies over the wide range of pH values normally found in drinking waters. By contrast, the recommended pH range for swimming pools and spas is much narrower, i.e. 7.4 to 7.6.

NOTE # 3. Bromine should be included in the list of other oxidants, even though it is not specifically mentioned, probably because it was not widely used at the time.

NOTE # 4. The last paragraph shows that ORP is a better test of water quality than the standard coliform count performed routinely by public health authorities. This has been confirmed in later studies on spas.

ORP STANDARDS FOR POOLS AND SPAS

The results of an extensive study on 30 public and semi-public spas in metropolitan Portland, Oregon were presented at the 1985 meeting of the NATIONAL ENVIRONMENTAL HEALTH ASSOCIATION (NEHA) by James C. Brown, of the Oregon Health Department and Professor Eric W. Mood of the Yale University School of Medicine.

Their conclusions should convince the most incredulous.

"ORP has been shown to be a monitoring parameter which takes into account the numerous water chemistry constituents that can affect overall bacteriocidal efficacy (i.e. pH, free chlorine residual, cyanuric acid concentration, organic and nitrogenous material loading, etc.) and ***converts them into a single value*** *(i.e. millivolts) which can continuously and reliably indicate acceptable bacterial quality.*

A review of the data shows that whenever the ORP is 650 mV or more, the water is well within bacteriological standards. However, ***whenever the ORP is below 650 mV bacteriological contamination is evident.***

Public health officials should adopt a requirement for the maintenance of an ORP reading of at least 650 mV (author's note: measured with a silver chloride electrode) *for all chlorinated or brominated pools and spas.*

Maintenance of a free chlorine residual of 2.0 ppm or more does not assure safe spa water".

NOTE # 1. The recommended ORP minimum of 650 mV for swimming pools and spas refers to a standard silver chloride electrode. It is therefore about 50 mV lower than the WHO level for viral inactivation in drinking water.

NOTE # 2. The recommended ORP minimum of 650 mV was found to apply across the board, over a wide range of pH values and of cyanuric acid levels. This effectively confirms that ORP monitors the activity of hypochlorous acid, the most active form of free chlorine (see “PPM or ORP: Which Should Be Used ?”, Swimming Pool Age, November 1985).

In 1982, the Deutsche Institut für Normung (DIN), the German Standards Agency adopted an ORP standard of 750 mV (measured with a silver electrode) for public and commercial pools in Germany, a country with a well-deserved reputation for cleanliness. In 1984, it was extended to public spas. France and most other European countries have since adopted them.

In the U.S., in 1988, the National Swimming Pool Institute (NSPI) also adopted a recommendation for a minimum ORP level of 650 mV in public spas. Since then, a number of Health Departments around the U.S, have started to require the use of chemical automation with ORP control. It is clearly in the public interest to adopt this safety standard as soon as possible.

Table II - SELECTIVITY OF ORP VS TEST KITS.

FORMS OF CHLORINE	TEST KITS		ORP
	OTO	DPD	
FREE CHLORINE Fast Acting (HOCl)	YES	YES	YES
FREE CHLORINE Slow Acting (OCl -)	YES	YES	
COMBINED CHLORINE	YES		

WHY IS ORP SO USEFUL ?

There are two basic reasons for using ORP in pool and spa sanitation.

1. ORP gives a simple, reliable and accurate reading of SANITIZER ACTIVITY and WATER QUALITY. With one single measurement, one can get information that otherwise requires a series of time-consuming and expensive chemical and bacteriological tests. In particular, ORP shows the effects of incorrect pH and cyanuric acid levels, both of which cause serious problems in commercial spas. Equally important, ORP works with all standard sanitizers (chlorine and bromine) as well as with alternative sanitizers, i.e. ozone, metal ions, and UV systems ... if they are used properly.

With ORP one can determine instantly - i.e. in the field and in real time - whether the water is free of germs and bacteria, or whether it is contaminated.

2. ORP is an ELECTRONIC MEASUREMENT and, as such, it can easily be analyzed by electronic instruments to show a display of water quality or, even better, to turn chemical feeders on and off, as required to maintain perfect water chemistry.

The combination of these two key advantages has given rise to the modern technology of Chemical Automation. This technology has been used for many years in standard water treatment applications and in large public pools. With progress in modern electronics, it is now cost effective and widely available even for smaller installations, i.e. semi-public and residential.

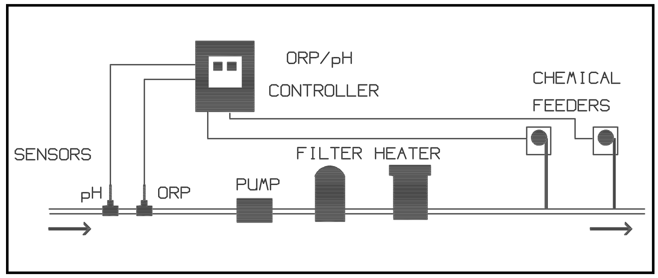

Figure 3 - Schematic of Installation of ORP/pH Controller.

HOW DOES IT WORK ?

ORP readings are expressed in millivolts (mV). They vary from 100 to 200 mV for pure water up to 700 mV or more for properly sanitized water. Figure 2 shows typical ORP values for both stabilized and non-stabilized chlorine at a pH of 7.5.

pH readings vary from 0 mV for a neutral pH of 7.0 to about -60 mV for a pH of 8.0.

The variations of ORP readings for chlorine as a function of concentration, pH level and cyanuric acid level are now understood to represent the variations in the level of Fast Acting Free Chlorine (HOCl) as it is affected by these various parameters.

Table II shows that this makes ORP a much more selective test of chlorine activity than either OTO and DPD test kits which cannot differentiate between the different forms of chlorine.

USING ORP

ORP can be tested with a portable tester or with a permanently installed analyzer or controller.

A portable ORP/pH tester is very convenient for field testing of different pools and spas. However, it is important to make sure that the sensors are in the water long enough for both readings to stabilize. For ORP, this may take from a few minutes to as long as half an hour, depending on the water temperature and chlorine concentration.

This problem is eliminated with a permanently installed tester, such as the AQUASENSE$_{TM}$ Analyzer, which gives instant readings of ORP and pH at the touch of a switch.

CHEMICAL AUTOMATION

Chemical automation equipment specially designed for swimming pools and spas is available from a number of U.S. and foreign manufacturers . All controllers use basically the same type of electrodes. The price differences among different models reflect differences in operating features, such as availability and type of readouts, overfeed safety features, chart recording, automatic superchlorination, etc.

As shown in Figure 3, installation of an ORP/pH controller is straightforward. The sensors are mounted on the recirculation line with standard PVC fittings or with saddle clamps fittings, either before or after the filter (or on a bypass line for a large pool). For chemical feeding, one can use either chemical feed pumps or a solenoid valve to control the flow of water through an erosion feeder. The pumps (or valve) are activated when required by the controller.

Figure 4 shows a sample of a continuous 3-hour chart recording of sanitizer and pH levels in a 200,000-gallon outdoor pool in Southern California automated with a $CHEMTROL_{TM}$ 500 Controller-Recorder. The traces show that close tolerances (+/ - 0.1 ppm of chlorine and +/- 0.1 pH unit) can be maintained even with intense sunlight and with varying bather loads and levels of swimming activities.

THE ECONOMICS OF CHEMICAL AUTOMATION

The best news about Chemical Automation is that it is practically free! Costs savings analyses show that a properly designed controller normally pays for itself within one to two years through savings in chemicals, labor and repairs.

In effect, chemical automation makes it possible to use less chemicals in a more efficient way. It is therefore no longer a luxury but a must for all commercial pools and spas as well as a popular feature for residential installations.

TABLE III - 1990 PRICE RANGE OF ORP EQUIPMENT

TYPE	PRICE RANGE	APPLICATIONS
ORP/pH ANALYZER	$ 300-400	Residential & Sanitarians.
ORP CONTROLLER	$ 500-700	Residential, Small hotels, motels, condos, health clubs, etc.
ORP/pH CONTROLLER	$ 900-2,000	
ORP/PPM/pH CONTROLLER	$ 2,000-3,000	All medium and large pools and spas
ORP/PPM/pH CONTROLLER-RECORDER	$ 3,000-6,000	

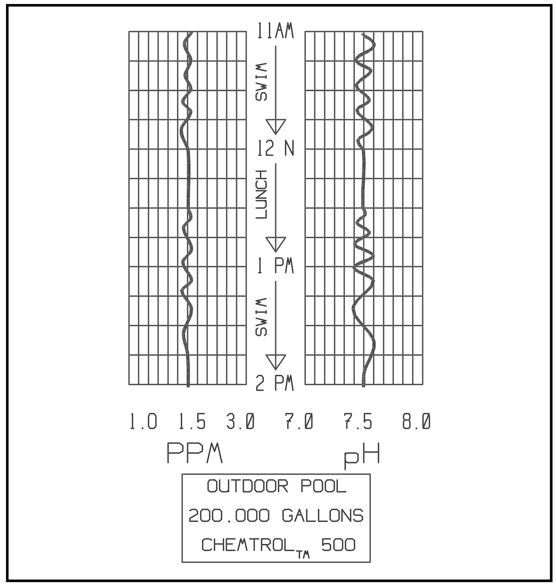

Figure 4 - Chart Recording of Chlorine and pH Levels with Chemical Automation.

IMPLEMENTATION PROGRAM

New technological developments in automatic water testing now make it possible to provide better protection for the bathing public and to facilitate the supervisory role of public health agencies. The following 4-step progressive implementation program is therefore recommended for adoption by state and local health departments across the country.

STEP 1.Recommend an ORP level of 700 to 750 mV for pools and spas already using chemical automation.

STEP 2.Recognize lower sanitizer levels if the minimum ORP level of 700 mV is maintained at all times.

STEP 3.Require ORP testing of all public and semi-public pools and spas, especially those using cyanuric stabilization or other alternative sanitation systems (metal ions, UV, etc).

STEP 4.Require chemical automation of ORP and pH for all public and semi-public pools and spas.

[1] Dr. Steininger is President of **SANTA BARBARA CONTROL SYSTEMS**, 5375 Overpass Rd, Santa Barbara, CA, 93111, the manufacturer of the $AQUASENSE_{TM}$ and $CHEMTROL_{TM}$ lines of Chemical Automation equipment for pools and spas.

Chemtrol TM
A DIVISION OF
SANTA BARBARA CONTROL SYSTEMS
Santa Barbara, CA 93111

CALL TOLL FREE
800-621-2279
www.sbcontrol.com