Recreational Water Disinfection by Copper/Silver Ions

(Synergistically with Chlorine), ABSTRACT by *CHARLES W. BEER, Ph.D.*

Efficacy of Copper/Silver Ion Generation with Reduced Chlorine Concentrations on Disinfection and Operation of a Municipal Swimming Pool.

ABSTRACT

The disinfection of swimming pool water in the Town of Brookline, Massachusetts' Municipal Swimming Pool Recreational Facility using chlorine concentrations according to the provisions of Chapter V of the Massachusetts Sanitary code (1.0 ppm free available chlorine) is compared with the use of Copper/Silver ion generation with the use of low levels of free available chlorine (0.4 ppm). Comparisons are made usin5 standard methods for the detection of coliform bacteria and heterotrophic bacteria using the standard plate count method. In addition, comparisons are made relative to trihalomethane production (THM) under conditions of chlorine disinfection alone and copper/silver ion.

I. Bathing Water Microorganisms and Traditional Disinfection Techniques

Microorganisms, including bacteria, protozoa and viruses occur naturally in recreational waters. Some of these microorganisms can be pathogenic, i.e., capable of causing human disease, and are, therefore, of legitimate public health concern. In swimming pools, these microorganisms may be introduced into the water by "carriers" and transmitted to other bathers via mechanisms of ingestion, inhalation, or broken skin. The literature is rife with instances of disease transmission involving the use of recreational waters (1).

Proper treatment of swimming pool water is essential to protection of the public health from diseases spread by microorganisms as discussed above. Swimming pool water treatment methodologies have traditionally incorporated the agglomeration of microorganisms and other water impurities utilizing chemicals such as aluminum sulfate and subsequent filtration through a medium such as sand or diatomaceous earth. However, due to a variety of reasons, including but not limited to the wide variation in size of microorganisms, the efficiency of the agglomeration technique and break-through in the filter medium, this treatment technology cannot be solely relied upon for water purification purposes. Effective disinfection of properly treated swimming pool waters has traditionally been accomplished by the addition of chlorine and chlorine compounds (2)(3)(4). In larger pools, chlorine is normally dispensed through a calibrated flow meter as gaseous chlorine or in aqueous solution as sodium hypochlorite, while in smaller residential pools, chlorine is dispensed as solid calcium hypochlorite. In all cases the active disinfecting agent is with low chlorine levels. Finally, the results of bather satisfaction using a bather survey technique are discussed under conditions of each test protocol. hypochlorous acid (HOCL). To insure effective elimination of all pathogenic microorganisms and to provide excellent general sanitary quality of swimming pool waters, State Health and/or Environmental regulatory agencies require that the bathing water contain an excess amount of free available chorine (FAC) above the amount which enters into reactions designed to inhibit the activity of microorganisms. In Massachusetts, swimming pool operators are currently required to maintain FAC levels of 1.0 ppm at all times when a pool is in use.

II. Disinfection Using Copper/Silver Ion Generation

The use of metallic ions in water disinfection techniques is not new. The early Greeks used copper and silver goblets and vessels for drinking and storage purposes (5). The low solubility of these metals served as a natural, controlled release mechanism which added trace amounts of these ions to the water. Such amounts were high enough to purify the liquid without causing objectionable taste.

More recent use of copper and silver ions to inactivate microorganisms is well documented (6)(7)(8)(9). In addition to bacteria, they also are effective in controlling viruses, algae and fungi in the part per billion (ppb) range. Copper and silver ion disinfection of swimming pool water has several advantages over chlorine, viz., the ions are chemically stable and do not undergo the destructive reactions of aqueous chlorine; they do not form objectionable by-products such as chloramine or Trihalomethanes (THM); they do not escape from the water by volatilization as chlorine does.

Maintaining ppm range concentrations of copper and silver ions in swimming pool water in a convenient and reproducible manner is accomplished by electrolytic generation of the ions. electrolytic ion generators consist of a positively charged anode consisting of the metals to be ionized and a negatively charged cathode. The electrodes are housed in a chamber through which the water to be purified flows. The anode and the cathode are connected to a power source and a weak electrical charge flows between them, releasing silver and copper ions from the anode. The metals ion concentration is precisely controlled by varying both the flow rate of water through the chamber and the current to the electrodes.

Experimentation and publication by Gerba and others (10)(11)(12)(13)(14) indicates that 300-400 ppb of copper and 40 ppb silver combined with 0.1 ppm -0.4 ppm of chlorine is more effective in controlling a host of microorganisms, including coliform, than the use of higher levels of chlorine. The research points toward a synergistic effect when water containing microorganisms is subjected to copper/silver ion treatment with low levels of chlorine.

III. Test Protocol

The Town of Brookline Municipal Swimming Pool was chosen as the site for the current study because it is well maintained and operated by the Recreation Department staff is well regulated by the Brookline Health Department staff and it is utilized year round by the citizens of the Town and the surrounding community and organized high school swimming programs.

Chapter V of the Massachusetts Sanitary Code requires swimming pool waters to be disinfected using chlorine at a rate resulting in a FAC of 1.0 ppm. The Code also allows for alternative treatment technologies, but, at present, since they are viewed only as supplementary disinfectants, they must still conform with the above chlorine standards. If an operator wishes to operate below this minimum FAC requirement, then that is handled as a matter of variance issued by the local Board of Health after a public hearing and subsequent approval of that variance by the Massachusetts Department of Public Health (MDPH).

The Brookline Recreation Department applied to the Brookline Commissioner of Public Health on February 20,1996, for a variance to conduct a ten (10) week study using copper/silver ionization with reduced chlorine levels. On March 5,1996, a public hearing was held and on March 21,1996 the Brookline Health Department issued a variance for test purposes. On March 27,1996 the MDPH approved the variance. .

Under terms of the issued and approved variance, the test was to be carried out under a protocol which is attached to this report (Appendix n. The protocol in summary required Crystal Water Systems to conduct a two (2) week `Baseline Period" study whereby physical, chemical and bacteriological data and samples would be gathered for analysis by a certified laboratory (G&L Labs of Quincy, Ma.). During this period, no changes would be made relative to pool operation, i.e. chlorine dosage would remain such that a 1.0 ppm FAC was maintained.

At the end of the `Baseline Period", the installed copper/silver generator would be activated. When the copper levels in the pool water reached 300 ppb, chlorine levels would be reduced to 0.4 ppm. The facility would then be operated in this manner for a period of eight (8) weeks, during which data gathering, sampling and analyses would be intense.

An integral part of the test protocol was the design and implementation of a consumer reaction questionnaire which is attached (Appendix II).

IV. Purpose of the Test

The test, under the protocol described, was carried out to determine whether copper/silver ion generation used in conjunction with substantial reduction in chlorine usage, provides the same or better public health protection as the use of high levels of chlorine alone. The test was also designed to determine if the use of lower levels of chlorine have any positive effects on bather satisfaction.

V. The Swimming Pool

The Brookline Municipal Swimming Pool was constructed in 1958. Three distinct areas comprise the total pool complex viz., the diving area the wading area, and the lap pool. The three pools have a total volume of 245, 880 gallons.

Water supply for the pools is obtained from the Town of Brookline municipal water supply system which obtains its water from the Massachusetts Water Resources Authority (MWRA), a regional water supplier for the entire metropolitan Boston area. MWRA water is obtained totally from surface supplies, is not presently filtered, and is treated only with chlorine for disinfection, soda ash for corrosion control and sodium fluoride for control of dental caries. The Brookline municipal pool water is filtered through enclosed low pressure sand filters having a total capacity of 520 gallons per minute (gpm). The entire content of the pools are, therefore, filtered every eight hours.

Sodium hypochlorite in 10% aqueous solutions used for the disinfection purposes. It is fed through an electrically operated pump calibrated to maintain a FAC level in the pool water of not less than 1.0 ppm. Average chlorine usage is 9-10 gallons per day, providing an average chlorine dosage of 1.8 ppm. when chlorine alone is used for disinfection purposes. During the Pilot Phase of the study after introduction of copper/silver ions at the desired level, chlorine usage was reduced to less than 3 gallons per day 2.67g.p.d.)

VI. The Cooper/Silver Generator

The copper/silver ion generator is a Water System Model CWS 3001. The unit is NSF approved per Standard 50-1992 and UL listed. The system consists of two components: a controller and two flow cells which contain six copper/silver electrodes each. The controller measures 19 ½" x 15 ¾" x 8 3/8" and weighs 25 lbs. Input power to the controller is 110/220 volts 50/60 hertz; while Output is 16 volts Max 10 amps. It is a Class 2 Transformer. The Flow cells are constructed of high pressure Schedule 80 PVC and measure 18" long. The ratio of copper/silver is 99:1, respectively. This ratio allows the copper/silver ions imparted into the pool to fall within EPA Drinking Water Regulations which is a NSF requirement. The System was installed on July 18,1996. The electrodes were inserted as an offset to a separate water loop fed off the main pool line that feeds the Dectron dehumidifier on the roof.

VII. Baseline Period Testing

On June 25,1996 baseline data relative to chlorine residual (FAC), coliform bacteria total heterotrophic plate count and trihalomethane (THM) began to be gathered and continued until July 3l, 1996 - a period of 5.5 weeks. This represents an almost three-fold increase in data relative to the test design protocol, but was thought to be prudent considering that a FAC concentrations ranged from a minimum of 0.3 ppm to 3.10 ppm.

Review of the data indicates that as expected coliform bacteria appeared to be well controlled with only a single sample showing one (1) coliform colony at a time when average FAC was 1.9 ppm.

Relative to heterotrophic bacteria, an average of 90.8 colonies/ml were determined during this period.

An average concentration of 121.2 micrograms per liter (ug/L) of trihalomethanes was detected during the Baseline Period.

Bather load was on average of 288 persons/day during the Baseline Period.

VIII. Ionizer Ramp UP Period

From August l, 1996 through September 16,1996, the copper/silver ion generator was introduced into the water treatment system, while chlorine dosage levels were reduced. The ion generator responded well to ramp-up, reaching a level of 0.3 ppm by August 17,1996, the pool was fully ionized. However since the pool was to be closed (August 25,1996 - September 10, 1996) for its annual maintenance program, the Pilot Phase part of the test was delayed until the reopening. Following the reopening of the pool and restoring the copper levels (see (1) below), The chlorine levels were reduced to the 0.4 ppm level as stipulated in the protocol and the Pilot Phase commenced.

IX. Pilot Test Periods

On September 17,1996, data began to be gathered relative to the actual performance of copper/silver ionization with reduced levels of chlorine and continued for an uninterrupted period of four weeks. During the period from October 19,1996 through October 23,1996, the Boston area received almost nine (9) inches of rainfall causing severe generalized flooding conditions throughout the area. The Brookline Municipal Pool Building was a victim of this flooding and the swimming pool water treatment room was inundated causing failure of all pumps. The pool, with ionizer fully operational, and copper levels restored to 0.3 ppm was not in operation until November 1l, 1996.
Upon restoration of all pool equipment, the Pilot Period was once again commenced on November 1l , 1996, and ran uninterrupted until December 21,1996, a period of six weeks. Pilot test period in the aggregate provide ten weeks of data.
During this time period FAC levels averaged 0.52 ppm with an occasional excursion to 1.0 ppmbut for the most part remained in the 0.4 - 0.5 ppm range.
Copper/silver ion levels remained consistent at the 0.3 ppm level with only occasional readings of 0.2- 0.25 ppm.
No coliform bacteria colonies were developed throughout the Pilot Period Test. Relative to heterotrophs, an average of 20.2 colonies were counted during this period. 48.5 ug/L of THM was detected as an average during the test period. Bather load during this period averaged 202 persons/day.

X. Discussion

A) Free Residual Chlorine (FRC)

It is interesting to note the extremes in chlorine concentrations during the Baseline Period data collection. Chlorine concentrations ranged from a maximum level of 3.10 ppm to a minimum of 0.3 ppm. The average maximum level was 2.7 ppm and the average minimum level was 0.6 ppm which is a spread of 4.5 times. This spread indicates two things: i) the chlorine residual is unstable and is quickly subject to the influence of chlorine demand (bather load); and ü) the chlorine feed system either reacts slowly to changes in chlorine residual or that high/low set point signals are set too widely apart.

Data collected during the Pilot Period demonstrated chlorine concentrations ranging form a maximum level of 1.3 ppm to a minimum of 0.2 ppm. The average maximum level was 1.0 ppm and the average minimum level was 0.4 ppm, which is a spread of only 2.5 times. This suggests that the chlorine residual was more stable when copper/silver ions were being used.

B) Coliform Bacteria

Coliform bacteria levels appeared to be well controlled throughout the duration of the study whether using conventional high levels of chlorine alone or when using copper/silver ions in conjunction with reduced levels of chlorine. The only coliform event detected during the study occurred during the Baseline Period data collection when chlorine levels were at an average of 1.9 ppm FAC.

C) Heterotrophic Plate Count

The heterotrophic plate count data provide the most significant information regarding the capabilities of the two disinfection strategies. This data provides a measure of the total heterotrophic bacteria in the pool water. It looks at a much larger population of bacteria than the important but more limited group of organisms detected in the coliform procedure. Therefore, the heterotrophic plate count provides a better measure of the overall sanitary condition of the pool water.

The Pilot Period study showed far lower numbers of heterotrophic bacteria detected than during the Baseline Period data collection. An average of 90.8 colonies/ml were found in samples collected during the Baseline Period, while only 20.2 colonies/ml were detected while using copper/silver ionization. This represents a 78% reduction in bacterial population.

D) Trihalomethanes (THM)

Trihalomethanes (THM) are a group of halogenated hydrocarbons which have been found to be potentially cancer causing. THM are produced when chlorine is introduced into water containing organic constituents and can either be ingested or absorbed through the skin. Therefore, THM concentrations in drinking water are regulated by the United States Environmental Protection Agency (LTSEPA) at a level of 100 ug/ml. There is no regulated maximum concentration for THMs in swimming pools.

An average concentration of I21.2 ug/L was found in samples collected during the Baseline Period, while an average concentration of only 48.5 ug/L was found during the Pilot Period of the study. This represents a 150% reduction in THM concentrations.

XI. User Satisfaction

In order to gain insight into whether the introduction of copper/silver ions with reduced levels of chlorine has any effect on the bathing experience of users of the swimming pool, a survey was designed, implemented and analyzed by Opinion Dynamics of Cambridge, Ma. The full report is attached (Appendix II].

It is well understood that bathers who use swimming pools using chlorine alone as a disinfectant have experienced a variety of unpleasant side effects, including but not limited to, bleaching of skin, hair and bathing suit material; eye, nose and throat mucous membrane irritation; unpleasant odors; and skin irritation and rashes. Such pool users seem to understand that these unpleasant effects are the price to be paid for assurance that the pool water is free from pathogenic organisms. In fact, some persons are so sensitive to chlorine as to cause them to avoid using swimming pools.

The survey found a marked increase in bather satisfaction swimming in water disinfected by copper/silver ions and low levels of chlorine, by a margin of 76% - 2%. Users experienced a very positive reaction to copper/silver ionization in that the incidence of eye irritation was cut by 16%; objectionable odors by I0o/a; bleaching of hair by 6%; and skin irritation by 4%.

XII Conclusions and Recommendations

Review of the data generated during the course of the study clearly supports the premise that copper/silver ionization technology is an effective and superior alternative to conventional swimming pool water disinfection by use of high levels of chlorine alone. The technology provides a high level of bacteria control, while lower chlorine levels result in substantial reduction of the production of trihalomethanes and increase substantially the enjoyment and satisfaction of the swimming experience for the pool user.

It is strongly recommended that the Massachusetts Department of Public Health after review of this evidence appropriately revise Chapter V of the State Sanitary Code to allow municipal Boards of Health to permit the use of copper/silver ionization technology with reduced levels of chlorine for indoor swimming pool disinfection.

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