Field Evaluation of a Bi-Polar Oxygen Sanitation System and a Mineral Purification System

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The following study is a field evaluation of the Bi–Polar Oxygen Sanitation System (B.O.S.S.) and the Mineral Purification System (DIGSYS), both products of NOGSYS Technologies. The study was commissioned by NOGSYS, who submitted the study for publication in the Journal with the permission of Mr. Hafer.

The parameters given for the treatment and purification of recreational water facilities are well established and insure the health and safety of swimmers. For health concerns, swimming pools and spas must be disinfected so as to prevent the spread and transmission of disease. For the safety of swimmers, the water must be free of turbidity and color so that the bottom surfaces are visible at all times. The water should be of drinking quality, non–irritating and free of objectionable odors and tastes.

Recreational waters have been traditionally treated with chlorine–based compounds, where levels reach as high as 5.0 ppm during non–use periods. Ensuring an adequate supply of free chlorine for sanitation during peak use periods can be and often is a difficult task for owners and operators of swimming pools and spas. Chlorine demand often exceeds the free chlorine availability causing greater amounts of chlorine to be used.

Free chlorine is affected not only temperature and sunlight, but also by swimmers and their organic waste. It has been shown that active swimmers can perspire up to 1 liter per hour (Kuno, 1956) and that the average swimmer contributes 25–50 ml of urine to the waters (Warren and Ridgeway, 1978). Along with body and sun tan oils, skin cells, hair, and detergents from creams, lotions and shampoos all of which create a chlorine demand.

Rain water and wind also contribute organic matter into recreational waters in the forms of algae, dirt, leaves and various particulate matter along with air pollution. All of these materials add to the chlorine demand, and reduce chlorine's effectiveness as a disinfectant. Chlorine also acts as a skin and eye irritant (Clark and Berman, 1983).

Recent research indicates that chlorinated organics can cause cancer in humans, as well as other health and reproductive problems. Chlorination of water containing organic contaminants results in the formation of chlorinated organics.

With the increased knowledge of the toxic potential of chemicals in water, a large number of physical and chemical methods are being investigated in an attempt to purify recreational waters. Of particular interest and importance is the use of hydroxyl radicals and ions as superior oxidizers when compared to chlorine compounds.

As described by David Woodbridge, Ph.D. in his paper entitled *Hydroxyl Radicals and Ions as Swimming Pool Water Purifiers*, the production of hydroxyl occurs by many different reactions. The asymmetrical distribution of the hydrogen and oxygen atoms in the water molecule appears to provide a structure where numerous types of energy exchange can remove one of the hydrogen atoms and leave the hydroxyl entity. Occurrence of the hydroxyl group will depend upon the building of the proton (hydrogen atom) to the diatomic species OH^+, OH^0, OH^- (Woodbridge, 1994).

Studies of new methodologies for treating waste water have shown that the hydroxyl radical is one of the most powerful oxidizing agents that can exist in water. Peroxone, a combination of hydrogen peroxide

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and ozone has shown excellent results in solving disinfection problems. Combining the two agents causes both constituents to be destroyed while forming the hydroxyl radical (McGuire and Davis, 1988). This agent reacts with organic compounds indiscriminately and will oxidize them to carbon dioxide and water.

The hydroxyl radical is one of the most reactive ions known. The federal government (U.S. Department of Commerce/National Bureau of Standards) has published a book entitled *Hydroxyl Radical and Perihydroxyl radical and their Radical Ions* (Farhataziz and Ross, 1977). Eighty pages are filled with OH^0 reactions with organic and inorganic substances. Generated hydroxyl radicals were found to produce rapid cell death of *Escherichia coli* in natural waters (Ireland *et al.*, 1993). In addition the hydroxyl radical has been found to break the carbon hydrogen bonds. Some twenty five contaminants were studied, including solvents, aromatic's, and pesticides containing nineteen additional compounds. All molecular structures were degraded by the hydroxyl radical.(6) Hydroxyl radicals readily mineralize chlorinated organics as well as breaking the hydrocarbon bond, thereby permitting the hydroxyl radical and it's ions to degrade volatile inorganic compounds (Woodbridge, 1994).

A large amount of data exists that shows the effectiveness of the hydroxyl radical and the associated ions in water purification. Both bacteriological and chemical pollutants are greatly reduced when the hydroxyl radical is generated within the water body. Thus, production of the OH^0 group in recreational waters will result in the reduction of both the microbiological organisms and the chemical contaminants of the water.

"Metals have been used as electrolytic devices for the disinfection of water since the 1930's (Dorroh, 1934). Copper has been shown to bind to bacterial DNA (Richards, 1981) thereby inactivating the organism's ability to reproduce. Copper is somewhat slower acting than chlorine in inactivating microorganisms (Landeen *et al.*, 1989) but it does not dissipate and it provides a longer residual effect (United States Department of Health and Human Services 1979)", (Friedman and Rose, 1993).

Chlorine has been shown to cause skin and eye irritation (Clark and Berman, 1983), as well as the formation of trihalomethane compounds which can be absorbed through the skin or volatilized and inhaled. It is due to these concerns and that of others that alternative methods to the disinfection of swimming pools are being sought by various manufacturers and laboratories in the recreational water industry.

Purpose of Study

The purpose of this study is to determine the effectiveness of the NOGSYS Technologies Bi–Polar Oxygen Sanitation System, known as B.O.S.S., and their ion purification device, known as DIGSYS, toward the purification of a recreational water facility under extreme and adverse conditions, using minimal levels of halogen as described.

Facility History

The facility used is a privately owned 19 year old kidney shaped pool, containing approximately 20,000 gallons of water. The construction is typical of that period, consisting of gunite and white plaster. The plaster is of original design, without having an acid wash. The pool was on gas chlorine treatment service for 1 year. It has a rough and pitted surface. Several areas of the plaster surface, each approximately 4–7 cm in diameter, have come loose. Some have been patched using a commercial plaster patch material.

Circulation is accomplished using a single 1 hp Swimquip bronze pump with a strainer. Filtration is by a 48 sq./ft. Swimquip diatomaceous earth filter, utilizing CF–138 media. Plumbing is 1½" throughout. There are four return lines without inlet fittings employed. There is no gas heater employed, nor is there use of solar heat. The pool is equipped with a Kreepy Krauly suction cleaner that operates daily with circulation. A standard skimmer (with a cleaner attached), and a bottom drain (blocked off for cleaner operation) are present.

The facility has been serviced weekly by Calavan's Pool Service since January, 1994. Normal service has been with the use of trichlor 3" tablets, hydrochloric acid, algaecides, and clarifiers.

Location

The location is within the central area of Las Vegas, with nearby Interstate 95 and major inner town artery, this pool is in a high pollutant area as described by the Air Pollution Control Division of the Clark County Health District, and is within flight paths of both military and commercial aircraft. This region lies in a floodplain and is often besieged with rain water run–off that fills the streets with various debris. It is not unusual for this run–off to enter pools in the area. Large and various indigenous and non–indigenous vegetation grows within this neighborhood. The pool area is landscaped with plants, trees, and grass.

The swimmer load varies with the seasons. The minimum swimmer load is 1 per day for 1 hour, and

the maximum swimmer load can be as high as 20 per day per hour for 8 hour usage as was seen on 10/11/94.

A NOGSYS Technologies Bi–Polar Oxygen Sanitation System (B.O.S.S.) was installed downstream from the filtration unit on 09–09–94 by Larry Calavan of Calavan's Pool Service, with the homeowner assisting. Installation material was schedule 40 PVC. A mazzei injector (venturi) was incorporated prior to the contact chamber with a flow bi–pass, as directed in manufacturers installation instruction. An 1½" swing check valve was installed downstream from the pump to prevent back flow during off periods. On 09–14–94 at 4:00 pm the B.O.S.S unit was activated. Operation was set for 12 hours per day. The water was turbid, with visibility to 3 feet. No chemicals were introduced at this time.

Materials and Test Methods

The methods used for the examination of these waters were spectrophotometric, colormetric, titration, membrane filtration, and biological activity reaction tests, using a HACH DREL/2000 Water Quality Lab, a MPN/MEL Biological Lab (HACH Comp. Loveland, CO.) and a TAYLOR K1744HABC Lab, (TAYLOR Technologies, Inc. Sparks, Maryland).

The methodologies incorporated into these testing devices are approved by the NSPI, US EPA, APHA, AWWA, and WEF.

The sampling bottles used for standard examination tests were 1000 ml polypropylene bottles with polypropylene screw closures. One bottle per sample was used, and then discarded after each use.

A membrane filtration (MF) test was performed by collecting 175ml of water from the vessel into a presterilized disposable container containing 0.01ml of sodium thiosulfate to stop the disinfection process. A ten–fold dilution process was performed to obtain a 0.01ml sample in 100ml using a 99mL of a sterile buffered dilution water. The 100ml solution was filtered in a type A filter unit, with a presterilized, disposable, 47–mm, 0.45µm cellulose nitrate membrane, conforming to the American Public Health Association (APHA) Standard Methods, and a 30ml rinse was performed. Incubations were at 35^{0}C for 24–48 hours. An illuminated magnifier, 10X – 20X, was used to enumerate colonies per plate with results reported as CFU/ml.

Media used: *E. coli*, Total Coliform – m–ColiBlue24 Broth PourRite Ampules, (HACH) / Total Coliform – m–Endo (HACH) / *E. coli* confirmation – Nutrient Agar w/MUG (HACH) // Heterotrophic – m–TGE/TTC Broth PourRite Ampules, (HACH)

The results of the standard examination of the water is shown in Tables 1 and 3. The results of the biological examination of the water is shown in Tables 2 and 4. The results of the biological examination of the water is shown graphically in Graphs 1 and 2.

B.O.S.S – Phase 1

09/03/94 – Pool drained and refilled / 2 weeks prior to drain, pool became infested with pink algae by natural sources / No treatment to destroy at this time / Growth allowed to remain / Visual inspection revealed algae located in skimmer, main drain, return lines, walls and filter.

09/05/94 – Pool filled with city water / Cl = 0.18 ppm – pH 7.84 / Circulation not started at this time to encourage algal and bacterial growth.

09/09/94 – B.O.S.S III installed by Larry C. of Calavan's Pool Service w/assist by owner / Circulation and B.O.S.S. remain off at this time / Water is turbid with less than 3 feet visibility / Cl = 0.06 ppm – pH 7.92

09/10/94 – Circulation without B.O.S.S. on 12 hours daily / Visibility less than 3 feet / Pink algae throughout pool surfaces and circulation system / Filter charged with CF–138 media / No chemicals added at this time / Biological Activity Reaction Test to algae confirm Blue–Green Algae / Cl = 0.01 ppm – pH 8.23

09/14/94 – Circulation on 12 hours daily / Addition of approx. 565 gallons make–up water added / Visibility less than 3 feet / Water extremely turbid / B.O.S.S activated / No chemicals added at this time.

09/15/94 – Circulation with B.O.S.S. on 12 hours daily / Visual inspection reveals no algae present as noted in 09/03 / Visibility to bottom / Water clear / Biological Activity Reaction Test to algae confirm no algae present / No chemicals added at this time / B.O.S.S. deactivated at this time / Cl = 0.06 ppm – pH 7.98

09/20/94 – Circulation without B.O.S.S. on 12 hours daily / Visibility to bottom / Green tint to water without turbidity / Remarkable amount of fine dust on bottom of pool due to monsoon type rain on 09/19 / 30 oz. hydrochloric acid added after sample

to lower pH / Cl = 0.00 ppm – pH 7.92.

09/26/94 – Circulation without B.O.S.S. on 12 hours daily / Visibility less than 1 foot / Water green, extreme turbid condition / Green algae on tile edge to bottom / Musty odor noted at surface / 384 oz. NaOCl @ 6% poured around perimeter / 30 oz. hydrochloric acid added for pH control / B.O.S.S. activated / Visual observation after chlorine addition with B.O.S.S. activated gave remarkable improvement / Bottom visible within 30 minutes with slight turbidity / Complete clarity within 2 hours / B.O.S.S. unit deactivated at this time / Cl = 0.82 ppm – pH 7.6

09/28/94 – Circulation without B.O.S.S. on 12 hours daily / Visibility to bottom / Water clear with very slight haze / Windy and dusty conditions present / No visible algae on surfaces / Physical feel to walls reveals rough feel / Cl = 0.11 ppm – pH 7.21.

10/04/94 – Circulation without B.O.S.S. on 12 hours daily / Pool party 10/02 with 6 bathers (juvenile) noted all day / Visibility 4 feet / Water extremely turbid and green in color / 128 oz. NaOCl @ 6% poured around perimeter / 10 oz. hydrochloric acid added for pH control / B.O.S.S. unit activated / Visual observation after chlorine addition with B.O.S.S. activated again gave remarkable improvement / Bottom visible within 30 minutes without turbidity / complete clarity within 1 hour / B.O.S.S. unit remains active at 12 hours daily / begin 128 oz. NaOCl addition each 48 hours by owner while swimmer load is as 10/02.

10/11/94 – Circulation with B.O.S.S. on 12 hours daily / Pool party 10/09 with 20 bathers (juvenile) noted all day / Visibility to bottom / No algae visible / No odor noted / Owner notes, "very pleased with unit" / Discontinued use of NaOCl / 7 oz. Dichloro––62% – 2 oz. QAC 60%\K–I – 8 oz. hydrochloric acid added after sample / Cl = 0.09 – pH 7.78.

10/18/94 – Circulation with B.O.S.S. on 12 hours daily / Visibility to bottom / No algae visible / No odor noted / Water clear / 7 oz. Dichloro–s–62% added after sample / Cl = 0.25 – pH 7.78.

10/25/94 – Circulation with B.O.S.S. on 12 hours daily / Visibility to bottom / No algae visible / No odor noted / Water is clear / No chemicals added at this time / Cl = 0.20 – pH 7.34

11/08/94 – Circulation with B.O.S.S. on 12 hours daily / Visibility to bottom / No algae visible / No odor noted / Water is clear / No chemicals added at this time / Cl = 0.07 – pH 7.94.

11/21/94 – Circulation with B.O.S.S. on, set to 9 hours daily / Visibility to bottom / Appearance of black algae on bottom surfaces (small colonies) / No odor noted / Water has slight haze to appearance / Chemicals added after sample – 7 oz. Dichloro–s–62% – 4 oz. QAC 60%\K–I – 30 oz. hydrochloric acid for pH control / Cl = 0.04 ppm – pH 8.16.

12/06/94 – Circulation with B.O.S.S. on 9 hours daily / Visibility to bottom / Appearance of black algae remains from 11/21 / No odor noted / Water clear / No chemicals added at this time / Cl 0.15 – pH 7.90.

End to Phase 1 – notes

1. While the NOGSYS B.O.S.S. unit was run at it's optimum output at the times noted, algae colonies were controlled with remarkably low levels of free available chlorine as noted. These levels are below those recommended by the manufacturer, of 0.4–0.8 ppm. Microbiological reductions were also noted in these studies. Levels of biologicals are commensurate with a sub–optimally chlorinated pool.

2. Introduction of increased chlorine amounts, while maintaining a below–minimum level of 0.4 ppm, and the addition of a quaternary ammonia compound at ½ the manufacturer's suggested level gave a significant decrease to the biological levels as noted.

3. The benefits of the NOGSYS B.O.S.S. in combination with extremely low levels of chlorine and the use of QACs have clearly demonstrated an adequately sanitized pool.

Under an abnormal challenge the B.O.S.S. unit, together with a significantly reduced chlorine residual than is recommended by manufacturer, demonstrated the ability to maintain an algae–free environment. With the introduction of a QAC the B.O.S.S. unit gave results suggesting that effective pool sanitation will be achieved with sodium bromide under similar conditions, along with the introduction of copper through the ionization process (DIGSYS). This premise will be tested and determined by the data obtained in Phase 2 of this study.

This concludes Phase 1 of the Field Study to the NOGSYS Technologies Bi–Polar Oxygen Sanitation System.

B.O.S.S. – DIGSYS – Phase 2

02/03/95 – Upgraded B.O.S.S. unit installed, (B.O.S.S.IV) not activated at this time / Circulation on 9 hours daily / Water clear and clean / Visibility to bottom / Appearance of black algae on bottom surface, (small colonies) from 11/28/94 / Chemicals added to lower TA, stabilized pH – 7 qt. hydrochloric acid – 10 oz. precipitant \ O–O – 2 oz precipitant \ C–X / Cl = 0.00 – pH = 7.81 – TA = 190 – Br= 0.00.

02/06/95 – Circulation without B.O.S.S. on 9 hours daily / Water clear and clean / Visibility to bottom / Appearance of black algae on bottom remains, no apparent increase in growth / Introduction of 32 lb. sodium bromide at this time / B.O.S.S. IV activated at this time / Test of levels after bromide introduction – Br = 0.21 ppm – pH 7.01.

02/17/95 – Circulation with B.O.S.S on 9 hours daily / Visual inspection revealed water clear and clean / Visibility to bottom / Owner's daily brushing of black algae growth has removed colonies / Biological Activity Reaction Tests for algae performed with negative results / Sample collection for MF test to heterotrophic only / Br = 0.16 – pH = 7.21.

02/21/95 – Circulation with B.O.S.S. on 9 hours daily / Water clear and clean / Visibility to bottom / No appearance of black algae / Appearance of green algae (slight) located along vertical surfaces within 1.5 ft. to surface / Biological Activity Reaction Tests for algae performed with negative results / Collection of algae at surface and Biological Activity Reaction Tests for algae performed with positive results for blue/green algae / Algae brushes off with reappearance within 72 hours as described by service agent and owner / Filter cleaned and recharged with CF–138 media at this time / No chemicals added at this time.

02/28/95 – Circulation with B.O.S.S. on 9 hours daily / Water clear and clean / Visibility to bottom / Appearance of green algae remains along vertical surfaces as noted 02/21 / Biological Activity Reaction Test for algae performed, and continues to give negative results / Surface collection of algae performed with BART test, giving positive results / Collection of plaster sample for examination denied by owner / Attempt to collect sample of material contained within plaster to be done once an apparatus can be fashioned (suction type) / Br = 0.05 ppm – pH 7.41.

03/19/95 – Question by owner, if flow were to be reduced going through B.OS.S. would it generate more bromine residual and reduce algae formation along vertical surfaces – This premise to be tested / By–pass installed by Service agent and owner and set for 5–8 gpm flow through B.O.S.S / Br = 0.06 – pH 7.39

03/21/95 – Circulation with B.OS.S. on and set to 12 hours / Water clear and clean / Visibility to bottom / Appearance of green algae remains as noted / Br = 0.06 – pH 7.96

04/20/95 – Circulation with B.O.S.S. on 12 hours daily / Water clear and clean / Visibility to bottom / Appearance of green algae remains as noted / Flow by–pass removed – conclusion is that this process (flow reduction) does not increase bromine nor decrease algae / Full flow of 37 gpm restored / DIGSYS (copper ionizer) installed and activated this date prior to filter / No chemicals added at this time / Br 0.06 ppm – pH 7.99.

04/25/95 – Circulation with B.O.S.S. / DIGSYS on 12 hours daily / Water clear and clean / Visibility to bottom / Appearance of green algae remains as noted / Chemicals added in attempt to eradicate algae growth along vertical surfaces – 24 oz. precipitant \ O–O – 3 oz. precipitant C–X – 2 oz. QAC 60%\K–I / Br 0.06 ppm – pH 8.46 – Cu 0.22 ppm

04/26/95 – Visual examination revealed no algae present along vertical surfaces / Water clear and clean / Visibility to bottom / Br 0.16 ppm – pH 7.56 – Cu 0.22

05/09/95 – Circulation with B.O.S.S. / DIGSYS on 12 hours daily / Water clear and clean / Visibility to bottom / No algae present along vertical surfaces / Br 0.07 ppm – pH 7.93 – Cu 0.25

05/25/95 – Circulation with B.O.S.S / DIGSYS on 12 hours daily / Water clear and clean / Visibility to bottom / Appearance to green algae (slight) reappearing along vertical surfaces / Chemicals added at this time provided by manufacturer – CV–600 20 oz. as per recommendation / Br 0.06 ppm – pH 7.56 – Cu 0.22

06/20/95 – Circulation with B.O.S.S. / DIGSYS on 12 hours daily / Water has slight haze condition / Visibility to bottom / Appearance of green algae (light) along vertical surfaces / Pool party with 8 swimmers (juvenile) on 06/18 – owner says water was clear after party and became hazy 06/19 evening / Filter cleaned and recharged with CF–138 media at this time / Chemicals added – CV–600 20 oz. – NaCO peroxyhydrate 12 oz. / Br 0.13 – pH 7.79 – Cu 0.2

06/21/95 – Circulation with B.O.S.S. / DIGSYS on 12 hours daily / Visual inspection reveals water clear and clean / Visibility to bottom / No appearance of green algae along vertical surface due to owner brushing pool 1 hour prior to visit / Br 0.06 – pH 7.67.

End to Phase 2 – Notes

1. While the NOGSYS B.O.S.S. IV unit was run at its optimum output during all circulation periods as noted, algae colonies within the water were controlled with remarkably low levels to bromine. These levels are below those recommended by the manufacturer. Microbiological reductions were also noted in these studies. Levels of biologicals are commensurate with a sub–optimally halogenated pool.

2. Cause of continued formation of blue–green algae along vertical surfaces is considered to be a combination of several possible causes – Low levels to halogen as noted – Rough plaster surface – Levels of algae nutrients present within plaster matrix. Although this premise has not yet been determined, further testing is required to conclude premise.

3. Introduction of ancillary chemicals including QAC's have clearly demonstrated an adequately sanitized pool.

Under an abnormal challenge the B.O.S.S. IV unit, together with a significantly reduced bromine residual than is recommended by manufacturer, demonstrated the ability to maintain an adequately sanitized pool. Algae formation along vertical surfaces did not appear to be present within the water body as a whole, and no bloom was noted. Introduction of ancillary chemicals for the control of organics in combination with the B.O.S.S. did demonstrate the ability to destroy vertical clinging algaes, while maintaining below minimum levels to bromine. The introduction of copper through the ionization process known as DIGSYS is seen to have contributed to the overall sanitation of this pool, although more testing will be needed to ascertain this premise.

This concludes Phase 2 of the Field Study of the NOGSYS Technologies Bi–Polar Oxygen Sanitation System.

Chemical listing definition:

QAC 60%\K–I = Bio–Dex sKill–it

NaCO peroxyhydrate = Bio–Dex ATTACK

Precipitant\C–X = Bio–Dex Clear–x–500

Precipitant\O–O = Bio–Dex OIL–OUT

CV–600 = Clearview™ – Orenda Technologies

Conclusion

With increased studies on the toxic potentiality of chemicals in water, and the growing interest in the use of hydroxyl radicals, nascent oxygen, oxygen radicals, dissolved oxygen and ions in recreational waters, it is seen by this lab and others in the recreational water industry that a new era in the purification process of swimming pools and spas has arrived.

As the general public becomes increasingly aware of possible negative effects of chlorine–based chemicals in their swimming pools and spas, manufacturers of recreational water purification devices respond by expounding upon the benefits of the hydroxyl radicals and their related ions.

These radicals are short–lived, but capable of inactivating bacteria under certain conditions. This type of bacterial inactivation is optimized when the bacteria are contained within a stream of water passing between two or more electrodes. By adding a venturi for increased O_2 content, the level of dissolved oxygen is increased, adding to the efficiency for bacterial inactivation. The addition of small amounts of halogen, such as chlorine or bromine, also increases the effectiveness of these radicals to inactivate bacteria, along with various forms of algae one might encounter within a swimming pool or spa.

An important note is needed here: when recreational water, which is contaminated with all types of organic and inorganic substances passes between electrolytic probes, the reduction that occurs at the cathode results in the creation of many hydroxyl groups. At normal temperature and pressures, the reaction starts at a voltage of 1.27 volts, and at voltages above 1.50 volts the extra energy heats the reaction and thereby increases the OH group production at the cathode and O at the anode (Woodbridge 1994). It is the production of the OH group that will

result in the reduction in both microbiological organisms and the chemical contaminants within the water.

NOGSYS Technologies Bi–Polar Oxygen Sanitation System (B.O.S.S.) functions by electronically directing low voltage DC current (2.5–5.0 volts) between a set of non–emitting carbon/ceramic electrodes which are housed in a clear contact chamber. Molecules of water, which pass between these electrodes, are electronically transformed into various species of oxygen known as hydroxyl radicals, oxygen radicals, and bi–polar oxygen. Clearly this design and operational electronics provides for the creation of the hydroxyl radicals (OH) as noted.

This lab's study was not to determine the effectiveness of the B.O.S.S. unit as set forth by the manufacturer in it's recommendations, but rather to determine the effectiveness of the B.O.S.S. unit under extreme and adverse conditions as might well be encountered by individual pool owners and/or their service agents, who might have a minimal level of knowledge of the water purification process.

During this study, the importance of aqueous temperatures in the creation of hydroxyl and peroxozone ions, as was described in the Woodbridge study was noted. As is seen in Phase 1 and 2, Tables 1, 2, 3, and 4 temperature fluctuations of both increasing and decreasing levels had a significant impact on the bacterium inactivation. Although several contributing factors also were present, its clearly seen that temperatures of the aqueous body played an influential part in the bacterium reduction.

While maintaining chlorine and bromine levels at or below 0.20 ppm, the B.O.S.S. unit was able to achieve a remarkable ability in deactivating algae and bacteria. This can only be attributed to the unit's ability to produce the hydroxyl radicals as described. With the additions of ancillary–type chemicals such as quaternary ammonia compounds and oil degrading enzymes, while maintaining below–minimum levels of halogens, the B.O.S.S. unit achieved log reductions to heterotrophic and coliform bacterias as would be expected with the use of higher levels of halogens. Although certainty as to which of the ancillaries used was of greater effect toward the bacterium reductions is probably best left open for debate and further studies, it is clearly demonstrated that the reductions occurred. What cannot be debated, however, is the effect of the OH group and it's role toward bacterium reductions.

To this end, the B.O.S.S. unit clearly demonstrated it's ability to reduce, degrade and destroy microbiological organisms along with organic and inorganic compounds as described. Therefore it is concluded that by following the manufacturer's recommended parameters for water chemistry as described in the owner's manuals for the B.O.S.S. and DIGSYS, owners and operators of recreational water facilities will establish an adequately sanitized body of water.

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Tests	09/10/94	09/28/94	10/04/94	10/11/94	10/25/94	11/08/94	11/21/94	12/06/94	Summary
pH	7.92	7.21	7.55	7.78	7.34	7.94	8.16	7.90	7.72
TA	142	153	110	102	96	124	126	170	127
Cl_2	0.06	0.11	0.07	0.09	0.20	0.07	0.04	0.15	0.10
$CaCO_3$	196	250	210	254	330	380	420	400	305
CO_2	9.0	38.0	36.0	32.0	28.0	40.0	56.0	42.0	35.1
Cu+*	0.12	0.10	0.06	0.00	0.00	0.00	0.00	0.00	.035
NaCl	N/T	N/T	N/T	N/T	N/T	N/T	800	800	200
Cl	380	134	138	210	230	208	188	214	212
TDS	539	581	615	636	810	727	729	776	676
Temp°C	23.6	25.6	24.4	22.8	22.8	22.0	20.6	20.0	22
NH_3	0.03	0.15	0.10	0.05	0.04	0.22	0.56	0.31	.183
NO_2	0.00	0.003	0.004	0.003	0.001	0.010	0.22	0.002	.030
NO_3	0.1	0.4	0.06	0.2	0.1	0.7	0.93	0.70	.40
DO	7.2	5.9	6.2	6.3	7.3	6.7	5.7	6.8	6.51
QAC	0.00	0.00	0.00	0.00	0.4	0.2	0.1	0.6	.21
Br									0.0

Notes: Copper is natural level from fill source. One 3" trichlor tablet used from 12/06/94 – 02/05/95. B.O.S.S. III

Table 1 – Test Data – Phase 1

Tests	09/26/94	09/28/94	10/04/94	10/11/94	10/25/94	11/08/94	11/21/94	12/06/94
Heterotrophic	$4.0 \cdot 10^6$	$9.0 \cdot 10^3$	$1.37 \cdot 10^5$	$2.0 \cdot 10^4$	$1.1 \cdot 10^1$	L/F	$9.0 \cdot 10^3$	0
Coliform	N/T	$1.97 \cdot 10^1$	$1.9 \cdot 10^4$	$1.4 \cdot 10^4$	$1.6 \cdot 10^1$	L/F	$1.18 \cdot 10^3$	0
E. Coli	N/T	$1.0 \cdot 10^1$	>10	N/D	N/D	L/F	N/D	N/D
Cl_2	0.06	0.11	0.07	0.09	0.20	0.07	0.04	0.15
pH	7.92	7.21	7.55	7.78	7.34	7.94	8.16	7.90
QAC	0.00	0.00	0.00	0.00	0.4	0.2	0.1	0.6
	Method m–Endo – Total Coliform Nutrient Agar w/MUG *E. coli*			Method m–ColiBlue24 – Total Coliform, *E. coli* simultanious detection. 10/11 & 10/21 – introduction to QAC 60% / K–1				

Notes: N/T = Not Tested, N/D = Not Detected, L/F = Lab Failure – contaminated sample. 09/26/94 – 384 oz. NaCl 6% added. 10/04/94 – 128 oz. NaCl 6% added. 10/11/94 – 7 oz. Dichloro–s–62% / 2 oz. QAC 60% after sample. 11/21/94 – 7 oz. Dichloro–s–62% / 4 oz. QAC 60% after sample.

Table 2 – Biological Data – Phase 1

Tests	Level	09/28/94	09/28/94	10/04/94	10/11/94	10/25/94	11/08/94	11/21/94	12/06/94
Heterotrophic	$4.0 \cdot 10^6$ $1.37 \cdot 10^5$ $2.0 \cdot 10^4$ $9.0 \cdot 10^3$ $9.0 \cdot 10^1$ $1.1 \cdot 10^1$ 0						Lab Failure		
Coliform	$1.9 \cdot 10^4$ $1.4 \cdot 10^4$ $1.18 \cdot 10^3$ $1.97 \cdot 10^1$ $1.16 \cdot 10^1$ 0	N/T					Lab Failure		
E. coli	$1.0 \cdot 10^1$ 0	N/T			N/D	N/D	Lab Failure	N/D	N/D

Graph 1 – Biological Data – Phase 1

Tests	02/06/95	02/21/95	02/28/95	03/21/95	04/25/95	05/09/95	05/25/95	06/20/95	Summary
pH	7.81	7.00	7.41	7.96	8.46	7.93	7.56	7.79	7.74
TA	190	120	80	90	100	100	90	130	112.5
Br	0.00	0.17	0.05	0.06	0.06	0.07	0.06	0.13	0.07
$CaCO_3$	372	372	480	500	340	450	550	470	442
CO_2	19.0	24.0	22.0	10.0	10.0	10.0	25.0	15.0	16.8
Cu+	0.00	0.00	0.00	0.00	0.22	0.25	0.22	0.21	.225
NaCl	700	600	700	700	600	600	700	1000	700
Cl	440	214	214	358	380	380	470	450	363
TDS	1194	1046	1000	1020	792	1166	1224	1303	1093
Temp°C	21.0	19.0	18.0	19.0	20.0	26.0	21.0	24.0	21
NH_3	0.32	0.23	0.10	0.06	0.18	0.18	0.12	0.39	.175
NO_2	0.03	0.00	0.00	0.00	0.014	0.014	0.032	0.009	.012
NO_3	0.05	0.15	0.03	0.01	0.01	0.10	0.50	0.80	.20
DO	8.2	7.3	8.9	8.1	8.1	7.2	7.1	7.4	7.78
QAC	0.00	0.00	0.00	0.00	0.00	0.2	0.20	0.40	.175
Cl_2									0.0

Notes: 32# NaBr used throughout Phase 2 – B.O.S.S. IV – 04/20/95 DIGSYS unit installed.

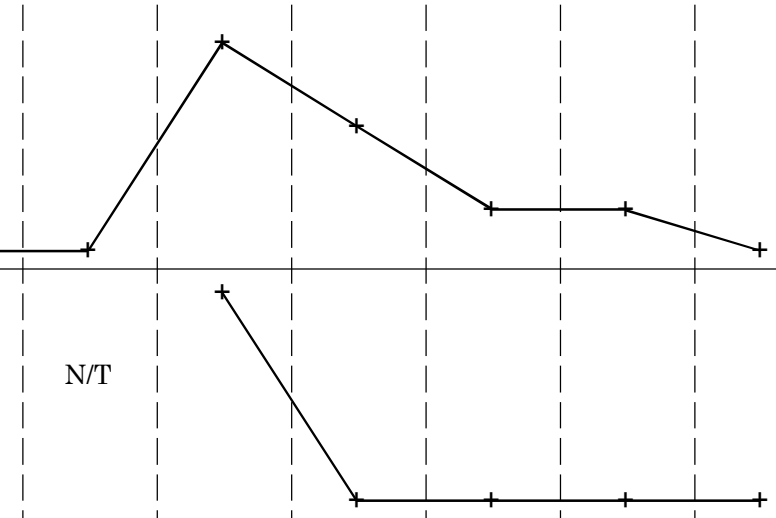
Table 3 – Test Data – Phase 2

Tests	02/06/95	02/17/95	02/21/95	03/21/95	04/25/95	05/09/95	05/25/95	06/20/95
Heterotrophic	TNTC	0	0	$1.2 \cdot 10^5$	$3.0 \cdot 10^3$	$1.0 \cdot 10^1$	$1.0 \cdot 10^1$	0
Coliform	N/T	N/T	N/T	$4.0 \cdot 10^4$	0	0	0	0
E. Coli	N/T	N/T	N/T	N/D	N/D	N/D	N/D	N/D
Br	0.00	0.16	0.17	0.06	0.06	0.07	0.08	0.13
pH	7.81	7.21	7.00	7.96	8.46	7.93	7.56	7.79
QAC	0.00	0.00	0.00	0.00	0.0	0.2	0.1	0.4
Cu	0.00	0.00	0.00	0.00	0.22	0.25	0.22	

Method m–ColiBlue24 – Total Coliform, *E. coli* simultanious detection. N/T = Not Tested, N/D = Not Detected, TNTC = Too Numerous To Count. 02/03/95 B.O.S.S. IV installed – replaces B.O.S.S. III of Phase 1. 02/11/95 32 lb. NaBr introduced. 03/19/95 Flow set 5–8 gpm. 04/20/95 DIGSYS (copper ionizer) installed upstream from filter. Flow bypass removed. Full flow through B.O.S.S. IV. 04/25/95 and 05/25/95 2 oz. QAC 60%\K–I added after sampling.

Table 4 – Biological Data – Phase 2

Tests	Level	02/06/95	02/17/95	02/21/95	03/21/95	04/25/95	05/09/95	05/25/95	06/20/95
Heterotrophic	TNTC $1.2 \cdot 10^5$ $3.0 \cdot 10^3$ $1.0 \cdot 10^1$ 0	TNTC							
Coliform	$4.0 \cdot 10^4$ 0	N/T	N/T	N/T					
E. coli	N/D	N/T	N/T	N/T	N/D	N/D	N/D	N/D	N/D



Graph 2 – Biological Data – Phase 2

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About the Author

Don Hafer works as the senior analyst at Perfect Balance Laboratory (PBL) in Las Vegas, Nevada. He has worked in the pool industry for 15 years as manager in retail pool stores, as a repair technician, and as a testing and treatment specialist. Mr. Hafer's extensive knowledge of water chemistry and treatments started in the US Navy where he was schooled in water analysis and treatment processes for their nuclear submarine fleet. He is currently preparing to obtain a bachelor's degree in microbiology.

Mr. Hafer moved to Las Vegas in 1990 to start PBL, a full–service analysis and treatment laboratory, specializing in the alternative methods of treatment. He consults on various water treatment processes with service technicians throughout the country, as well as with various manufacturers and engineers throughout the world. He speaks at local NSPI and IPPSA functions and is the author of several papers outlining water chemistry and treatment. He is on the advisory board of Total Maintenance Review, a bi–monthly publication for engineers and architects in Las Vegas. PBL is currently conducting a study on the phenomenon of plaster discoloration.