A Comparison of the Disinfectant Capabilities of Various Spa Products

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Numerous outbreaks of microbial illnesses have been associated with spa use. These are the result of improper sanitation of the spa water. Proper spa water sanitation is by chemical disinfection, usually with chlorine or bromine which are the most commonly used spa sanitizing products. In addition to these, there are many new products available which imply that they are a replacement for chlorine or bromine that have not been evaluated for their sanitizing abilities.

The products tested were a bromine generator, an ozone generator, an enzymatic product, bromine tablets and chlorine (as a control). The modified National Sanitation Foundation (NSF) Standard 50 test used a simulated hot tub (1/12th scale) filled with water heated to 41° C. The products were used or the system was operated as per manufacturer directions. To simulate bathers, baby oil and urea were added to the hot tub water and the water was challenged Pseudomonas aeruginosa and Enterococcus hirae.

Ozone and the enzymatic product reduced bacteria by less than 1 log_{10} within the 30 minute test period. In contrast, generated bromine reduced E. hirae and P. aeruginosa by 6 log_{10} during the same time period. Electrically generated bromine produced a more rapid rate of bacterial kill than bromine added as tablets.

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INTRODUCTION

Microorganisms implicated in pool and spa disease outbreaks include bacteria, such as *Pseudomonas aeruginosa* (Silverman and Nieland, 1983; Levy *et al.*, 1998), *Escherichia coli* O157:H7 (Friedman *et al.*, 1999), *Legionella pneumonphila* (Thomas *et al.*, 1993; Jernigan *et al.*, 1996; Luttichau *et al.*, 1999; McEvoy *et al.*, 2000) and *Mycobacterium avium* (Embil *et al.*, 1997), the protozoan parasites *Giardia lamblia* (Porter *et al.*, 1988) and *Cryptosporidium parvum* (MacKenzie *et al.*, 1995), and hepatitis A virus (Mahoney *et al.*, 1992), Norwalk virus (Kappus *et al.*, 1982) and adenovirus (D'Angelo *et al.* 1979; Martone *et al.*, 1980; Papapetropoulou and Vatarakis, 1998). Diseases caused by these microorganisms are wide ranging and include dermatitis, folliculitis, gastroenteritis, Legionnaire's Disease, Pontiac Fever, hepatitis, pharyngoconjunctivitis and urinary tract infections (Denkewicz, 1996). These outbreaks usually occur from improperly treated pool and spa water (Foy *et al.*, 1968; Mahoney *et al.*, 1992). Although the population at greatest risk are the immunocompromised, the very young, the very old, and pregnant women, (which combined constitute 25% of the population in the United States), healthy individuals are also at risk (Broadbent, 1996; Gerba, 1996). Figure 1 shows disease outbreaks associated with swimming pools and spas and their causative agents in the United States up to 1996.

The continued occurrence of these diseases indicate that there is a need for proper disinfection practices, especially in public pools and spas where there is a greater number of people that are likely to become infected. Proper disinfection of pool and spa water prevents the transmission of disease from

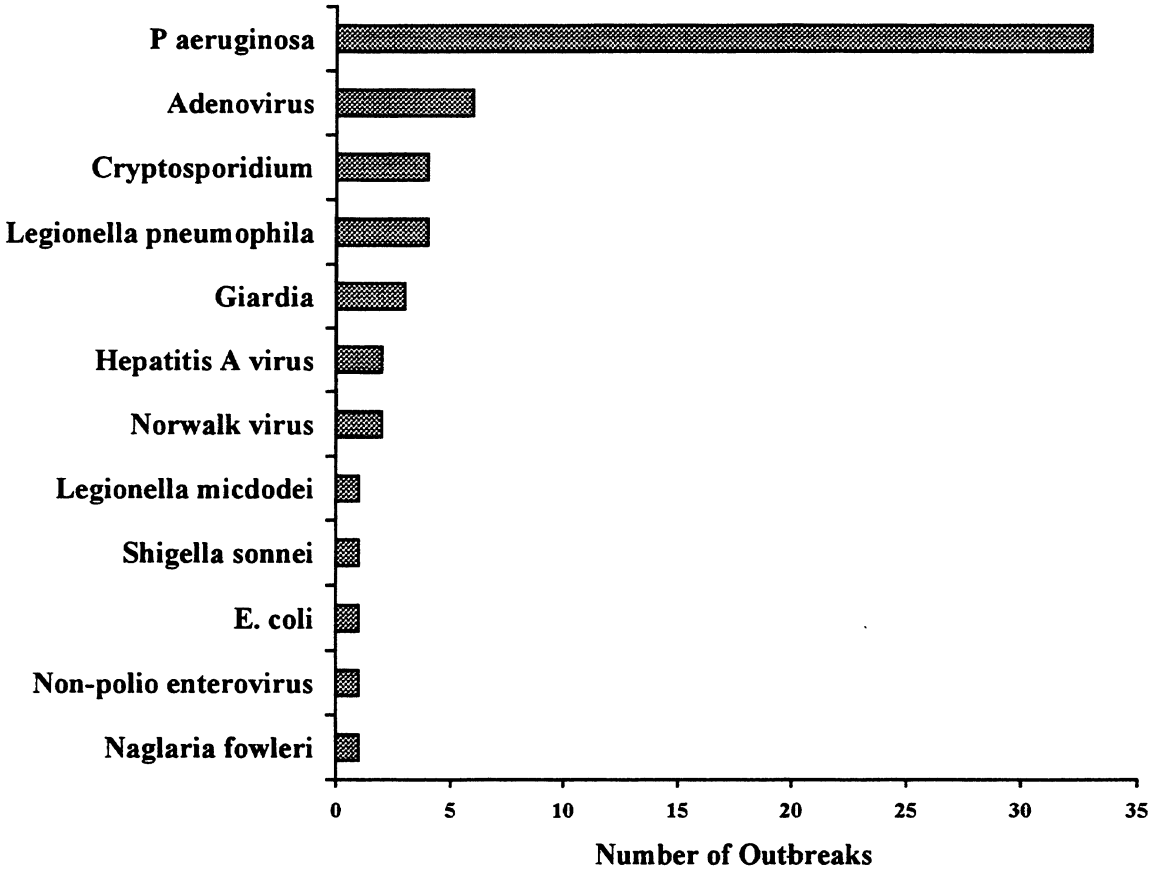

Figure 1 – Spa and Pool Outbreaks in the United States by Infectious Agent up to 1996 (Denkewicz, 1996).

bather to bather. A disinfectant or sanitizer must prove to be effective at killing these and other disease causing microorganisms in order to prevent the spread of disease.

Two tests are available to determine the efficacy of spa sanitizers are the National Sanitation Foundation (NSF) Standard 50 (NSF, 1996) and the Association of Official Analytical Chemists (AOAC) standard 965.13 (AOAC, 1990). The NSF Standard 50 test is a simulated hot tub test. This study modified the spa size to a 1/12th scale. In this test, *Pseudomonas aeruginosa* must be reduced by 99.9% within 30 minutes of exposure *Enterococcus hirae* must be reduced by 99.999% within 30 minutes of exposure to the spa product. Organic matter, in the form of urea (a component of urine) and baby oil (to simulate body oil), is added to the hot tub system to simulate bathers. The AOAC Standard 965.13 test is a laboratory test carried out in a beaker. The test product is evaluated side by side with chlorine. The product must reduce both *Streptococcus fecalis* and *Escherichia coli* by 99.9999% at the same disinfection rate as 0.6 mg/ L (0.6 ppm) of free chlorine. For a spa or swimming pool product to be registered with the USEPA, it must pass the AOAC Standard 965.13.

There are numerous spa products commercially available. Of these, chlorine, bromine and biguanides are EPA registered, while ozone, ionization, silver and enzymes are not. The purpose of this study was to determine the ability of new spa products/ systems and products with chlorine–free claims to kill or inactivate bacteria by the NSF Standard 50 test.

MATERIALS AND METHODS

The products tested in this study were an electrically generated ozone system, an electrically generated bromine system, chemical bromine (tablets), an enzymatic product and chlorine. These were examined for their ability to reduce numbers of bacteria added to the test system as per the NSF Standard 50 protocol.

Previous to any disinfection experiment, bacterial cultures of *P. aeruginosa* (Strain 27313, ATCC, Rockville, MD) and *E. hirae* (Strain 8043, ATCC, Rockville, MD) were grown on Tryptic Soy Agar (TSA, Difco, Detroit, MI) for 24 hours at 37° C. The bacteria were collected in sterile deionized water. Two, 100–L tanks were filled with dechlorinated tapwater (250

mg/L dissolved solids, a turbidity of < 1 NTU and a pH of 7.5) and heated to 41° C with a recirculating heater (Brett Aqualine, Las Vegas, NV) for the generated bromine tests and with a submersible heater for all other tests (George Ulamet Co., Newark, NJ). The product was added or operated as per manufacturer instructions. The water was then challenged with 21.0 mg/L baby oil (Johnson & Johnson, Skillman, NJ), 8.7 mg/L urea (EM Science, Gibbstown, NJ) and the bacteria. Samples were collected at 0, 2, 5, 10, 15 and 30 minutes and placed on DE neutralizing broth (Difco, Detroit, MI) to neutralize the sanitizer. The pH and temperature were measured at each collection period, as well as the residual concentration of the product. Bromine concentrations were measured by digital amperometric titration, and ozone and chlorine concentrations were measured by the DPD method (APHA, 1995). The enzymatic product does not contain a chemical disinfectant, so no residual concentration was measured. Samples were assayed onto 0.45 ?m membrane filters (Millipore, Bedford, MA) or by dilution onto selective media, KF Streptococcus Agar with 1% TTC supplement (Difco, Detroit, MI) for the detection of *E. hirae*, and Pseudomonas agar base with CN supplement (Oxoid, Basingstoke, UK) for the detection of *P. aeruginosa*. The agar plates were incubated at 37° C for 24 hours, the colonies were enumerated (Figure 2) and the log reduction of the bacteria was determined by total number of surviving colonies divided by initial number of colonies (N/N_0).

RESULTS

The results from the NSF Standard 50 tests of the different products are shown in Figure 3. After a 30–minute exposure to the product at a concentration of 2 ppm, a 6–$\log_{10}$ reduction of *E. hirae* and *P. aeruginosa* was achieved by bromine tablets, generated bromine and chlorine. Testing of the generated bromine and bromine tablets at a lower concentration (0.8 ppm) was done to determine if there was any difference between the two types of products. Reduction of both bacteria at least 1–$\log_{10}$ higher when the generated bromine was used (Figure 4). The electrically generated ozone unit was not able to produce more than 0.1 ppm ozone in the testing tank at anytime and showed a <1–$\log_{10}$ reduction of both bacteria tested. These were the same log reductions seen with the heat (no sanitizer added) control. When a new ozone generator was obtained from the manufacturer and tested to assure that the first generator was not defective, similar results were obtained. The enzymatic product reduced *E. hirae* by <1–$\log_{10}$, but had no effect on *P. aeruginosa*.

DISCUSSION AND CONCLUSIONS

This study showed that the generated and tablet bromine spa products were effective in reducing bacteria to a safe level as per the NSF Standard 50 test. Additionally, further testing of tablet versus generated bromine showed that the generated bromine (at 0.8 ppm) had a 1–$\log_{10}$ higher reduction than the chemical bromine.

The enzyme product tested in this study did not reduce either bacteria by even 1–$\log_{10}$ after the 30 minute exposure time period. The same results were seen from testing of the generated ozone system. These results essentially showed no significant reduction, as they were equal to or less than the $\log_{10}$ reductions from the controls with no product (heat

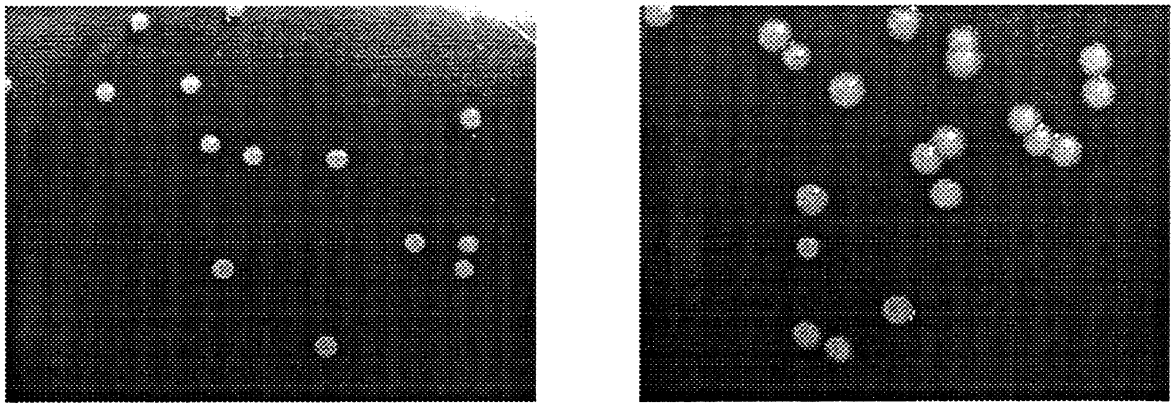

Figure 2 – (a) *E. hirae* produces red to pink colonies on KF Streptococcus Agar; (b) *P. aeruginosa* produces yellow to greenish colonies on the Oxoid Pseudomonas Agar.

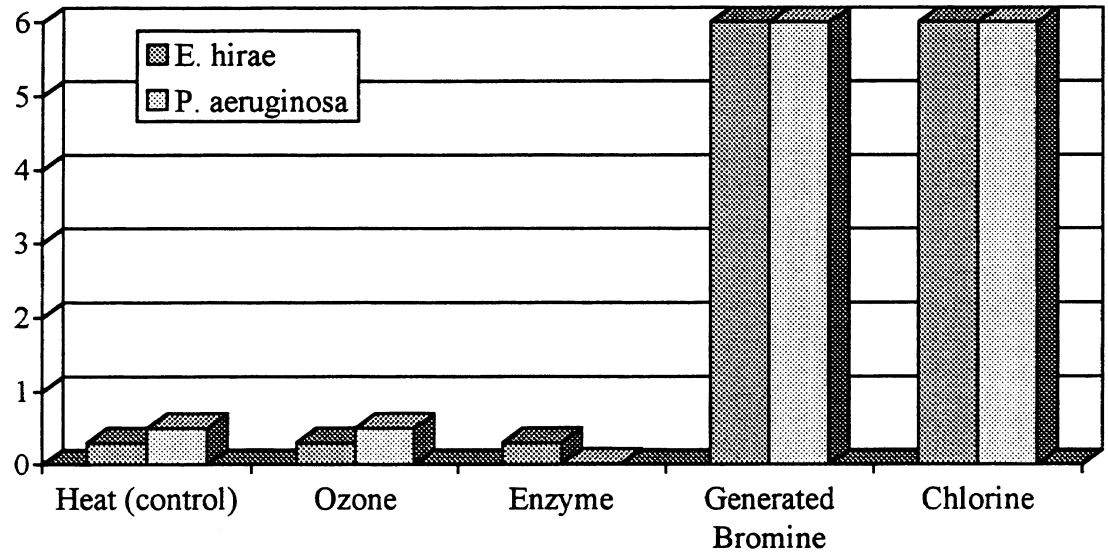

Figure 3 – Log reduction (N/N_o) of *E. hirae* and *P. aeruginosa* after exposure to different spa products and systems.

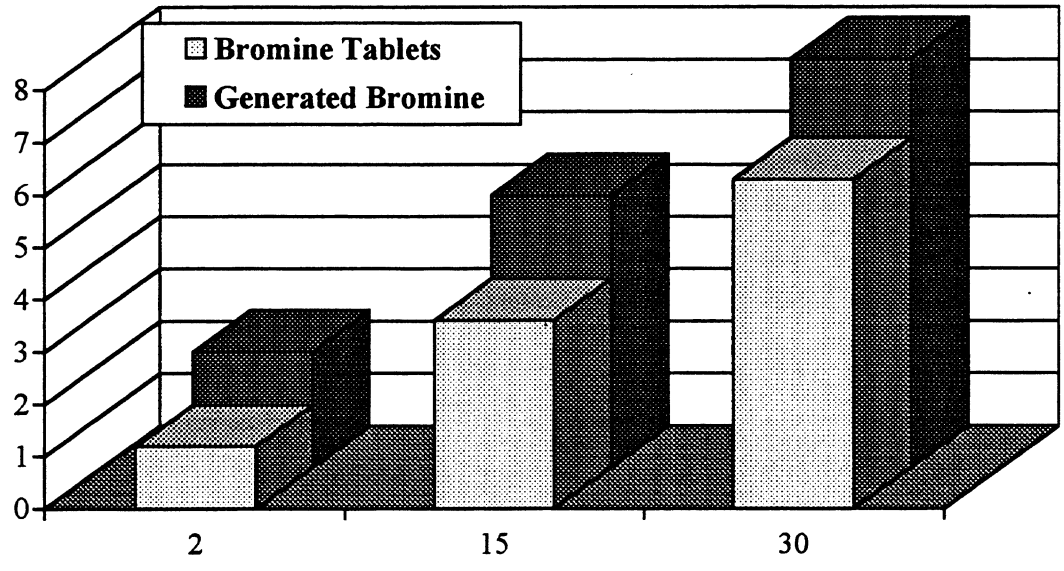

Figure 4 – Log reduction (N/N_o) of *E. hirae* by bromine tablets and generated bromine.

only). Ozone is a highly effective disinfectant, however, it does not maintain a residual in water. The results from this study showed little reduction of the bacteria, indicating that the ozone generators were not producing enough concentration of ozone to kill bacteria in the spa water. Previous studies of ozone disinfection show that a concentration of 0.35 ppm is sufficient to reduce *E. coli*, *P. aeruginosa* and other bacteria by 5 $\log_{10}$ (Korol *et al.*, 1995). The concentrations of ozone observed in the simulated tank usually not detected (>0.01 ppm) and were never higher than 0.05 ppm during the tests.

One of the claimed benefits of "chemical–free" enzyme sanitizers and generated ozone is that their usage eliminates or reduces the need for chemical disinfectants. When ozone is used to sanitize drink-

ing water, a chemical disinfectant is added after the ozone treatment to maintain a residual concentration of disinfectant. This is essential for the inactivation of bacteria and to prevent the regrowth of bacteria in the water. It is important to remember that only EPA registered products have been proven effective in reducing bacteria in spa waters to a safe level. Consumers need to be cautious of products that claim to be chlorine or chemical free. These products do not maintain a residual concentration in water, and the addition of chemicals such as chlorine or bromine is essential to reduce the numbers of bacteria that can cause disease.

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