EVALUATION OF THE DISINFECTION EFFECTIVENESS OF AN OZONE TREATMENT DEVICE FOR INDIVIDUAL WATER SUPPLY

Albert F. Iglar and Bawo E. Okome
Department of Environmental Health
East Tennessee State University

INTRODUCTION

As a disinfectant, ozone has a number of advantages over other chemical agents. It does not increase the organic salt content of the water, it does not impart any taste or color, and it is a powerful disinfectant (Thirumurthi, 1968). For such reasons, ozone has been used, especially in Europe, as a disinfectant of water, principally for municipal supplies. In the United States, ozone is not in common use, apparently chiefly because it produces little or no residual in the distribution system. However, it has been noted that ozone treatment is potentially adaptable to individual water supplies. Its advantages in this application include simplicity, effectiveness over a wide range of pH (Burris, 1977), and minimum need for consumable supplies, such as chlorine.

OBJECTIVE

The objective of this study was to determine the effectiveness of a particular compact ozonator, the "Sojo Model 243-INGL," based on levels of microorganisms prior to and after treatment. Tests were performed for heterotrophic plate count coliforms, and fecal coliforms. Three samples were studied from each of six water supplies.

METHODOLOGY

The samples studied were untreated well and spring waters from private supplies in the vicinity of Elizabethton and Johnson City, Tennessee. The water sources were as follows:

Site 1: Well, 285 feet deep.
Site 2: Well, 100 feet deep.
Site 3: Well, 82 feet deep.
Site 4: Well, 375 feet deep.
Site 5: Spring
Site 6: Spring

Samples for ozone treatment were collected in a 10 liter wide-mouth bottle, which had been washed, rinsed with distilled water, and sterilized. The bottle was kept closed until filled, held near the base to fill, the cap replaced immediately, and aluminum foil wrapped around the neck of the container to prevent contamination. However, approximately 100 ml of air space was left in the bottle to facilitate mixing by shaking before examination. Each sample was transported to the laboratory packed in ice and processed within six hours.

The treatment device produces ozone by electrical discharge. Flow of water through the ozonator was provided by a small pump connected to the 10 liter sampling bottle. Ozonated water was passed through the device prior to and after each use in order to remove contaminants.

The bacteriological tests were carried out before and after ozone treatment. For heterotrophic plate count, plates suitable for counting were obtained by plating 1 ml and 0.1 ml of undiluted sample, and 1 ml of sample diluted 1:100. The required volumes were transferred into test tubes containing 15 ml of Standard Methods Agar (tryptone glucose extract agar, or TGEA) and the pour plates prepared. The plates were incubated at 35° C for 24 hours. Plates showing 30 to 300 colones were used for determining the heterotrophic plate count, which was calculated as number per ml of undiluted sample (APHA, 1980).

In the fecal coliform procedure, undiluted samples of 50 ml and 100 ml were vacuum filtered. The procedure was similar to that for total coliforms, except that the filters were placed in petri dishes containing 2 ml of M-FC medium, were sealed in water- tight plastic bags, and then were submerged in a waterbath at 44.5°C for 24 hours. Colonies with the characteristic blue appearance were counted as fecal coliforms (APHA, 1980)

Values for pH and temperatures were measured at the site of sample collection, using a pH meter that incorporated a temperature probe. Turbidities were measured using a Hach 2100 turbidimeter, which utilized the principle of nephelometry. The ozone residual was measured using the iodometric method, which was begun immediately when sufficient sample had passed through the ozonator. All procedures were performed according to the latest edition of *Standard Methods for the Examination of Water and Wastewater* (APHA, 1980).

RESULTS

Table 1 shows the effect of the ozone treatment on heterotrophic plate count. The average reduction for the sites ranged from 54% to 100%. However, variation in reduction in heterotrophic plate count at four sources (sites 1,2,4 and 5) was great.

Table 2 shows the effect of ozone treatment on total coliform count. IN all trials except two, the treated water showed no detectable coliforms. The level was recorded as <1 per 100 ml in these cases. Other factors made the percent reduction difficult to interpret. In two instances, one at a well and one at a spring, the coliform level in the untreated water had to be recorded as "too numerous to count." In addition, at site 6, a public spring, no coliforms were detected in any sample for either the raw or the ozone treated water. Thus, all levels were recorded as <1 per 100 ml.

Table 3 shows the effect of the ozone treatment on fecal coliform levels. In every sample from every source, the treated water showed no detectable fecal coliforms, meaning that a value of <1 per 100 ml was recorded. The percent reduction was not determined in two cases where the raw water showed levels "too numerous to count," and in three instances (the samples from site 6, a spring) where the raw and treated water both showed values of <1 per 100 ml.

Table 1
Effect of Ozonation on the Heterotrohic Plate Count in Well and Spring Water from Sites 1 through 6

Site	Trail	HPC[a] (CPU[b]/100 mL) Before O_3	After O_3	%Reduction	O_3 Residual (mg/L)
1. Well	1	7.1×10^3	4.6×10^3	35	0.50
	2	1.2×10^4	4.0×10^3	66	0.23
	3	2.6×10^3	1.0×10^3	61	0.50
	Average	7.2×10^3	3.2×10^3	54[A]	0.41
2. Well	1	5.0×10^3	<1	100	0.46
	2	4.2×10^3	1.5×10^3	64	0.19
	3	1.1×10^4	4.0×10^2	96	0.42
	Average	6.7×10^3	6.3×10^2	86[B]	0.36
3. Well	1	9.3×10^3	4.0×10^3	95	0.54
	2	6.0×10^2	<1	100	0.19
	3	3.1×10^3	<1	100	0.46
	Average	3.2×10^3	1.3×10^3	98[C]	0.40
4. Well	1	3.6×10^4	<1	100	0.58
	2	9.1×10^3	3.4×10^3	62	0.38
	3	6.3×10^5	2.0×10^4	96	0.42
	Average	2.3×10^5	7.8×10^3	86[B]	0.46
5. Spring	1	7.2×10^3	1.4×10^3	80	0.35
	2	1.9×10^4	6.0×10^3	68	0.38
	3	3.6×10^4	1.0×10^3	97	0.58
	Average	2.1×10^4	2.8×10^3	81[B]	0.44
6. Spring	1	2.7×10^4	<1	100	0.31
	2	<1	<1		0.50
	3	<1	<1	—	0.54
	Average	9.0×10^3	<1	100[C]	0.45

A, B, C: Average % Reductions with the same letter are not significantly different.

Table 2
Effect of Ozonation on the Total Coliform Population in Well and Spring Water from Sites 1 through 6

Site	Trail	HPC[a] (CPU[b]/100 mL) Before O_3	After O_3	%Reduction	O_3 Residual (mg/L)
1. Well	1	16	<1	100	0.50
	2	TNTC[a]	3	—[b]	0.23
	3	83	<1	100	0.50
	Average	49	1	100	0.41
2. Well	1	4	<1	100	0.46
	2	225	<1	100	0.19
	3	205	<1	100	0.42
	Average	144	<1	100	0.36
3. Well	1	3	<1	100	0.54
	2	1	<1	100	0.19
	3	59	<1	100	0.46
	Average	21	<1	100	0.40
4. Well	1	12	<1	100	0.58
	2	305	8	97	0.38
	3	97	<1	100	0.42
	Average	138	2	99	0.46
5. Spring	1	71	<1	100	0.35
	2	TNTC[a]	<1	—[b]	0.38
	3	114	<1	100	0.58
	Average	92	<1	100	0.44
6. Spring	1	<1	<1	—	0.31
	2	<1	<1	—	0.50
	3	<1	<1	—	0.54
	Average	<1	<1	—	0.45

[a]TNTC: Too numerous to count
[b]TNTC: Not included in the average

Table 3
Effect on Ozonation on the Fecal Coliform Population in Well and Spring Water from Sites 1 through 6

Site	Trail	HPC[a] (CPU[b]/100 mL) Before O_3	After O_3	%Reduction	O_3 Residual (mg/L)
1. Well	1	2	<1	100	0.50
	2	TNTC[a]	<1		0.23
	3	25	<1	100	0.50
	Average	13	<1	100	0.41
2. Well	1	1	<1	100	0.46
	2	18	<1	100	0.19
	3	15	<1	100	0.42
	Average	11	<1	100	0.36
3. Well	1	1	<1	—	0.54
	2		<1	—	0.19
	3	7	<1	100	0.46
	Average	2	<1	100	0.40
4. Well	1	2	<1	100	0.58
	2	33	<1	100	0.38
	3	30	<1	100	0.42
	Average	21	<1	100	0.46
5. Spring	1	38	<1	100	0.35
	2	TNTC[a]	<1		0.38
	3	36	<1	100	0.5%
	Average	37	<1	100	0.44
6. Spring	1	<1	<1	—	0.31
	2	<1	<1	—	0.50
	3	<1	<1	—	0.54
	Average	1	<1	—	0.45

[a]TNTC: Too numerous to count

Table 4
Charcteristics of Water Supplies

Site	Trail	Temperature (T^oC)	pH	Turbidity (NTU)	O_3 Residual (mg/L)
1. Well	1	15	7.1	6.0	0.50
	2	18	7.3	8.1	0.23
	3	18	7.2	0.41	0.50
	Average	17		4.8	0.41
2. Well	1	19	7.3	5.0	0.46
	2	19	7.3	0.71	0.19
	3	18	7.3	0.72	0.42
	Average	19		2.1	0.36
3. Well	1	18	7.6	0.28	0.54
	2	17	7.5	0.25	0.19
	3	20	7.5	0.15	0.46
	Average	18		0.23	0.40
4. Well	1	21	7.1	0.45	0.58
	2	26	7.0	1.5	0.38
	3	23	7.0	0.23	0.42
	Average	23		0.73	0.46
5. Spring	1	20	7.2	0.45	0.35
	2	16	7.1	2.3	0.38
	3	22	7.2	0.64	0.58
	Average	19		1.1	0.44
6. Spring	1	14	8.4	0.45	0.31
	2	12	8.2	0.21	0.50
	3	14	8.2	0.12	0.54
	Average	13		0.26	0.45

Table 4 shows other characteristics of the water supplies. Temperatures were moderate, ranging from 12 to 26o C. No clear trend in temperature could be seen in successive samples. Values for pH were rather consistent for samples from the same source, differing by no more than 0.2 unit. Overall, the range of pH values was 7.0 to 8.4. Values for turbidity were low in most instances, under 1 unit in 13 out of 18 samples. However, a few samples showed intermittent elevated turbidity, ranging to 8.1 units. Overall, the range in turbidity value was 0.12 to 8.1 units.

The ozone residual ranged from 0.19 to 0.58 mg/1 in individual samples. However, the average residuals for the six sources ranged from 0.36 to 0.46 mg/1.

DISCUSSION

The results for heterotrophic plate count showed reductions of 54% to 100%. Although this indicates that the ozone had value, it is not a clear indicator of the effectiveness of ozone as a disinfectant. Analysis of variance was performed on the results for heterotrophic plate count, and showed that there were some significant differences among the mean levels in the ozone treated water ($p=0.05$, as shown in Table 1).

The results for total and fecal coliforms showed satisfactory disinfection in most of the samples tested, with no detectable organisms being found in most samples of treated water. However, this study did not provide clear information on the effectiveness of the ozone treatment under actual conditions of use. Occasional elevated values for turbidity may indicate potential for interference with disinfection. One also may wonder about interference with disinfection if there was an interruption in the supply of electricity. In addition, malfunctions occurred in the ozonator, including blown fuses (apparently produced by a malfunction in the unit's transformer), and leakage of water from the device. An ozonator for individual supplies must be dependable in operation.

The range of pH from 7.0 to 8.4 observed in this study compares with a range of 5.6 to 9.8 given by J. C. Block for bacteriocidal activity from ozone. Thus, there is no reason to infer that the pH levels found in this study interfered with treatment. Block also noted that a temperature range from 0° to 37° C would have little effect on the efficiency of ozone as a disinfectant. Thus, the water temperatures observed in this study, which ranged from 13°C to 23'C, cannot be said to have affected disinfection (Block, 1982).

The few instances of elevated turbidity levels may have been the result of entrance of drainage from the surface. This could not be established, since information on the condition of source protection features was not always available.

The ozonator which was used provided no indication of the ozone dose, and no way to vary the dose in a convenient manner. However, ozone residual was measured in the treated water. The levels in the individual samples ranged from 0.19 to 0.58 mg/1. For comparison, Block listed residual ozone levels of 0.1 to 0.4 mg/1 as required for disinfection, depending on the micro-organisms, and based on a contact period of 10 seconds to 5 minutes (Block, 1982). Therefore, the ozone residuals may have been satisfactory.

CONCLUSIONS

1. The ozone treated water showed satisfactory disinfection in most samples.
2. Use of ozone treatment for individual water supplies must be evaluated in consideration of the protection of the source, quality of water being treated, dependability of the ozonator, and ability to indicate and permit control of ozone dose.

REFERENCES

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