THE EFFECT OF PRECHLORINATION ON FECAL COLIFORM BACTERIA AT CANTON, NORTH CAROLINA

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Thomas J. Hemphill

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ABSTRACT

THE EFFECT OF PRECHLORINATION ON
FECAL COLIFORM BACTERIA
AT CANTON, NORTH CAROLINA

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The purpose of this study was to determine the effective dosage of chlorine needed to control the fecal coliform bacteria in the sewage effluent of the Town of Canton, North Carolina.

After an initial testing period, during which various chlorine dosages were tested, it was determined that the effective dosage would be between 10 mg/l and 20 mg/l. Further refinements of the testing established the fact that a range of 16 mg/l to 18.6 mg/l was needed for control.

ACKNOWLEDGEMENTS

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INTRODUCTION

In 1975 the Environmental Protection Agency requested the Town of Canton, North Carolina, to reduce the amount of fecal coliform bacteria entering the Pigeon River.

The sewage system of the Town of Canton utilizes the wastewater treatment facility of Champion International Corporation, a large paper manufacturing plant. This unique arrangement is of special interest considering that the Town's wastewater is combined with the wastewater from Champion before any treatment is initiated.

Typical chlorination procedures for the reduction or elimination of fecal coliform bacteria involves the addition of gaseous chlorine after treatment (Strandskov, 1949). However, in this situation Champion discharges approximately 50 million gallons of wastewater per day. This effluent does not contain coliform bacteria, however the Town contributes 500,000 to 700,000 gallons of household wastewater per day which contains fecal coliform bacteria. It would be both costly and wasteful to chlorinate the total amount of treated wastewater in the usual way.

The city officials of Canton examined several ways to control the bacteria and decided to use a prechlorination facility which adds gaseous chlorine to Canton's wastewater before mixing with the wastewater of Champion.

Because a large amount of wastewater containing no fecal coliform bacteria is combined with a smaller amount of wastewater which does contain fecal coliform bacteria, it is feasible to chlorine the smaller amount before mixing for treatment.

DISCUSSION AND REVIEW OF LITERATURE

Chlorination has sometimes been mistakenly viewed as the universally accepted method of disinfection, used for many years in the treatment of water and wastewater effluents but in the light of recent events universal chlorination must be evaluated. After issuance of the National Environmental Policy Act of 1969, chlorination was often seen by legislators as the most effective means of controlling the transmission of disease producing organisms.

Although chlorination of sewage effluents appears to be an accepted practice for disinfection in many sewage treatment facilities throughout the country, this was not always the case. As late as 1958, it was reported that only 30% of all sewage treatment plants in the United States were using chlorination facilities (AWWA, 1960).

Recent testing and concern about some of the carcinogens appearing in drinking water has resulted in the scientific community reappraising the wisdom of indiscriminate use of chlorine as a disinfectant. It was discovered that, in addition to the partial disinfection of wastewater effluent, chlorination can result in secondary toxic effects on other biota within receiving waters and in the formation of chlorinated hydrocarbons which could prove carcinogenic to man (Breidenbach, 1966).

To explain the secondary toxic effects that chlorine may have on an environmental system, a comprehensive review of pertinent literature was undertaken. Within the literature appeared extensive descriptions of the toxic effects of chlorine residuals and chlorinated compounds. The effects of chlorinating wastewaters were found to range from aesthetic problems of taste and odor, through toxic effects on fish and aquatic vegetation, to potential toxic effects on man.

Taste and odor problems occurring in water may be due to chlorinated phenolic compounds which can also change the flavor of fish flesh. Eisenhauer in the Journal of the WPCF in 1961 proposed the chlorination of wastes containing phenol produces chlorophenols, and chloro-substituted aliphatic acids. His work indicated that chlorophenols appeared whether pure phenol and hypochlorite or a stripped refinery waste containing phenol and hypochlorite was used. He also found that a dichlorosubstituted aliphatic acid was produced in increasing amounts and showed no sign of being destroyed for increasing concentrations of available chlorine (up to 5000 mg/l) used on a refinery waste containing 78 mg/l of phenolic waste.

D. L. Shumway of Oregon State University studied the effect of secondary municipal wastewater treatment plant effluent on the impairment of the flavor of fish flesh. He found that chlorinated effluents (20% by volume) increased the extent of an "off" flavor in fish.

After analysis of the findings of these studies, a number of generalizations can be made. For example, chlorination of wastewaters has the potential to produce chlorine residuals and chlorinated compounds with varying toxic effects. Chlorine itself is a powerful oxidizing agent, and, as such, is toxic to bacteria. It can also exist in water as free available chlorine in the form of hypochlorous acid, hypochlorite ion, and combined available chlorine in the form of chloromines or other chloro-derivatives. Chloramines, formed from the combination of chlorine and nitrogen compounds, are also toxic. Their disinfecting action, however, is recognized as much less effective than free chlorine, although it persists for a longer period of time. In the past, free available chlorine was seldom found in treated waste-waters and treatment plant effluents because chlorine was usually added in amounts less than the total chlorine demand required to form free available chlorine.

A number of comments made by the National Water Commission would seem to lend weight to the view that the country's large scale use of chlorination needs to be re-examined. These comments appear in the Commission's booklet on water pollution control entitled "New Directions in U. S. Water Policy, (pages 36 to 43): "Operation of waste treatment systems consumes scarce minerals and energy. The chemicals used in waste treatment are them-selves products of a process which also creates wastes. These chain effects mean that a large expenditure of resources to produce a small improvement in water quality may turn out to be counter-productive when total environmental consequences are considered....

"Public expenditures for water pollution abatement must compete for limited tax monies with social demand for housing, education, medical care, slum clearance, full employment, and price stability....

"The regulations should recognize that streams have a self-purifying capacity which allows them to absorb some kinds of discharges in reasonable quantity without harm....

"Drinking water requires high standards, navigation practically no standards at all."

MATERIALS AND METHODS

Two 1000 ml. samples of wastewater from the Town of Canton's low lift pumps were collected daily at 7:00 A.M. and 2:00 P.M. During the summer, a total of 316 samples were taken. The temperature and pH was recorded.

The samples were then taken to the laboratory for addition of gaseous chlorine by a method developed by Hocutt Phillips. The apparatus for the addition of chlorine gas consisted of a lecture bottle of chlorine which was connected to a 250 ml. erlenmeyer flask by Tygon tubing. At the end of the tubing a hypodermic needle was connected. In this procedure 250 ml. samples of wastewater were injected with gaseous chlorine, which simulated full scale prechlorination of the untreated wastewater. A 4 ml. chlorinated sample was taken to determine the parts per million of chlorine which it contained. The remainder was subjected to agitation of 1000 rpms. for one minute, which simulated agitation by the low lift pumps.

After the wastewater was exposed to the chlorine for 20 minutes, a second titration was conducted to determine the residual chlorine. The determination of the parts per million of chlorine and the residual chlorine taken after a 20 minute exposure was determined as follows:

1. Pipet 4 ml. of chlorinated sample into a 250 ml. erlenmeyer flask containing 75-100 ml. of distilled water.

2. Add approximately 10 ml. of 4N Sulfuric Acid and 50 ml. of 10% Potassium Iodide.

3. Titrate the sample with .1N Sodium Thiosulfate until it changes from brown to light yellow.

4. Add 5-10 ml. of starch water and continue to titrate with .1N Sodium Thiosulfate, until the solution turns colorless.

5. Read buret for the number of milliliters titrated and find corresponding mg/l of Chlorine.

Calculation of the parts per million of chlorine as indicated above was primarily the Iodometric Method of Standard Methods, 1971, but was altered somewhat by Hocutt Phillips to hasten the determinations. Standardized solutions of titrants were mixed in Champion International Corporation's laboratory as follows:

Reagents:

1. .1N Sodium Thiosulfate - In a 44 liter tank put in 1100 grams of $Na_2S_2O_3$, .4 grams Na_2CO_3, 10 ml. $CHCl_3$ and q.s. with distilled water.

2. 4N Sulfuric Acid - In a 44 liter tank put in 4920 ml. of concentrated H_2SO_4 and q.s. with distilled water.

3. 10% Potassium Iodide - In a 26 liter tank put in 2600 grams KI and q.s. with distilled water.

4. Starch Water - Using a 250 ml. beaker add 1 level teaspoon of starch and a pinch of salcyclic acid and add about 175-200 ml. of cold distilled water. Add this to a 2000 ml. erlenmeyer flask of boiling water, and then boil for 2-3 minutes.

Calculations:

1. Multiplying the number of milliliters of Sodium Thiosulfate used times the normality of the Sodium Thiosulfate (0.1N) and dividing by the number of ml. of sample used (4 ml.) will yield the normality of the chlorine in the sample.

$$\text{Chlorine Normality} = \frac{(\text{ml. } Na_2S_2O_3)\ (0.1N)}{4 \text{ ml. of sample}}$$

2. Multiplying the normality of chlorine (Cl_2) by the gram equivalent weight of chlorine (35.453) will yield the number of grams of chlorine per liter.

$$\text{gpl } Cl_2 = \text{normality of Chlorine} \times 35.453$$

3. The above calculations can be combined so that the grams per liter of chlorine equals the milliliters of Sodium Thiosulfate times .8863.

$$\text{gpl } Cl_2 = (\text{ml. } Na_2S_2O_3)\ .8863.$$

Two methods were used in determining the presence of the coliform group: The 408B. Fecal Coliform Membrane Filter Procedure, and the 407A. Standard Total Coliform Tests from the Standard Methods, 1971.

Using the Standard Total Coliform Tests the presumptive, confirmed, and completed tests were run taking 72 hours to complete. Identical results were found using the Coliform Membrane Filter Procedure, which was simpler and taking only 24 hours for results.

EXPERIMENTAL RESULTS

It was determined after preliminary chlorine dosages that more chlorine was required in the morning than the evening and a range somewhere between 10 mg/l and 20 mg/l, (tables 1 and 2), would be sufficient to reduce the fecal coliform bacteria to zero.

The amount of rainfall was a major problem. As the precipitation increased, the amount of chlorine needed was less because the household wastes were diluted (table 4).

Temperature variation also had a slight effect on the amount of kill by the chlorine gas. As the temperature of wastewater increased, the chlorine dosage was also increased to achieve the desired result (table 5).

Final results showed that between 16 mg/l and 18.6 mg/l would be an adequate chlorine dosage to control the fecal coliform bacteria in all conditions during the testing period.

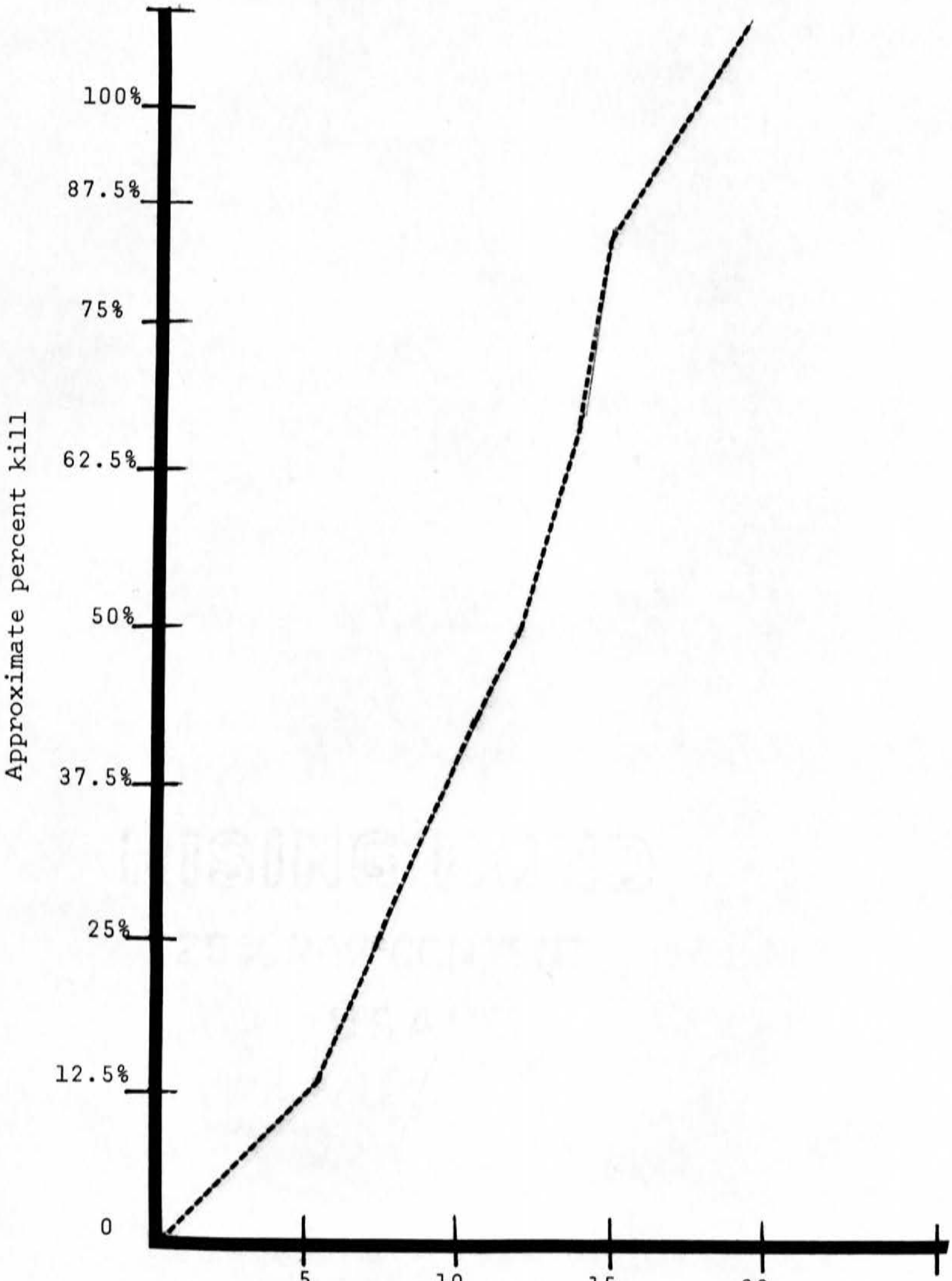

Figure 1. Amount of Kill of Coliform Bacteria by Increasing Chlorine Concentrations

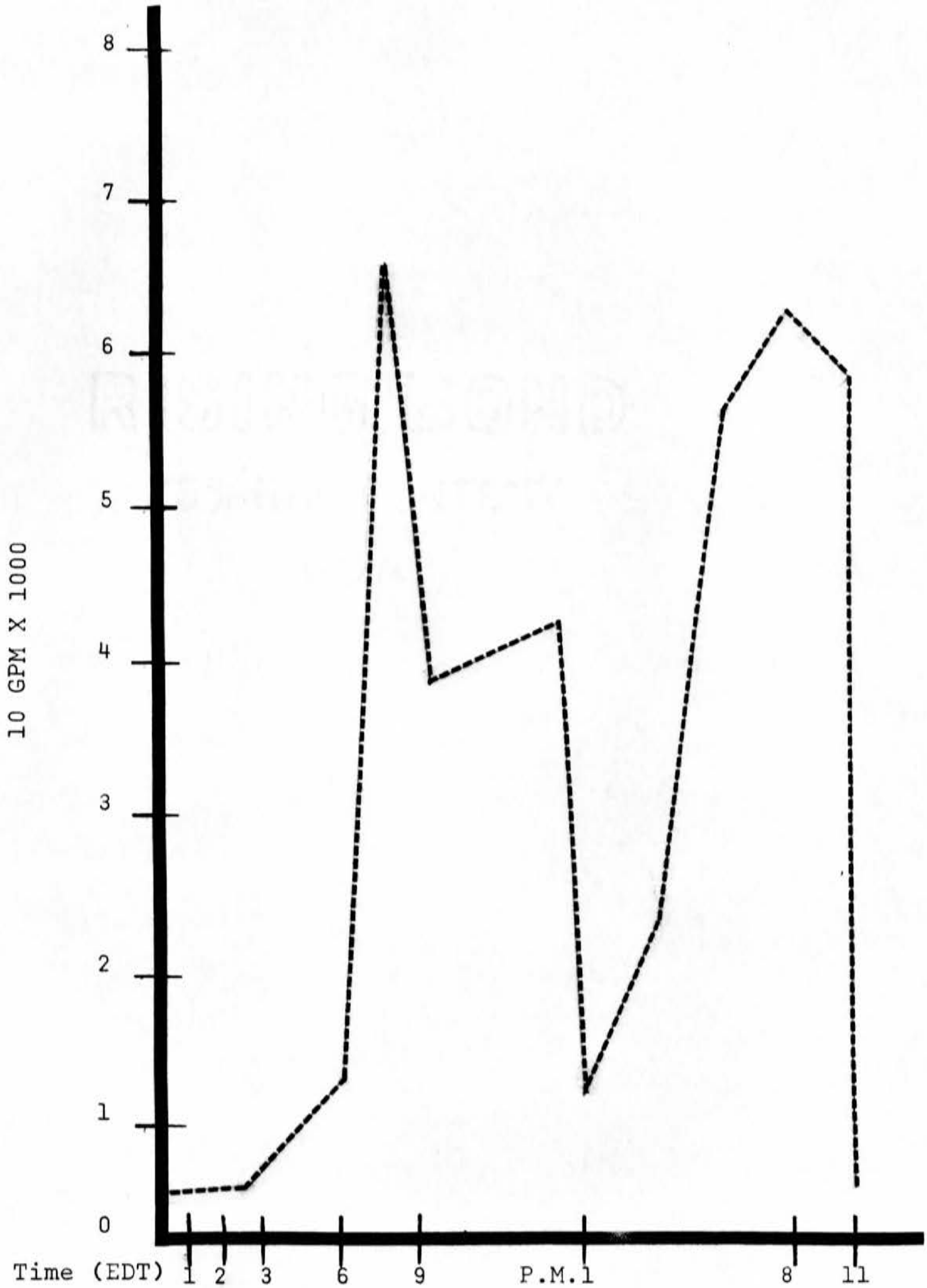

Figure 2. Average Municipal Wastewater Flow
(May 1976 through August 1976)

Table 1. Preliminary Chlorine Dosages

Date	mg/l of Cl_2	Time of Sample	Presence of Fecal Coliform Bacteria	Sample Temp. (°F)	Residual Chlorine
May 15, 1976	0 (Control)	7:00 A.M.	+	50°	0
May 15, 1976	9.8	7:00 A.M.	+	50°	0
May 17, 1976	21.3	7:00 A.M.	0	50°	4.3
May 17, 1976	30.1	7:00 A.M.	0	50°	13.1
May 19, 1976	43.0	7:00 A.M.	0	51°	25.8
May 19, 1976	47.2	7:00 A.M.	0	50°	30.0

Table 2. Preliminary Chlorine Dosages

Date	mg/l of Cl_2	Time of Sample	Presence of Fecal Coliform Bacteria	Sample Temp. (°F)	Residual Chlorine
May 15, 1976	0 (Control)	2:00 P.M.	+	50°	0
May 15, 1976	8.1	2:00 P.M.	+	50°	0
May 17, 1976	22.0	2:00 P.M.	0	50°	5.9
May 17, 1976	29.1	2:00 P.M.	0	50°	13.0
May 19, 1976	43.2	2:00 P.M.	0	51°	26.9
May 19, 1976	46.3	2:00 P.M.	0	50°	30.0

Table 3. Chlorine Dosages after Preliminary Survey Comparing A.M. to P.M.

Date	mg/l of Cl_2	Time of Sample	Presence of Fecal Coliform Bacteria	Sample Temp. (°F)	Residual Chlorine
June 5, 1976	15.0	2:00 P.M.	+	52°	0
June 5, 1976	19.0	7:00 A.M.	0	52°	.4
June 20, 1976	16	2:00 P.M.	0	52°	0
June 20, 1976	20	7:00 A.M.	0	52°	0
June 28, 1976	15.8	2:00 P.M.	0	53°	0
June 28, 1976	17.2	7:00 A.M.	0	53°	0

Table 4. Effect of Precipitation on Cl_2 Kill

Date	mg/l of Cl_2	Time of Sample	Presence of Fecal Coliform Bacteria	Sample Temp. (°F)	Residual Chlorine	Amount of Precip.
June 26, 1976	16	7:00 A.M.	0	53°	0	.81
August 2, 1977	16.3	7:00 A.M.	0	53°	0	.28
August 27, 1977	16.8	7:00 A.M.	0	54°	0	.50
August 28, 1977	16.1	7:00 A.M.	0	54°	0	1.53

Table 5. Effect of Temperature on Cl_2 Kill

Date	mg/l of Cl_2	Time of Sample	Presence of Fecal Coliform Bacteria	Sample Temp. (°F)	Residual Chlorine
June 20, 1976	16	2:00 P.M.	0	52°	0
June 25, 1976	16.8	2:00 P.M.	+	53°	0
July 10, 1976	16.3	2:00 P.M.	+	53°	0
July 21, 1976	17.4	2:00 P.M.	0	54°	.3
August 10, 1976	18.0	2:00 P.M.	+	55°	0
August 16, 1976	18.6	2:00 P.M.	0	56°	0

Table 6. Climatological Data May 1976 - Canton Station

DAILY PRECIPITATION

Day of Month	Precip.	Day of Month	Precip.	Day of Month	Precip.
1	.36	12		23	
2		13	.76	24	
3		14	1.08	25	.33
4		15	2.26	26	.10
5		16		27	
6		17		28	.65
7		18	.03	29	6.65
8	.43	19		30	1.26
9	.35	20		31	
10		21			
11	.38	22			

DAILY TEMPERATURES

Day of Month	Max.	Min.	Day of Month	Max.	Min.
1	69	50	17	62	45
2	69	43	18	67	31
3	65	42	19	79	35
4	63	33	20	81	39
5	75	32	21	81	39
6	74	49	22	82	43
7	70	56	23	79	56
8	62	49	24	71	51
9	73	39	25	69	49
10	73	40	26	72	42
11	69	50	27	68	44
12	76	46	28	62	54
13	80	43	29	65	51
14	70	56	30	76	48
15	70	51	31	86	49
16	73	46			

Average: Max. 71.6 Min. 45.9

Table 6. (Continued)

Average Maximum	Average Minimum	Departure from Normal	Highest	Date	Lowest	Date
71.6	45.9		86	31	31	18

Table 7. Climatological Data June 1976 - Canton Station

DAILY PRECIPITATION

Day of Month	Precip.	Day of Month	Precip.	Day of Month	Precip.
1	.20	11		21	.05
2	.12	12		22	
3	.06	13		23	.05
4		14	.25	24	
5		15		25	
6		16	.04	26	.81
7		17	.16	27	.13
8		18		28	
9		19	.10	29	.14
10	.03	20	.50	30	.18

DAILY TEMPERATURES

Day of Month	Max.	Min.	Day of Month	Max.	Min.
1	81	53	16	85	62
2	73	55	17	82	62
3	65	55	18	84	61
4	61	53	19	80	59
5	70	47	20	75	58
6	73	38	21	73	56
7	76	42	22	78	48
8	80	48	23	80	53
9	80	56	24	80	55
10	81	51	25	86	55
11	83	50	26	79	64
12	84	51	27	79	62
13	85	53	28	82	60
14	77	51	29	82	55
15	82	54	30	79	57
		Average:	Max. 78.5	Min. 54.1	

Table 7. (Continued)

Average Maximum	Average Minimum	Average	Departure from Normal	Highest	Date	Lowest	Date
78.5	54.1	66.3		86	25	38	6

Table 8. Climatological Data July 1976 - Canton Station

DAILY PRECIPITATION

Day of Month	Precip.	Day of Month	Precip.	Day of Month	Precip.
1		12	.01	23	
2		13		24	
3	.01	14		25	1.02
4		15	.56	26	
5		16	.14	27	.21
6		17		28	
7		18		29	.02
8		19		30	.20
9	.02	20	.02	31	.70
10		21			
11		22	.29		

DAILY TEMPERATURES

Day of Month	Max.	Min.	Day of Month	Max.	Min.
1	75	51	17	79	59
2	80	50	18	81	50
3	75	55	19	81	49
4	69	60	20	85	54
5	69	56	21	85	58
6	72	53	22	85	57
7	76	50	23	87	61
8	81	51	24	90	61
9	83	57	25	87	59
10	84	54	26	89	61
11	89	55	27	88	64
12	89	60	28	85	60
13	83	60	29	89	59
14	85	49	30	86	60
15	86	56	31	84	60
16	84	60			

Average: Max. 82.6 Min. 56.4

Table 8. (Continued)

SUMMARIZED TEMPERATURE DATA

Average Maximum	Average Minimum	Average	Departure from Normal	Highest	Date	Lowest	Date
82.6	56.4	69.5		90	24	49	19

Table 9. Climatological Data August 1976 - Canton Station

DAILY PRECIPITATION

Day of Month	Precip.	Day of Month	Precip.	Day of Month	Precip.
1		12		23	.16
2	.28	13	.20	24	
3	.31	14		25	
4		15	.46	26	.03
5		16		27	.50
6		17		28	1.53
7	.07	18		29	
8		19		30	
9		20		31	
10		21	.11		
11		22			

DAILY TEMPERATURES

Day of Month	Max.	Min.	Day of Month	Max.	Min.
1	86	59	17	81	58
2	77	59	18	78	51
3	77	55	19	76	50
4	80	50	20	75	52
5	82	52	21	70	59
6	83	53	22	81	61
7	82	53	23	86	59
8	76	59	24	85	60
9	81	54	25	83	58
10	84	48	26	83	61
11	87	50	27	80	62
12	87	55	28	85	62
13	84	57	29	82	64
14	87	58	30	79	52
15	87	56	31	77	48
16	78	57			

Average: Max. 81.3 Min. 55.9

Table 9. (Continued)

SUMMARIZED TEMPERATURE DATA

Average Maximum	Average Minimum	Average	Departure from Normal	Highest	Date	Lowest	Date
81.3	55.9	68.6		87	15	48	31

SUMMARY

The objective in treating the wastewater effluent of Canton, North Carolina is to eliminate the fecal coliform bacteria.

"Chlorine demand," as defined in Part 100 of Standard Methods, is of little significance in relation to the objectives of wastewater chlorination. "Chlorine requirement" is a more suitable term.

The chlorine requirement is defined as the amount of chlorine which must be added per unit volume to produce the desired result under stated conditions. The result may be based on any number of criteria, such as stipulated coliform density and a specified residual concentration. In each instance a definite chlorine dosage will be necessary. This dosage constitutes the chlorine requirement (Standard Methods, 1971).

In those cases where the desired result is a specified residual chlorine concentration, residuals may be determined by either the iodometric or the orthotolidine method. It is important that the same method be used for both laboratory testing and operational control. The iodometric method was used at the Canton facility.

At the Canton facility it was determined that: (1) a zero amount of fecal coliform should exist after prechlorination with a contact time of 20 minutes and temperatures of 60°F for the water and 70°F for the air; and (2) the minimum chlorine dosage to produce the desired result of zero coliform bacteria was 16 mg/l and the maximum dosage required was 18.6 mg/l.

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VITA

Thomas J. Hemphill was born on July 3, 1953 in Waynesville, North Carolina. His parents are Charles Thomas and Rutha Lee Hemphill of Canton, North Carolina. Thomas was graduated from Pisgah High School in Canton, North Carolina in 1971. Upon graduation from high school he entered Appalachian State University and received the B. A. degree with a major in biology in June 1975.

Upon completion of his undergraduate program, Thomas accepted an assistantship for graduate study at Appalachian State University, and began work on the Master of Science degree in September 1975.