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INFLUENCE OF pH AND TEMPERATURE ON THE SURVIVAL OF COLIFORMS AND ENTERIC PATHOGENS WHEN EXPOSED TO CHLORAMINE [1]

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In a preceding paper of this series (*1*), data were presented on the influence of pH and temperature on the survival of coliforms and enteric pathogens when exposed to free chlorine. In that paper it was pointed out that very little information was available concerning the bactericidal properties of free chlorine, to the exclusion of all chlorine-addition products. It also was emphasized that (*a*) the bacterial kills were obtained with free chlorine to the exclusion of all chlorine-addition products; (*b*) free chlorine was a much more effective bactericidal agent than any equivalent amount of chloramine or any combination of chlorine and chloramine, and (*c*) consequently the results presented were applicable as a criterion in estimating the bactericidal efficiency of water disinfection by chlorine, only when the chlorine was present as free chlorine. That is, the results are applicable only when the water under treatment is free of substances which would combine with chlorine to form chlorine-addition products, or when the chlorine being measured is post-break-point chlorine in the break-point chlorination process. It was indicated also that little information was available concerning the action of chloramine in the absence of free chlorine.

Since the studies reported at this time were completed, Weber and Levine (*2*) have reported on factors affecting the germicidal efficiency of chlorine and chloramine, using a standardized suspension of spores

[1] From Sanitary Engineering Division, Water and Sanitation Investigations, East Third and Kilgour, Cincinnati 2, Ohio.

of *B. metiens* as test organisms. They consider the results obtained with spores applicable to vegetative cells of bacteria such as the coliforms and enteric pathogens. They conclude in part that in disinfection with free chlorine there is a decided lag at first, followed by increasing death rates; whereas with chloramine, death rates, in general, were quite constant throughout the period of disinfection. They also state that in reactions more alkaline than pH 9.4 chloramine is a better disinfectant than free chlorine.

Results obtained with vegetative cells, which will be herein presented, are not in complete agreement with these observations. This probably means that there are definite differences in the effects obtained with vegetative cells and with spores.

Weber and Levine conclude further that with Cl_2:N ratios of 4:1 or less the chlorine available was but slightly altered and was all chloramine; whereas with Cl_2:N ratios of 8:1 or more, chlorine residuals were reduced and the available chlorine was present as free chlorine. That is, they suggest that (*a*) the hump of the break point curve comes at a Cl_2:N ratio of about 4:1; (*b*) the break point of the curve is at a Cl_2:N ratio of about 8:1; and (*c*) free chlorine is present with Cl_2:N ratios between 4:1 and 8:1.

Moore, Megregian, and Ruchhoft (*3*), reporting on the chemical aspects of the ammonia-chlorine treatment of water, have shown that in a system freed of all oxidizable organic matter, the hump in the break point curve occurs at a Cl_2:N ratio of about 5:1 and the break point at a ratio of about 9:1. They also have shown that both the Marks titrator test and the p-aminodimethylaniline flash test indicated no free chlorine present up to the time of break point and no chloramine-chlorine beyond the break point. The concensus appears to favor these observations, though considerable disagreement exists regarding these matters, with the literature appearing to indicate that break point may occur at Cl_2:N ratios of from 5:1 to 25:1. For more complete information regarding this and other related factors, the reader should review the literature cited in references (*1*), (*2*), and (*3*).

In the studies reported at this time the bactericidal efficiency of the chloramines for the coliforms and some of the enteric pathogens has been determined under various conditions, to the exclusion of free chlorine or any other toxic agent. To assure such conditions, tests were conducted with Cl_2:N ratios of 6:1 or less, with a contact period of 1 hour for the Cl_2 and ammonium chloride solution added, before the test organisms were introduced. Examinations made during the study indicated that at this and lesser ratios, oxidation of ammonia did not occur, and the residual chlorine content (in the absence of other substances with a chlorine demand) was approximately the same as the amount of chlorine added, and was all chloramine. With ratios of Cl_2:N of 6:1 or more, oxidation of the chloramines formed began and was carried to completion (break point) at ratios of about 9:1 to 10:1. During this period of oxidation the residual chlorine content, present as chloramine, is reduced in proportion to the amount of N oxidized until a zero residual chlorine reading is obtained at break point, when all of the N present has been oxidized. Any residual chlorine found post-break point is free chlorine or hypochlorite. These observations would be equally applicable to water disinfection processes using chlorine regardless of whether N was present in the water from natural or pollutional sources, or had been added as an ammonium compound in connection with the chlorine-ammonia process. The results presented at this time on the bactericidal efficiency of chloramines should be of especial interest wherever water disinfection by the chlorine-ammonia process is used or such use is contemplated.

METHODS

In general, the methods followed in this study were the same as in the previous investigation of the bactericidal properties of free chlorine, and reference is made to that report (*1*) for their description. This applies particularly to the preparation of (*a*) chlorine-free, chlorine-demand-free water, buffered at the desired pH ranges; (*b*) glassware; (*c*) stock chlorine solutions; (*d*) bacterial suspensions; (*e*) the determination of the hydrogen-ion concentration; (*f*) the making of bacterial counts and the identification of survivor bacteria; and (*g*) the neutralization of the residual chloramine in sample portions withdrawn for test. In working with chloramines certain additional methods necessarily were required. These may be described as follows:

Preparation of stock nitrogen solution.—A standardized solution of ammonium chloride (0.5728 gm. of NH_4Cl per liter) was prepared for these tests. This strength of solution was selected to facilitate the preparation for each test. That is, the major portion of the tests was made with a concentration of nitrogen as N of 0.3 p. p. m., and the standard amount of water used in these tests was 500 ml. One milliliter of this standardized ammonium chloride solution added to 500 ml. of chlorine-free, chlorine-demand-free water produced a N content of 0.3 p. p. m.

Determination of chloramine residual.—The methods given in reference (*1*) for the preparation of chlorine solutions and the determination of chlorine residuals were used in this study. However, certain additional factors should be noted. The minimum effective amount of residual chlorine as chloramine was 0.15 p. p. m. whereas in the study with free chlorine, residuals of 0.03 p. p. m. or less were found to be bactericidal. Thus the minimum residuals of chloramine, being of greater magnitude, could be determined more accurately.

Check tests for the presence of free chlorine were made with the p-aminodimethylaniline indicator described by Moore (*4*) but free chlorine indications with this flash test were never observed in this study at Cl_2:N ratios below 9:1. Tests for residual chlorine as chloramine were made with orthotolidine, using 2.0 ml. of reagent per 100 ml. of sample with the temperature adjusted to between 20° and 25° C. when such adjustment was needed. Readings were made after 10 to 30 seconds and again after standing for 10 minutes; the former to check on the flash test for free chlorine and the latter to determine the total residual present. The appearance of color in 30 seconds would have been considered definite evidence of the presence of free chlorine, and preliminary tests had proved that full color development from chloramine would take place in 10 minutes at 20° C.

It is realized in making these tests and in basing this report on these methods that the residual chlorine results recorded are not in themselves a direct measure of the effective bactericidal agent, active in the waters tested. That is, it is recognized that the bactericidal action is a function of (*a*) the available concentration of the toxic agent; (*b*) the period of exposure; and (*c*) the temperature. In the waters used in this study, which had been freed of all chlorine-utilizing or -combining substances, the available concentration of the active bactericidal agent depended entirely on the extent to which the total toxic agent present could release the active agent; or, the extent to which the chloramine present could provide ionized chlorine or hypochlorite under the existing conditions. It has been estimated that at pH readings of 5.0, 6.0, 7.0, 8.0, 9.0, and 10.0 the amount of ionized hypochlorite is 100, 97, 75, 23, 3.0, and 0.3 percent, respectively, and that at pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5 the chloramine present as monochloramine is 35, 51, 84, 98, 100, and 100 percent, respectively. In each case the remaining chloramine is probably dichloramine. Thus, the hydrogen-ion concentration of the water appears to be the most important factor in determining the availability of the bactericidal agent. In the results reported at this time with the residual chlorine based on the total titratable chlorine, or the residual indicated by orthotolidine after 10 minutes at 20° C., no measure was made of the active bactericidal agent. If this had been done, it is logical to assume that equivalent amounts of active, available bactericide would produce equal bacterial kills regardless of the pH of the water. However, it seemed advisable to report the results based on these methods as in practically all cases tests made for chloramines in actual plant operation will depend entirely on such procedures. To attempt to estimate the active chlorine available from chloramine would only cloud the issue, when practical tests for such determinations are not available for routine plant operation.

Preparation of bacterial suspensions.—For this chloramine study, bacterial suspensions were prepared in the manner described in the free chlorine study (*1*) from the 11 strains of the 5 genera used in that study. Ten additional strains of the genus *Shigella*, freshly isolated or virulent cultures, were available for test in the chloramine study. These were composed of 1 strain of dysenteriae, 4 strains of sonnei and 5 strains of paradysenteriae, the latter including 1 Flexner V, 1 Flexner W, 2 Flexner Z, and 1 Boyd 88. These additional *Shigella* cultures were available through the courtesy of Maj. K. S. Wilcox of the United States Army Medical School.

TEST PROCEDURES

Using the methods, equipment, and materials above described, 193 series of tests have been performed in addition to a considerable number of preliminary exploratory experiments. The complete program of the study occupied a period of about 2 years. A series consisted of repeated observations on a number of test portions of water. The number of test portions in a series was varied in a few instances, but in general eight was the number used. Of these, one was a control, containing the buffered water with N added, and the other seven were test portions with increasing amounts of chloramine present. The set-up of a standard series may be described as follows:

Ten milliliters of standardized stock ammonium-chloride solution were added to 5 liters of sterile, chlorine-free, chlorine-demand-free water which had been prepared as described and buffered at the desired pH. (This provided a nitrogen content, as N, of 0.3 p. p. m. In a few series, 18, the Cl_2 content was kept constant with the N content varied to determine the effect of such variations.) The contents were mixed thoroughly and 500-ml. portions of this mixture were transferred to each of eight sterile, chemically clean, 1-liter Erlenmeyer flasks, numbered from 1 to 8. Flask No. 1 was a control, which received no chlorine and was equipped with a thermometer to provide for temperature readings. The remaining seven flasks received increasing amounts of standardized chlorine solution (titrated by acid starch-iodide procedure), at appropriate intervals, to produce concentrations of 0.15, 0.3, 0.6, 0.9, 1.2, 1.5, and 1.8 p. p. m., respectively. This produced Cl_2:N ratios of 0.00, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, and 6.0 to 1.0, respectively in the eight flasks. The term "appropriate interval" means that additions of chlorine to each succeeding flask were made with such intervening time periods that conflicts would not occur in the times for subsequent examinations of the various test portions. In preliminary series various periods of contact (from a few minutes to 68 hours) of the nitrogen and chlorine before the addition of the test bacteria were tried. It was found, as has been reported by Moore et al (*3*), that the chlorine-ammonia reaction was quite rapid, particularly in the lower pH ranges, and was complete in all cases before 1 hour had elapsed. A contact period of 1 hour, therefore, was made the standard for the routine series of this study.

At the end of the 1-hour contact period a 100-ml. portion of the 500 ml. in each flask was removed for a residual chlorine determination, the temperature was read and recorded, and 1 ml. of a suspension of the test bacteria was added. Vigorous mixing was started at once and continued for 1 minute before a portion was withdrawn for plating. Preliminary tests had indicated that uniform distribution was obtained under the given conditions in 15 to 30 seconds, and the period of 1 minute (approximately twice the time indicated for uniform mixing) was adopted so that this initial period could be observed exactly for all test portions in all series. Examinations for survivor bacteria were made uniformly at the 1.0-, 3.0-, 5.0-, 10.0-, 20.0-, 40.0-, 60.0-, 90.0-, 120-, 180-, and 240-minute periods of exposure. Occasionally, as indicated, examinations were made also at the 6- and 24-hour periods. Likewise, examinations were discontinued when previous tests showed that 100-percent kills had been obtained for at least two of the preceding test periods. Hydrogen-ion concentrations were also checked at the start and at the close of each run.

Examinations for residual chlorine in each flask of a series were made at the start, after 1 hour, and again at the end of each run. Initial chlorine residuals only are shown in the tables presented, as variations in chloramine residuals observed at later periods were never in excess of the observational error. In fact, a detailed study of the persistence of chloramine residuals under the conditions of this study showed reductions in residuals were not to be anticipated during the first 24 hours. A time schedule was prepared for each flask to provide for accuracy in observing the correct times for sampling and examination. Series were run at 2° to 6° C., and at 20° to 25° C., and with waters at pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5, with the greatest number at pH 8.5, being representative of an average water. For all series conducted at 2° to 6° C., and also at 20° to 25° C., when room temperatures were not within this range, the flasks were kept in a constant-temperature water bath. The temperature ranges given represent the average minimum and maximum temperatures observed during the entire course of a series; actually the average ranges of temperature observed during the more important period of each series (first 2 hours), were 2° to 4° C. and 20° to 22° C.

RESULTS

In performing these 193 series of tests, the range of observations was extended to the limits which it was thought might be met under natural conditions in practical water-treatment operations. The accomplishment of two objects was sought in this: To obtain data which, even though limited, might be useful as a general guide in controlling water-disinfection processes; and to provide data for a direct comparison of the relative efficiency of water disinfection under the various conditions of the tests by the use of (*a*) chloramine and (*b*) free chlorine, utilizing for the latter the data presented in the previous report (*1*). Thus, with regard to hydrogen-ion concentration, series were run at pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5, the maximum range which would be expected in nature under average conditions. With regard to temperature, two ranges, 2° to 6° C. and 20° to 25° C., the average extremes to be expected in nature, were studied.

Of the 193 series (*a*) 32 were performed at the 2° to 6° C. temperature range; of these, 12 were with *Escherichia coli* and 12 with *Eberthella typhosa* in waters of pH 7.0, 8.5, and 9.5, and 8 with *Shigella sonnei* in waters at pH 8.5; (*b*) 143 were performed at 20° to 25° C., 26 with *Esch. coli* strains, 24 with *Aerobacter aerogenes,* 25 with *Pseudomonas pyocyanea,* 24 with *Eber. typhosa,* and 24 with *S. dysenteriae,* each in waters of all the pH values noted; and 8 series were carried on with *S. sonnei* and 12 series with *S. dysenteriae* in waters at pH 8.5 only; and (*c*) also at 20° to 25° C., 18 series conducted with *Esch. coli* in waters of pH 7.0, 8.5, and 10.5 with the Cl_2 content kept constant at 0.3 p.p.m. and the N content varied so that Cl_2:N ratios ranging from 1:1 to 1:25 were obtained.

As has been noted, every series with each strain under test was repeated at least once and the results averaged. Then the averaged results for all strains of a given genus, obtained under the same conditions, were averaged to obtain the data presented in the tables. The number of cultures used of each genus and the total number of series represented in each averaged result are shown in the tables. The average results obtained with *Esch. coli, A. aerogenes, P. pyocyanea Eber. typhosa,* and *S. dysenteriae* are presented in tables 1 to 5, respectively. In table 6 the results obtained with various strains of *S. dysenteriae, S. sonnei,* and *S. paradysenteriae* at 20° to 25° C. are compared, and in table 7 the results obtained with *S. sonnei* in waters of pH 8.5 at 2° to 6° C. are shown. Table 8 contains the results obtained in waters at pH 7.0, 8.5, and 10.5, at 20° to 25° C., with *Esch. coli* when the Cl_2 content was kept constant and the N content varied, so that Cl_2:N ratios of from 1:1 to 1:25 existed. These data of table 8 may be compared with those of table 1 where Cl_2:N ratios of 0.5:1 to 6:1 prevailed. In table 9 data are compiled from tables 1 to 7, inclusive, to show the average time in minutes required to produce a 100-percent kill of the bacteria of the various genera under the various conditions of test.

TABLE 1.—*Average survival of* Escherichia coli, *expressed in percent of initial number, when exposed to chloramine in various concentrations at pH 7.0, 8.5, and 9.5 at 2° to 6° C., and at pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5, at 20° to 25° C., with nitrogen content constant (0.3 p. p. m.) and contact time of Cl_2 and N, 1 hour before addition of bacteria.*

Number of strains	Number of tests	Average percentage surviving after exposure											Residual Cl_2 p. p. m.	Cl_2/N
		1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	0 minutes	Ratio
At 2° to 6° C.														
pH 7.0														
2	4	100.0	-----	-----	-----	-----	-----	-----	-----	92.4	-----	88.4	0	0-1
2	4	94.4	-----	-----	93.0	81.5	70.7	67.7	60.0	48.8	31.1	21.0	.15	0.5-1
2	4	97.2	-----	-----	85.3	74.0	61.0	57.3	34.6	16.1	4.3	.8	.30	1-1
2	4	92.8	-----	-----	76.2	67.7	36.1	17.5	2.8	.5	0	0	.60	2-1
2	4	95.2	-----	-----	64.0	47.0	13.7	2.2	.1	0	0	-----	.90	3-1
2	4	96.0	-----	74.9	49.2	21.8	2.0	.1	0	0	-----	-----	1.20	4-1
2	4	92.4	-----	62.9	43.6	13.4	.7	0	0	0	-----	-----	1.50	5-1
2	4	88.6	65.7	44.4	9.8	0.1	0	0	-----	-----	-----	-----	1.80	6-1
pH 8.5														
2	4	100.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	90.8	0.02	0-1
2	4	100.0	-----	-----	[1] 99.7	-----	-----	99.0	-----	82.7	-----	76.4(1)	.15	0.5-1
2	4	97.0	-----	-----	94.8	-----	-----	90.0	81.7	75.9	58.6	41.8(2)	.30	1-1
2	4	96.1	-----	-----	95.5	-----	-----	85.2	70.6	58.7	40.1	26.4(3)	.60	2-1
2	4	94.6	-----	-----	88.9	-----	-----	66.8	52.4	39.0	20.7	14.6(4)	.90	3-1
2	4	93.8	-----	-----	92.0	80.0	74.8	54.8	40.9	22.1	4.5	1.3(5)	1.20	4-1
2	4	94.4	-----	-----	88.4	78.8	57.1	43.4	35.4	9.8	2.8	1.0(6)	1.50	5-1
2	4	82.4	44.8	20.8	.2	0	0	0	-----	-----	-----	-----	1.80	6-1
pH 9.5														
2	4	100.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	86.5	0	0-1
2	4	94.4	-----	-----	91.8	-----	-----	84.2	-----	85.0	83.5	72.0(7)	.30	1-1
2	4	98.6	-----	-----	93.5	-----	-----	88.3	-----	80.4	67.5	68.5(8)	.60	2-1
2	4	96.6	-----	-----	91.8	-----	-----	83.1	-----	76.0	65.7	61.3(9)	.90	3-1
2	4	95.1	-----	-----	90.2	-----	-----	75.6	-----	68.0	62.9	52.0(10)	1.20	4-1
2	4	94.0	-----	-----	84.2	-----	-----	73.0	-----	64.3	49.9	23.4(11)	1.50	5-1
2	4	86.2	-----	67.0	54.9	13.5	13.8	2.6	0	0	-----	-----	1.80	6-1

[1] Interpolated figure.

NOTE.—Percentages surviving at the sixth and twenty-fourth hours were respectively: (1) 67.1 and 5.0; (2) 35.1 and 0.1; (3) 0.2 and 0; (4), (5), and (6), 0 and 0; (7) 61.5 and 48.1; (8) 66.5 and 4.4; (9) 56.0 and 0; (10) 33.2 and 0; and (11) 7.4 and 0 percent.

Number of strains	Number of tests	1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	Residual Cl_2 0 minutes	Cl_2/N Ratio
At 20° to 25° C.														
pH 6.5														
2	5	100.0	-----	-----	-----	-----	-----	91.3	-----	98.3	-----	93.7	0.01	0-1
2	5	88.6	-----	-----	77.2	54.4	15.6	.5	-----	-----	-----	-----	.15	5-1
2	5	94.1	-----	[1]79.3	60.8	27.2	.2	0	0	0	-----	-----	.30	1-1
2	5	81.7	88.5	49.0	20.7	.1	0	0	-----	-----	-----	-----	.60	2-1
2	5	72.5	57.5	36.8	2.4	0	0	0	-----	-----	-----	-----	.90	3.1
2	5	67.5	47.7	22.2	.8	0	0	-----	-----	-----	-----	-----	1.20	4-1
2	5	56.2	17.2	.9	0	0	0	-----	-----	-----	-----	-----	1.50	5-1
2	3	60.5	.1	0	0	0	0	0	-----	-----	-----	-----	1.80	6-1
2	3	59.2	0	0	0	0	0	-----	-----	-----	-----	-----	1.80	7-1
2	3	15.0	0	0	0	0	0	-----	-----	-----	-----	-----	1.40	8-1
2	3	0	0	0	0	0	0	-----	-----	-----	-----	-----	1.10	9-1
2	3	0	0	0	0	0	0	-----	-----	-----	-----	-----	.50	10-1

TABLE 1.—*Average survival of* Escherichia coli, *expressed in percent of initial number, when exposed to chloramine in various concentrations at pH 7.0, 8.5, and 9.5, at 2° to 6° C., and at pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5, at 20° to 25° C., with nitrogen content constant (0.3 p. p. m.) and contact time of* Cl_2 *and N, 1 hour before addition of bacteria*—Continued

Number of strains	Number of tests	Average percentage surviving after exposure											Residual Cl_2 p. p. m.	Cl_2/N
		1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	0 minutes	Ratio
						At 20° to 25° C—Continued pH 7.0								
2	4	100.0	----	----	----	97.6	100.0	100.0	----	86.6	100.0	77.4	0.01	0–1
1	2	97.3	----	76.6	82.6	69.8	54.4	25.2	----	.1	----	----	.15	.5–1
2	4	99.0	----	81.7	76.4	59.6	4.4	.1	0	0	----	----	.30	1–1
2	4	92.4	----	72.8	60.2	4.2	0	0	0	0	----	----	.60	2–1
2	4	96.2	85.9	58.2	23.5	.4	0	0	0	----	----	----	.90	3–1
2	4	78.4	61.0	41.2	3.2	0	0	0	----	----	----	----	1.20	4–1
2	4	72.1	52.5	17.8	.2	0	0	0	----	----	----	----	1.50	5–1
1	2	86.6	15.4	0	0	0	0	0	----	----	----	----	1.80	6–1
1	2	86.4	.5	0	0	0	0	0	----	----	----	----	1.10	7–1
1	2	5.6	0	0	0	0	0	0	----	----	----	----	1.10	8–1
1	2	0	0	0	0	0	0	0	----	----	----	----	.40	9–1
1	2	0	0	0	0	0	0	0	----	----	----	----	.50	10–1
						pH 7.8								
2	2	100.0	----	----	----	----	----	----	----	----	----	100.0	0	0–1
2	2	100.0	----	----	87.0	81.8	39.8	8.7	1.3	0.3	0	0	.30	1–1
2	2	98.8	----	81.7	79.3	35.0	1.4	.1	0	0	0	0	.60	2–1
2	2	91.1	----	74.0	55.8	2.3	.1	0	0	0	----	----	.90	3–1
2	2	81.8	----	59.7	19.6	.1	.0	0	0	----	----	----	1.20	4–1
2	2	76.0	67.9	----	3.8	0	0	0	----	----	----	----	1.50	5–1
2	2	67.4	----	36.6	6.0	0	0	0	----	----	----	----	1.80	6–1
						pH 8.5								
2	5	100.0	----	----	----	----	----	98.8	----	100.0	----	93.7	0.01	0–1
2	3	100.0	95.3	[1]98.5	----	----	92.5	94.2	83.4	67.5	28.8	6.5	.15	5–1
2	5	99.1	[1]98.3	[1]97.0	93.6	[1]90.5	78.9	62.9	32.0	14.6	4.1	.1	.30	1–1
2	5	97.9	[1]93.0	[1]89.1	79.7	72.9	42.4	12.8	1.8	0	0	0	.60	2–1
2	5	95.3	80.7	75.0	75.1	61.0	22.7	1.6	0	0	0	----	.90	3–1
2	5	89.7	75.8	74.0	63.6	30.5	1.4	0	0	0	----	----	1.20	4–1
2	5	87.1	77.1	65.7	46.9	9.0	0	0	0	----	----	----	1.50	5–1
2	3	43.1	19.1	10.1	.1	0	0	0	----	----	----	----	1.80	6–1
2	2	0	0	0	0	0	0	0	----	----	----	----	1.30	7–1
1	1	0	0	0	0	0	0	0	----	----	----	----	1.30	8–1
1	1	0	0	0	0	0	0	0	----	----	----	----	1.20	9–1
1	1	0	0	0	0	0	0	0	----	----	----	----	1.20	10–1
						pH 9.5								
2	5	100.0	----	----	----	----	----	98.9	----	97.6	----	92.8	0.015	0–1
1	2	100.0	----	98.1	88.2	94.0	98.6	99.2	----	83.4	----	17.1	.15	.5–1
2	5	99.1	----	----	[1]97.6	96.2	93.4	88.5	----	59.7	24.1	6.8	.30	1–1
2	5	100.0	----	----	[1]96.1	92.5	82.3	52.6	21.5	4.2	.8	0	.60	2–1
2	5	95.8	----	[1]94.5	87.1	79.1	50.3	18.0	2.2	.2	0	0	.90	3–1
2	5	97.3	94.0	84.4	73.4	55.6	18.3	1.2	0	0	----	----	1.20	4–1
2	5	82.3	55.1	41.9	34.4	24.4	3.8	0	0	0	----	----	1.50	5–1
2	3	52.9	6.9	0	0	0	0	0	----	----	----	----	1.80	6–1
1	1	1.5	0	0	0	0	0	0	----	----	----	----	2.00	7–1
1	1	0	0	0	0	0	0	0	----	----	----	----	2.00	8–1
1	1	0	0	0	0	0	0	0	----	----	----	----	2.40	9–1
1	1	0	0	0	0	0	0	0	----	----	----	----	2.40	10–1
						pH 10.5								
2	5	100.0	----	----	----	----	----	87.6	----	74.2	67.8	74.4	0.01	0–1
1	3	96.1	----	----	----	----	----	100.0	----	93.7	84.2	65.6	0.15	.5–1
2	5	98.9	----	----	----	----	----	94.7	----	85.7	74.8	56.6	.30	1–1
2	5	97.2	----	----	----	100.0	100.0	90.0	70.8	73.2	39.7	20.7	.60	2–1
2	5	98.5	----	----	100.0	93.5	84.7	82.0	64.7	39.0	22.8	7.3	.90	3–1
2	5	96.4	----	96.5	92.4	91.2	77.2	63.6	24.4	30.3	5.4	.2	1.20	4–1
2	5	91.2	86.9	74.7	81.5	76.4	50.6	27.9	7.9	2.7	0	0	1.50	5–1
1	2	100.0	83.2	86.0	70.4	27.9	5.1	0	0	0	----	----	1.80	6–1

[1] Interpolated figures.

TABLE 2.—*Average survival of* A. aerogenes *expressed in percent of initial numbers, when exposed to chloramine in various concentrations at pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5 at 20°–25° C. with nitrogen content constant (0.3 p. p. m.) and contact of* Cl_2 *and N, 1 hour before addition of bacteria*

Number of strains	Number of tests	Average percentage surviving after exposure											Residual Cl_2 p. p. m.	Cl_2/N
		1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	0 minutes	Ratio
pH 6.5														
2	4	100.0	----	----	----	----	----	----	----	----	----	94.5	Trace	0-1
2	3	93.1	----	----	86.8	69.8	45.9	31.2	5.2	0.4	0	0	.15	0.5-1
2	4	96.4	----	----	69.4	38.5	4.4	.1	0	0	0	----	.30	1-1
2	4	86.4	----	73.9	39.1	5.0	0	0	0	0	----	----	.60	2-1
2	4	89.7	70.1	48.2	7.5	0.1	0	0	0	----	----	----	.90	3-1
2	4	88.2	60.8	25.6	1.0	0	0	0	----	----	----	----	1.20	4-1
2	4	74.8	28.4	3.0	0	0	0	0	----	----	----	----	1.50	5-1
2	3	61.1	1.4	0	0	0	0	0	----	----	----	----	1.80	6-1
pH 7.0														
2	4	100.0	----	----	----	----	----	----	----	----	----	99.0	0.01	0-1
1	1	100.0	----	----	91.7	75.0	61.4	49.1	24.5	8.6	1.2	0	.20	0.5-1
2	4	96.6	----	----	89.0	59.6	25.4	2.2	.1	0	0	----	.30	1-1
2	4	96.6	----	87.6	70.6	23.3	.2	0	0	0	0	----	.60	2-1
2	4	95.2	----	79.3	43.9	2.0	0	0	----	----	----	----	.90	3-1
2	4	92.7	79.6	55.8	12.6	.1	0	0	----	----	----	----	1.20	4-1
2	4	83.6	66.1	29.5	.7	0	0	0	----	----	----	----	1.50	5-1
2	3	90.9	21.5	0	0	0	0	0	----	----	----	----	1.80	6-1
pH 7.8														
2	4	100.0	----	----	----	----	----	----	----	----	----	96.8	0	0-1
2	4	95.8	----	----	91.2	75.6	57.6	44.6	34.7	13.4	1.2	.1	.30	1-1
2	4	97.0	----	88.5	82.6	67.4	39.6	15.4	.4	.2	0	----	.60	2-1
2	4	98.5	----	82.2	61.1	33.8	10.2	.5	0	0	----	----	.90	3-1
2	4	91.0	81.6	76.4	56.9	22.8	.2	0	0	----	----	----	1.20	4-1
2	4	96.4	87.2	68.8	44.7	3.4	0	0	0	----	----	----	1.50	5-1
2	4	85.7	42.0	24.4	9.9	0	0	0	----	----	----	----	1.80	6-1
pH 8.5														
2	4	100.0	----	----	----	----	----	----	----	----	----	90.0	0.01	0-1
2	4	96.0	----	----	[2] 90.0	----	72.0	52.2	21.1	7.3	0.2	0	.30	.1-1
2	4	98.0	----	----	72.2	62.2	46.2	11.4	1.3	.1	----	----	.60	2-1
2	4	93.6	----	----	68.8	54.9	14.8	.9	.1	0	----	----	.90	3-1
2	4	88.0	----	74.0	62.7	46.0	3.0	.1	0	----	----	----	1.20	4-1
2	4	84.4	70.8	61.8	54.0	18.4	.2	0	0	----	----	----	1.50	5-1
2	3	62.2	.2	0	0	0	0	0	----	----	----	----	1.80	6-1
pH 9.5														
2	4	100.0	----	----	----	----	----	----	----	----	----	92.4	Trace	0-1
1	2	90.8	----	----	----	100.0	----	93.0	----	83.0	40.0	[1] 6.4	0.15	0.5-1
2	4	99.2	----	----	98.3	90.8	83.6	68.6	----	35.0	9.2	8.6	.30	1-1
2	4	96.2	----	----	87.9	78.7	58.2	46.7	22.6	12.3	3.9	.6	.60	2-1
2	4	96.1	----	93.4	80.6	66.3	48.1	26.4	----	5.0	.1	----	.90	3-1
2	4	91.4	----	81.5	80.9	62.0	37.6	20.0	----	.9	----	----	1.20	4-1
2	4	88.1	85.8	79.4	72.2	54.0	22.2	5.8	.2	----	----	----	1.50	5-1
1	2	94.2	78.6	45.0	1.0	0	0	0	0	----	----	----	1.80	6-1
pH 10.5														
2	4	100.0	----	----	----	----	----	----	----	----	----	93.4	Trace	0-1
1	1	100.0	----	----	----	----	----	98.3	----	99.8	87.9	65.3	0.15	0.5-1
2	4	97.4	----	----	99.4	----	----	94.0	89.6	82.6	74.2	62.2	.30	1-1
2	4	99.4	----	----	96.3	----	----	89.0	81.7	71.1	58.0	38.4	.60	2-1
2	4	99.3	----	----	96.8	----	83.5	69.9	56.5	41.1	26.1	15.6	.90	3-1
2	4	91.3	----	----	93.7	80.4	82.8	72.0	57.5	33.6	23.6	6.3	1.20	4-1
2	4	97.8	----	----	88.0	75.6	61.8	43.4	28.6	12.6	.8	----	1.50	5-1
2	3	91.6	77.0	77.6	39.1	2.6	0	0	0	----	----	----	1.80	6-1

[1] 0 percent at 360 minutes.
[2] Interpolated figure.

TABLE 3.—*Average survival of* Ps. pyocyaneus *expressed in percent of initial number when exposed to chloramine in various concentrations at pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5 at 20°–25° C. with nitrogen content constant (0.3 p.p.m.) and contact of* Cl_2 *and N, 1 hour before addition of bacteria.*

Number of strains	Number of tests	Average percentage surviving after exposure											Residual Cl_2 p. p. m.	Cl_2/N
		1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	0 minutes	Ratio
							pH 6.5							
2	4	100.0	----	----	----	----	----	85.4	----	89.5	78.7	78.8	Trace	0-1
2	4	94.0	----	83.0	85.2	77.4	61.8	64.2	2.9	0	0	0	.15	0.5-1
2	4	91.8	88.6	76.2	68.9	44.3	.2	0	0	0	----	----	.30	1-1
2	4	89.6	69.0	73.0	37.0	.1	0	0	----	----	----	----	.60	2-1
2	4	77.5	61.0	40.9	2.9	0	0	0	----	----	----	----	.90	3-1
2	4	71.1	55.7	12.2	.1	0	0	0	----	----	----	----	1.20	4-1
2	4	52.0	39.6	4.4	0	0	0	0	----	----	----	----	1.50	5-1
2	4	42.6	8.6	0	0	0	0	----	----	----	----	----	1.80	6-1
							pH 7.0							
2	5	100.0	----	----	----	----	----	100.0	----	87.0	84.9	82.5	Trace	0-1
2	3	95.9	----	----	75.6	87.6	89.0	70.1	44.8	17.9	0.4	0	.15	0.5-1
2	5	93.7	----	85.4	93.5	76.4	16.4	2.0	0	0	0	----	.30	1-1
2	5	95.9	----	95.6	56.2	7.4	0	0	0	----	----	----	.60	2-1
2	5	92.7	91.0	76.9	11.7	0	0	0	----	----	----	----	.90	3-1
2	5	94.2	74.9	43.9	3.3	0	0	0	----	----	----	----	1.20	4-1
2	4	72.2	33.4	24.3	.1	0	0	0	----	----	----	----	1.50	5-1
2	3	74.2	17.8	.6	0	0	0	----	----	----	----	----	1.80	6-1
							pH 7.8							
2	4	100.0	----	----	----	----	----	----	----	----	----	93.2	Trace	0-1
2	4	95.3	----	----	94.6	92.3	74.8	52.6	16.1	3.2	0	0	.30	1-1
2	4	94.5	----	86.5	69.5	41.8	7.6	.1	0	0	0	----	.60	2-1
2	4	88.2	----	85.1	58.4	11.2	0	0	0	----	----	----	.90	3-1
2	4	92.6	82.6	63.8	28.8	.1	0	0	----	----	----	----	1.20	4-1
2	4	88.6	67.2	49.1	7.3	0	0	0	----	----	----	----	1.50	5-1
2	4	77.4	65.5	13.7	0	0	0	0	----	----	----	----	1.80	6-1
							pH 8.5							
2	4	100.0	----	----	----	----	----	----	----	----	86.4	----	Trace	0-1
2	4	90.7	----	----	92.9	94.4	76.1	56.6	9.6	0.3	0	----	.30	1-1
2	4	93.3	----	----	76.9	75.0	37.0	2.6	0	0	0	----	.60	2-1
2	4	87.8	----	83.9	85.4	31.0	1.5	0	0	0	0	----	.90	3-1
2	4	84.6	----	88.0	59.1	4.2	0	0	0	0	----	----	1.20	4-1
2	4	91.4	84.5	59.2	36.8	2.6	0	0	0	----	----	----	1.50	5-1
2	4	64.7	48.3	30.3	16.3	2.0	0	0	----	----	----	----	1.80	6-1
							pH 9.5							
2	4	100.0	----	----	----	----	----	86.8	----	72.4	----	50.7	Trace	0-1
2	4	94.7	----	----	90.8	94.8	82.0	72.8	40.8	19.3	0.3	0	.30	1-1
2	4	94.9	----	----	87.4	85.4	68.4	32.3	24.0	2.6	0	0	.60	2-1
2	4	95.6	----	85.8	92.4	75.0	34.3	14.4	5.8	0	----	----	.90	3-1
2	4	87.3	83.2	78.0	71.8	50.4	20.3	5.8	.3	0	----	----	1.20	4-1
2	4	91.1	80.0	71.8	50.8	34.8	16.3	6.8	0	----	----	----	1.50	5-1
2	4	74.7	51.3	44.1	23.5	.8	.1	0	----	----	----	----	1.80	6-1
							pH 10.5							
2	4	100.0	----	----	----	----	----	68.6	----	52.2	45.2	71.6	Trace	0-1
2	4	92.2	----	----	----	83.6	62.1	72.2	53.8	10.6	3.3	2.4	.30	1-1
2	4	95.8	----	----	90.1	86.4	60.2	47.2	28.9	.3	.3	0	.60	2-1
2	4	89.8	----	85.4	78.5	75.5	35.0	28.8	16.0	0	0	----	.90	3-1
2	4	91.9	----	83.4	78.6	44.2	40.0	20.8	3.0	0	0	----	1.20	4-1
2	4	87.8	82.6	79.3	42.3	37.8	37.5	15.1	0	0	----	----	1.50	5-1
2	4	58.9	50.9	41.0	33.6	20.8	.2	0	0	----	----	----	1.80	6-1

TABLE 4.—*Average survival of* Eberthella typhosa, *expressed in percent of initial number when exposed to chloramine in various concentrations at pH 7.0, 8.5, and 9.5 at 2° to 6° C., and at pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5 at 20° to 25° C., with nitrogen content constant (0.3 p.p.m.) and contact time of Cl_2 and N, 1 hour before addition of bacteria*

Number of strains	Number of tests	Average percentage surviving after exposure											Residual Cl_2 p. p. m.	Cl_2/N
		1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	0 minutes	Ratio
							At 2°—6° C. pH 7.0							
2	4	100.0	----	----	----	----	----	----	----	----	----	95.8	0	0-1
2	4	92.7	----	----	93.2	86.9	78.8	71.7	61.4	44.4	17.9	10.7(1)	.15	0.5-1
2	4	92.2	----	----	85.4	76.3	68.9	50.6	27.3	10.0	1.8	.7	.30	1-1
2	4	90.4	----	80.9	73.0	67.6	31.6	14.1	3.6	1.1	0	----	.60	2-1
2	4	79.1	----	79.6	64.6	41.4	6.0	2.3	.2	0	----	----	.90	3-1
2	3	83.8	----	58.8	42.1	11.8	.8	.1	0	----	----	----	1.20	4-1
2	4	76.1	56.9	38.0	20.8	3.1	.1	0	----	----	----	----	1.50	5-1
2	4	63.0	32.8	17.2	.6	0	0	0	----	----	----	----	1.80	6-1
							pH 8.5							
2	4	100.0	----	----	----	----	----	----	----	----	----	94.8	0	0-1
2	4	97.2	----	----	99.1	89.1	89.1	82.5	83.0	77.6	75.2	58.7(2)	.15	0.5-1
2	4	98.4	----	----	94.9	88.2	84.4	79.2	79.8	69.1	56.0	50.4(3)	.30	1-1
2	4	98.3	----	----	90.6	87.2	81.2	75.0	67.5	52.9	22.1	11.0(4)	.60	2-1
2	4	94.8	----	94.7	87.9	79.8	77.4	65.0	44.2	25.8	5.3	1.0	.90	3-1
2	4	94.0	----	91.0	81.2	77.1	64.4	51.0	25.2	11.0	1.8	.2	1.20	4-1
2	4	92.5	88.8	77.3	73.6	65.8	40.0	20.1	4.5	.4	----	----	1.50	5-1
2	4	60.7	20.5	1.4	0	0	0	0	0	----	----	----	1.80	6-1
							pH 9.5							
2	4	100.0	----	----	----	----	----	----	----	----	----	86.2	0	0-1
2	4	95.6	----	----	94.6	----	----	85.4	----	83.9	75.5	76.6(5)	.30	1-1
2	4	90.5	----	----	90.7	----	----	86.8	84.8	81.0	70.2	69.5(5)	.60	2-1
2	4	94.1	----	----	90.6	----	----	85.3	80.1	76.9	61.7	44.4(6)	.90	3-1
2	4	84.1	----	----	85.2	----	82.7	77.6	72.5	61.4	50.9	35.7(7)	1.20	4-1
2	4	84.0	----	----	85.2	78.4	75.8	66.1	66.0	55.0	31.8	13.5(8)	1.50	5-1
2	4	89.5	----	57.4	25.2	22.6	18.1	14.8	14.0	0	0	0	1.80	6-1

NOTE.—(1) 0 percent at 24 hours, (2) 58.4 percent at 360 minutes, and 0 percent at 24 hours, (3) 24.2 percent at 360 minutes and 0.1 percent at 24 hours, (4) 2.8 percent at 360 minutes and 0 percent at 24 hours, (5) 0 percent at 24 hours, (6) 7.4 percent at 360 minutes and 0 percent at 24 hours, (7) 0.40 percent at 360 minutes and 0 percent at 24 hours, (8) 0.1 percent at 360 minutes and 0 percent at 24 hours.

At 20° to 25° C.

pH 6.5

2	4	100.0	----	----	----	----	----	----	----	----	94.8	----	0.01	0-1
2	4	94.3	----	[1]82.0	67.4	58.5	23.8	4.9	0.1	0	0	----	.15	0.5-1
2	4	89.5	----	68.2	55.2	20.8	0	0	0	0	----	----	.30	1-1
2	4	77.8	59.6	52.7	21.4	0	0	0	0	0	----	----	.60	2-1
2	4	67.6	50.0	28.8	.4	0	0	0	0	----	----	----	.90	3-1
2	4	54.2	29.7	3.7	0	0	0	0	----	----	----	----	1.20	4-1
2	4	43.4	6.3	0	0	0	0	----	----	----	----	----	1.50	5-1
2	4	15.1	0	0	0	0	0	----	----	----	----	----	1.80	6-1

[1] Interpolated figures.

TABLE 4.—*Average survival of* Eberthella typhosa, *expressed in percent of initial number when exposed to chloramine in various concentrations at pH 7.0, 8.5, and 9.5 at 2° to 6° C., and at pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5 at 20° to 25° C., with nitrogen content constant (0.3 p.p.m.) and contact time of Cl_2 and N, 1 hour before addition of bacteria*—Continued.

Number of strains	Number of tests	Average percentage surviving after exposure											Residual Cl_2 p. p. m.	Cl_2/N
		1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	0 minutes	Ratio
At 20° to 25° C.—Continued														
pH 7.0														
2	4	100.0									97.8		0	0-1
2	4	95.6		[1]94.9		93.7	67.3	49.9	27.4	30.6	3.4	0.6	.15	0.5-1
2	4	95.4		83.1	77.4	62.6	13.4	1.3	0	0	0		.30	1-1
2	4	88.6		79.1	58.0	5.7	0	0	0	0			.60	2-1
2	4	75.5	66.8	53.9	9.0	0	0	0					.90	3-1
2	4	63.6	43.3	23.2	.3	0	0	0					1.20	4-1
2	4	46.4	22.0	1.4	0	0	0	0					1.50	5-1
2	4	20.6	.2	0.	0	0	0	0					1.80	6-1
pH 7.8														
2	4	100.0									96.7	92.2	0	0-1
2	4	94.6			96.6	70.4	29.4	4.9	0.2	0	0	0	.30	1-1
2	4	87.8		76.8	60.7	20.1	.2	0	0	0	0	0	.60	2-1
2	4	83.8	73.7	55.3	38.4	3.2	0	0	0	0			.90	3-1
2	4	75.1	54.7	48.0	12.1	0	0	0	0				1.20	4-1
2	4	59.4	43.0	25.4	5.2	0	0	0	0				1.50	5-1
2	4	24.5	2.0	0	0	0	0	0					1.80	6-1
pH 8.5														
2	4	100.0									96.2	98.0	0	0-1
2	4	93.4		[1]97.0	100.0	83.7	58.4	24.9	6.1	0.7	0	0	.30	1-1
2	4	92.7		90.3	81.2	53.6	15.8	6.7	0	0	0		.60	2-1
2	4	90.8	98.6	82.8	75.4	29.4	1.5	0	0	0			.90	3-1
2	4	85.6	100.0	80.7	45.2	5.4	0	0	0				1.20	4-1
2	5	86.1	74.0	55.1	22.3	0.6	0	0					1.50	5-1
2	3	8.1	0	0	0	0	0						1.80	6-1
pH 9.5														
2	4	100.0								89.0		86.6	0	0-1
2	4	94.5			100.0	93.2	89.1	73.6	66.1	51.0	11.9	.4	.30	1-1
2	4	92.8		96.0	92.4	86.2	67.9	55.6	35.8	8.4	0	0	.60	2-1
2	4	91.5		100.0	79.2	73.9	52.4	33.7	4.1	.1			.90	3-1
2	4	84.8		77.9	71.6	54.6	29.0	6.3	0	0			1.20	4-1
2	4	84.0	78.2	75.2	64.5	38.4	3.8	0	0				1.50	5-1
2	4	43.8	0	0	0	0	0	0					1.80	6-1
pH 10.5														
2	4	100.0						73.3		59.6	37.5	40.1	0	0-1
2	4	89.0			[1]88.0		85.4	75.6	55.2	54.9	30.0	17.4	.30	1-1
2	4	93.2			[1]89.9	86.6	78.2	71.2	40.9	36.8	4.9	.5	.60	2-1
2	4	90.1			[1]89.6	89.1	69.5	44.8	21.3	7.0	.3	0	.90	3-1
2	4	97.2			[1]91.2	85.3	54.5	30.3	7.8	1.9	0	0	1.20	4-1
2	4	89.7		86.8	76.2	68.8	27.4	6.6	.2	0			1.50	5-1
2	4	76.2	70.0	15.7	1.5	0	0	0					1.80	6-1

[1] Interpolated figures.

TABLE 5.—*Average survival of* Shigella dysenteriae *expressed in percent of initial numbers, when exposed to chloramine in various concentrations at pH 6.5, 7.0, 7.8, 8.5, 9.5 and 10.5 at 20°–25° C., with nitrogen content constant (0.3 p. p. m.) and contact of Cl_2 and N, 1 hour before addition of bacteria*

Number of strains	Number of tests	Average percentage survival after exposure: 1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	Residual Cl_2 p. p. m.: 0 minutes	Cl_2/N: Ratio
							pH 6.5							
2	4	100.0	----	----	----	----	----	----	----	----	94.0	----	0.01	0-1
2	4	99.3	82.2	70.4	50.1	26.0	6.2	0.8	0	0	0	----	.15	0.5-1
2	4	97.6	53.8	39.7	21.6	2.8	0	0	0	0	----	----	.30	1-1
2	4	68.2	34.1	19.9	4.2	0	0	0	----	----	----	----	.60	2-1
2	4	51.7	19.0	4.6	0	0	0	0	----	----	----	----	.90	3-1
2	4	40.4	7.8	.9	0	0	0	0	----	----	----	----	1.20	4-1
2	4	28.2	.4	0	0	0	0	----	----	----	----	----	1.50	5-1
2	4	6.5	0	0	0	0	0	----	----	----	----	----	1.80	6-1
							pH 7.0							
2	4	100.0	----	----	----	----	----	96.7	----	85.8	88.0	----	Trace	0-1
2	4	95.5	----	76.2	43.3	32.8	11.4	2.1	0.1	0	0	----	0.15	0.5-1
2	4	95.3	63.2	51.4	33.6	15.4	.4	0	0	0	0	----	.30	1-1
2	4	84.5	44.6	28.9	11.1	.4	0	0	0	----	----	----	.60	2-1
2	4	62.6	27.8	11.8	1.9	0	0	0	----	----	----	----	.90	3-1
2	4	46.6	19.5	6.5	.1	0	0	0	----	----	----	----	1.20	4-1
2	4	37.9	7.3	.4	0	0	0	----	----	----	----	----	1.50	5-1
2	4	45.6	.6	0	0	0	0	----	----	----	----	----	1.80	6-1
							pH 7.8							
2	4	100.0	----	----	----	----	----	93.7	----	----	91.2	----	0	0-1
2	4	91,0	----	46.5	40.7	28.8	5.4	1.6	0.1	0	0	----	.30	1-1
2	4	74.5	45.3	35.8	24.7	6.4	.1	0	0	0	----	----	.60	2-1
2	4	69.4	31.7	23.9	8.6	.3	0	0	0	----	----	----	.90	3-1
2	4	50.2	28.4	17.7	3.1	0	0	0	----	----	----	----	1.20	4-1
2	4	42.6	19.2	6.6	.5	0	0	----	----	----	----	----	1.50	5-1
2	4	28.4	4.0	.4	0	0	0	----	----	----	----	----	1.80	6-1
							pH 8.5							
2	4	100.0	----	----	----	----	----	100.0	----	100.0	84.1	----	0	0-1
2	4	95.4	----	89.4	63.3	59.5	37.0	13.9	1.9	.1	0	----	.30	1-1
2	4	90.6	----	66.4	46.2	33.3	6.8	.2	0	0	0	----	.60	2-1
2	4	86.2	62.3	47.4	34.7	25.5	0.7	0	0	0	----	----	.90	3-1
2	4	84.4	47.2	44.0	29.6	7.1	0	0	0	----	----	----	1.20	4-1
2	4	65.0	43.4	37.0	22.1	3.4	0	0	----	----	----	----	1.50	5-1
2	4	40.7	15.2	6.9	.1	.0	0	----	----	----	----	----	1.80	6-1
							pH 9.5							
2	4	100.0	----	----	----	----	----	100.0	----	89.0	87.0	84.1	0	0-1
2	4	95.5	----	----	100.0	93.7	91.2	77.3	69.4	35.8	2.0	.1	.30	1-1
2	4	97.6	----	----	79.6	68.5	63.2	37.5	12.3	.5	0	0	.60	2-1
2	4	97.1	----	63.3	56.8	52.2	33.1	10.0	0.2	0	0	----	.90	3-1
2	4	97.3	57.2	55.8	51.7	42.1	12.6	.6	0	0	----	----	1.20	4-1
2	4	74.8	48.6	46.5	50.7	27.9	.9	0	0	----	----	----	1.50	5-1
2	4	44.7	26.0	14.8	6.1	0	0	0					1.80	6-1
							pH 10.5							
2	4	100.0	----	----	----	----	----	84.6	----	68.0	60.2	53.3	0	0-1
2	4	89.3	----	----	86.2	86.8	86.8	81.9	64.0	52.9	31.6	23.5	.30	1-1
2	4	91.2	----	----	83.8	78.6	71.2	52.5	37.7	26.6	9.2	1.3	.60	2-1
2	4	89.2	----	69.7	71.2	62.6	54.3	33.2	22.0	8.2	.3	0	.90	3-1
2	4	82.7	60.6	61.6	58.8	50.0	37.8	26.3	5.4	.9	0	----	1.20	4-1
2	4	66.9	49.6	43.1	49.1	43.5	28.5	8.0	1.0	0	----	----	1.50	5-1
2	4	50.5	38.9	36.6	15.4	8.5	.5	0	----	----	----	----	1.80	6-1

TABLE 6.—*Average survival of various species of* Shigella *expressed in percent of initial number when exposed to chloramine in various concentrations at pH 8.5 and at 20° to 25° C., with nitrogen content constant, (0.3 p. p. m.) and contact of Cl_2 and N, 1 hour before addition of bacteria*

Species of *Shigella*	Number of strains	Number of tests	Average percentage surviving after exposure at chloramine concentration given										
			1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes
0.00 p. p. m. Cl_2/N, 0–1													
Dysenteriae	3	6	100.0	----	----	----	----	----	----	----	----	----	88.2
Sonnei	4	8	100.0	----	----	----	----	----	----	----	----	----	82.0
Paradysenteriae [1]	5	10	100.0	----	----	----	----	----	----	----	----	----	89.9
0.30 p. p. m. Cl_2/N, 1–1													
Dysenteriae	3	6	94.2	----	76.7	55.4	57.8	35.6	11.2	1.0	0.1	0.0	0.0
Sonnei	4	8	95.3	----	----	89.6	87.7	81.4	69.8	35.5	8.3	0,1	0.0
Paradysenteriae [1]	5	10	91.2	----	----	68.9	59.0	33.2	9.7	0.9	0.1	0.0	0.0
0.60 p. p. m. Cl_2/N, 2–1													
Dysenteriae	3	6	89.0	----	58.0	49.3	35.9	4.8	0.1	0.0	0.0	0.0	----
Sonnei	4	8	91.8	----	----	86.7	69.0	47.6	16.8	1.2	0.1	0.0	----
Paradysenteriae [1]	5	10	81.2	----	62.4	54.9	29.9	3.2	0.1	0.0	0.0	0.0	----
0.90 p. p. m. Cl_2/N, 3–1													
Dysenteriae	3	6	84.0	61.0	49.4	39.2	23.6	0.4	0.0	0.0	0.0	----	----
Sonnei	4	8	91.0	----	76.9	71.5	53.0	14.8	0.9	0.1	0.0	0.0	----
Paradysenteriae [1]	5	10	79.3	52.8	52.4	38.7	10.9	0.1	0.0	0.0	0.0	----	----
1.20 p. p. m. Cl_2/N, 4–1													
Dysenteriae	3	6	72.5	49.6	44.9	32.2	6.0	0.0	0.0	0.0	----	----	----
Sonnei	4	8	85.8	71.2	66.2	56.2	33.4	2.2	0.1	0.0	----	----	----
Paradysenteriae [1]	5	10	68.7	47.8	40.1	27.4	3.4	0.0	0.0	0.0	----	----	----
1.50 p. p. m. Cl_2/N, 5–1													
Dysenteriae	3	6	63.9	46.2	37.1	24.4	1.9	0.0	0.0	----	----	----	----
Sonnei	4	8	85.2	67.8	66.8	52.4	19.8	0.2	0.0	----	----	----	----
Paradysenteriae [1]	5	10	60.1	41.3	36.2	18.0	0.6	0.0	0.0	----	----	----	----
1.80 p. p. m. Cl_2/N, 6–1													
Dysenteriae	3	6	29.9	7.6	3.4	0.1	0.0	0.0	0.0	----	----	----	----
Sonnei	4	8	22.6	1.0	0.1	0.0	0.0	0.0	0.0	----	----	----	----
Paradysenteriae [1]	5	10	24.3	0.2	0.0	0.0	0.0	0.0	0.0	----	----	----	----

[1] Average results from 1 Flexner V, 1 Flexner W, 2 Flexner Z, and 1 Boyd 88, 2 tests with each. Of these species the Flexner Z strains were slightly more sensitive.

TABLE 7.—*Average survival of* Shigella sonnei *expressed in percent of initial numbers when exposed to chloramine in various concentrations at pH 8.5 and at 2° to 6° C., with nitrogen content constant (0.3 p. p. m.) and contact time of* Cl_2 *and N, 1 hour before addition of bacteria.*

Number of strains	Number of tests	Average percentage surviving after exposure													Residual Cl_2 p.p.m.	Cl_2/N
		1 minute	3 minutes	5 minutes	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	360 minutes	1,440 minutes	0 minute	Ratio
pH 8.5																
4	8	100.0	-----	-----	-----	-----	-----	-----	-----	-----	-----	85.1	82.6	67.2	0	0–1
4	8	97.5	-----	-----	91.9	-----	-----	84.5	83.0	76.6	67.1	68.0	59.3	2.0	.15	5–1
4	8	94.3	-----	-----	91.8	-----	-----	78.1	72.0	70.4	59.2	53.9	41.1	0	.30	1–1
4	8	97.1	-----	-----	91.5	-----	-----	71.9	61.0	55.9	33.1	19.2	7.0	0	.60	2–1
4	8	96.5	-----	-----	89.0	-----	65.0	63.0	44.8	32.7	11.4	6.0	2.5	0	.90	3–1
4	8	95.1	-----	-----	84.6	-----	59.4	48.0	29.4	17.4	5.4	2.2	.2	-----	1.20	4–1
4	8	92.5	-----	-----	77.9	57.8	42.6	26.8	9.8	6.1	1.2	0	-----	-----	1.50	5–1
4	8	57.1	32.1	20.8	11.1	7.1	3.7	1.5	0	0	0	-----	-----	-----	1.80	6–1

TABLE 8.—*Average survival of* Escherichia coli, *expressed in percent of initial numbers, when exposed to chloramine with the residual chlorine content constant, 0.3 p. p. m., and the nitrogen content varied, at pH 7.0, 8.5, and 10.5 and at 20° to 25° C., with contact time of 1 hour for* Cl_2 *and N, before addition of bacteria*

Number of strains	Number of tests	Average percentage surviving after exposure										Residual Cl_2 p. p. m.	Cl_2/N
		1 minute	10 minutes	20 minutes	40 minutes	60 minutes	90 minutes	120 minutes	150 minutes	180 minutes	240 minutes	0 minutes	Ratio
pH 7.0													
2	6	100.0	------	------	------	------	------	------	------	------	99.4	0	0–7
2	4	97.8	88.8	67.7	25.1	7.0	0.6	0.2	------	0	0	.30	1–1
2	4	98.0	88.6	63.7	33.2	14.5	2.9	1.0	------	.4	.1	.30	1–7
2	4	93.1	91.4	77.4	46.3	18.8	3.2	1.0	------	.4	.3	.30	1–25
pH 8.5													
2	8	100.0	------	------	------	------	------	------	------	------	95.6	0	0–7
2	6	99.2	93.3	90.4	81.4	67.2	37.8	14.6	------	3.7	.1	.30	1–1
2	8	96.6	97.8	85.8	74.6	65.0	46.6	32.2	38.0	12.6	3.8	.30	1–3
2	8	96.5	96.0	85.6	73.3	59.5	44.7	34.8	39.4	14.0	8.1	.30	1–7
2	4	95.3	96.7	93.4	80.8	75.6	65.9	56.8	40.4	29.0	16.3	.30	1–10
2	2	100.0	98.0	82.8	62.1	78.1	65.3	63.4	50.6	33.0	26.0	.30	1–25

		Average percentage surviving after exposure											
		1 minute	10 minutes	20 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes	360 minutes	1,440 minutes		
pH 10.5													
2	4	100.0	------	------	96.1	------	85.6	81.7	75.8	71.3	73.1	0	0–7
2	4	97.6	88.2	------	91.8	81.8	74.8	69.2	66.0	24.3	0	.30	1–1
2	4	94.1	92.0	------	87.2	80.3	80.5	79.3	67.0	16.8	0	.30	1–7
2	4	91.5	87.2	------	86.4	76.8	72.9	63.7	49.9	5.0	0	.30	1–25

TABLE 9.—*Time in minutes required to produce a 100-percent kill of bacteria when exposed to chloramine at various hydrogen-ion concentrations and at two temperatures*

2° to 6° C.

Cl_2/N ratio	Residual Cl_2 p. p. m.	pH 7.0		pH 8.5			pH 9.5	
		Esch. coli	*Eber. typhosa*	*Esch. coli*	*Eber. typhosa*	*S. sonnei*	*Esch. coli*	*Eber. typhosa*
0.5-1	0.15	>240	1,440	>1,440	1,440	>1,440	----	----
1-1	.30	>240	>240	>1,440	>1,440	1,440	>1,440	1,440
2-1	.60	180	180	1,440	1,440	1,440	>1,440	1,440
3-1	.90	120	120	360	>240	1,440	1,440	1,440
4-1	1.20	90	90	360	>240	>360	1,440	1,440
5-1	1.50	60	60	360	180	240	1,440	1,440
6-1	1.80	40	20	20	10	90	90	120

20° to 25° C.

Cl_2/N ratio	Residual Cl_2 p. p. m.	pH 6.5					pH 7.0				
		Esch. coli	*Aer. aerogenes*	*Ps. pyocyanea*	*Eber. typhosa*	*S. dysenteriae*	*Esch. coli*	*Aer. aerogenes*	*Ps. pyocyaneae*	*Eber. typhosa*	*S. dysenteriae*
0.5-1	0.15	>60	180	120	120	90	>120	240	240	>240	120
1-1	.30	60	90	60	40	40	90	120	90	90	60
2-1	.60	40	40	40	20	20	40	60	40	40	40
3-1	.90	20	40	20	20	10	40	40	20	20	20
4-1	1.20	20	20	20	10	10	20	40	20	20	20
5-1	1.50	10	10	10	5	5	20	20	20	10	10
6-1	1.80	5	5	5	3	3	5	5	10	5	5

20° to 25° C.

Cl_2/N ratio	Residual Cl_2 p.p.m.	pH 7.8					pH 8.5						
		Esch. coli	*Aer. aerogenes*	*Ps. pyocyaneae*	*Eber. typhosa*	*S. dysenteriae*	*Esch. coli*	*Aer. aerogenes*	*Ps. pyocyaneae*	*Eber. typhosa*	*S. dysenteriae*	*S. sonnei*	*S. paradysenteriae*
0.5-1	0.15	----	----	----	----	----	>360	----	----	----	----	----	----
1-1	.30	180	>240	180	120	120	300	240	180	180	180	240	180
2-1	.60	90	180	90	60	60	120	>120	90	90	90	180	90
3-1	.90	60	90	40	40	40	90	120	60	60	60	120	60
4-1	1.20	40	60	40	20	20	60	90	40	40	40	90	40
5-1	1.50	20	40	20	20	20	40	60	40	40	40	60	40
6-1	1.80	20	20	10	5	10	20	5	40	3	20	10	5

20° to 25° C.

Cl_2/N ratio	Residual Cl_2 p. p. m.	pH 9.5					pH 10.5				
		Esch. coli	*Aer. aerogenes*	*Ps. pyocyaneae*	*Eber. typhosa*	*S. dysenteriae*	*Esch. coli*	*Aer. aerogenes*	*Ps. pyocyaneae*	*Eber. typhosa*	*S. dysenteriae*
0.5-1	0.15	>360	360	----	----	----	>360	>240	----	----	----
1-1	.30	>240	>240	240	>240	>240	>360	>240	>240	>240	>240
2-1	.60	240	>240	180	180	180	>360	>240	240	>240	>240
3-1	.90	180	>180	120	150	120	>300	>240	120	240	240
4-1	1.20	90	>120	120	90	90	>240	>240	120	180	180
5-1	1.50	60	>90	90	60	60	150	>180	90	120	120
6-1	1.80	5	20	60	3	20	60	40	60	20	60

Additional data, which are available concerning (*a*) the influence of variations in the nitrogen content when the amount of chlorine added is constant, (*b*) the influence of the time of contact between chlorine and nitrogen before bacteria are exposed to the resultant chloramine, and (*c*) the relative efficiency of free chlorine and chloramine as bactericidal agents, are not presented in tabular form, as they are quite comparable to these shown in the tables presented. However, the implications of these data will be considered in the discussion of the results obtained.

DISCUSSION OF RESULTS

To aid in demonstrating the influence of certain factors on the bactericidal efficiency of chloramine and to facilitate the discussion of the results, parts of the data shown in the tables have been presented in diagrams. In selecting the portions of the data for graphic presentation, an effort was made to use results typical of general trends, illustrating a particular point in question. Because of the number of factors affecting the results, however, all of the data concerned with any one variable could not be presented in one figure without considerable confusion. Similarly, the preparation of a series of figures, demonstrating in the aggregate the effects of all of the factors under all conditions, would not be of material value and would add greatly to the space requirements of this report. Consequently, the data presented thus have been limited, and if the results presented in the figures do not fulfill the particular need of the reader, appropriate data for this purpose may be selected from the tables and plotted in a similar manner.

The influence of various factors on the bactericidal properties of chloramine and the relative efficiency of free chlorine and chloramine in water disinfection processes will be discussed in the text which follows.

INFLUENCE OF RESIDUAL AND EXPOSURE TIME

In figures 1A to 1F, inclusive, the average percentage of survival of *Esch. coli* exposed to chloramine in varying concentrations and at two temperature ranges, 2° to 6° C. and 20° to 25° C., have been plotted against time in minutes. Results from waters at three hydrogen-ion concentrations, pH 7.0, 8.5, and 9.5, were used. Data for periods of exposure up to 120 minutes only are included in the plotted points with percentages for longer periods indicated in the margin.

It is noted that, regardless of the temperature of the water or its hydrogen-ion concentration, the amount of chloramine present and the length of the exposure time markedly affected the results. Without exception an increase in the amount of chloramine present increased the rate of kill of *Esch. coli* and any increase in exposure time likewise increased the extent of the kill. However, marked increases in the extent of kill were not observed in 60 minutes of exposure at 2° to 6° C., with less than about 1.2 p. p. m. residual at pH 8.5, and 1.5 p. p. m. residual at pH 9.5. At the higher temperature range, 20° to 25° C., residuals of about 0.3 p. p. m. and 0.6 p. p. m., respectively, were required to obtain approximately the same kill.

The results to be anticipated in practical operation with exposures up to 240 minutes, using amounts of chloramine varying from 0.15 to 1.8 p. p. m., in waters of pH 7.0 to 9.5, may be determined from these figures and tables. However, it should be noted that these data probably represent the maximum disinfecting action which can be expected from chloramine under the conditions given, as the suspending waters used in these tests did not contain (*a*) any substance which might reduce either the amount or the bactericidal potency of the chloramine, or (*b*) any particulate matter which might act as a protective covering for bacterial cells.

In figures 1G to 1J, inclusive, corresponding data for two other genera, *Eber. typhosa* and *S. sonnei*, for one pH value only, 8.5, have been plotted. Additional data for these two genera at other pH values, and for the other genera studied, which have not been presented graphically, may be found in tables 1 to 6. These figures show that at pH 8.5 and at 2° to 6° C., the influence of the time of exposure to chloramine, and the amount of chloramine present, produced approximately the same effect on the rate and extent of kill of these two genera as was observed for *Esch. coli*. The same is true at the higher temperature, 20° to 25° C., when the residuals were 0.9 p. p. m. or more. At lower residuals, strains of *S. sonnei* tested appeared to be slightly more resistant than *Esch. coli*.

EFFECT OF VARIATIONS IN HYDROGEN-ION CONCENTRATION

In figures 2A, 2B, 2C, and 2D selected data are presented to show the influence of the pH of the water on the bactericidal efficiency of chloramine. The selection of the data to be used was made by limiting the pH values compared to pH 7.0, 8.5, and 9.5, and by eliminating the time variable from consideration, all results plotted being those obtained after a 10-minute or a 60-minute exposure. In figures 2A and 2C these results for the percentage survival of *Esch. coli* and *Eber. typhosa*, respectively, obtained after 10 minutes' exposure, are plotted against residual chlorine in parts per million. In figures 2B and 2D corresponding results obtained after 60 minutes of exposure are shown. Results obtained at both the temperature ranges studied are presented in these figures.

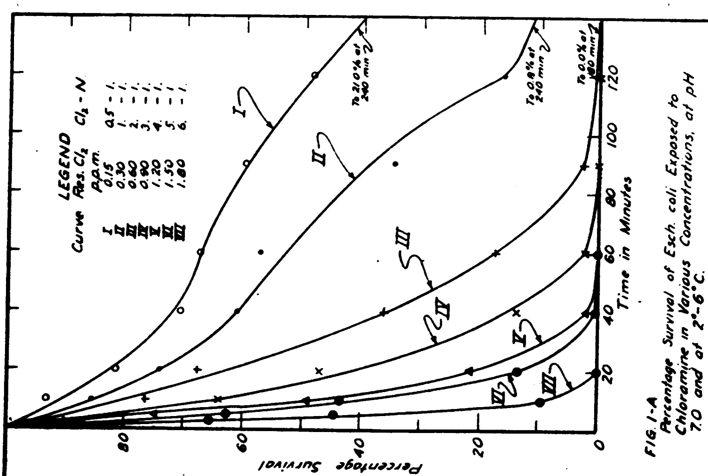

FIG. 1-A Percentage Survival of Esch. coli Exposed to Chloramine in Various Concentrations, at pH 7.0 and at 2°-6°C.

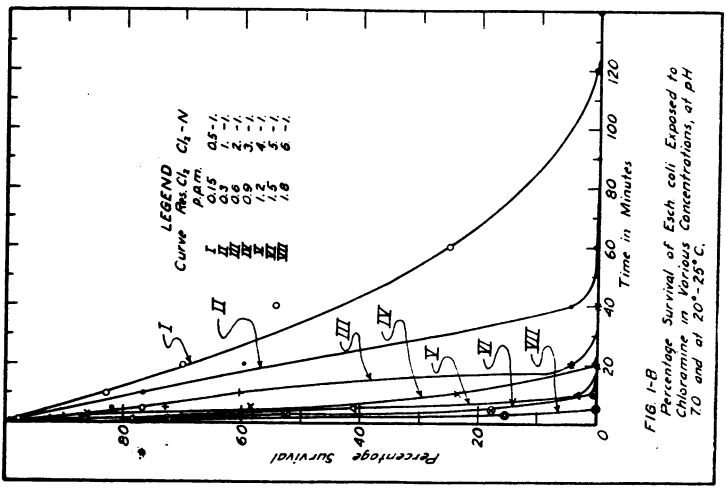

FIG. 1-B Percentage Survival of Esch. coli Exposed to Chloramine in Various Concentrations, at pH 7.0 and at 20°-25°C.

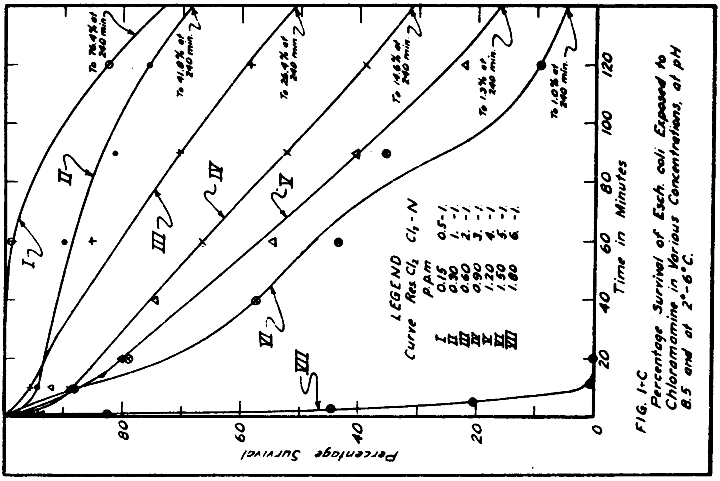

FIG. 1-C Percentage Survival of Esch. coli Exposed to Chloramine in Various Concentrations, at pH 8.5 and at 2°-6°C.

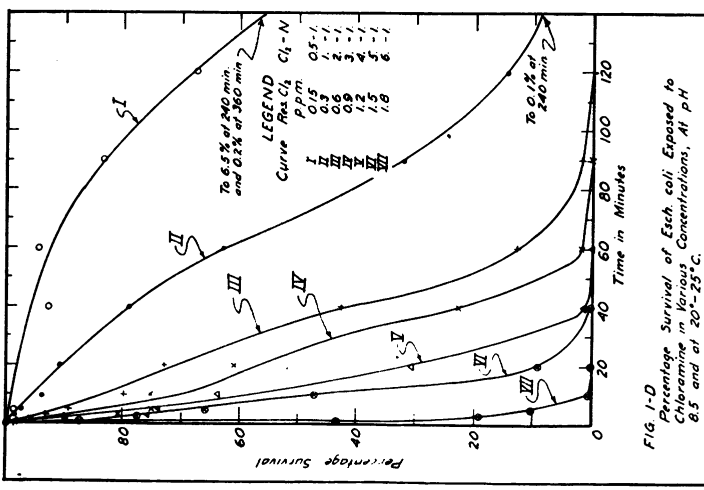

FIG. 1-D
Percentage Survival of Esch. coli Exposed to Chloramine in Various Concentrations, At pH 8.5 and at 20°-25°C.

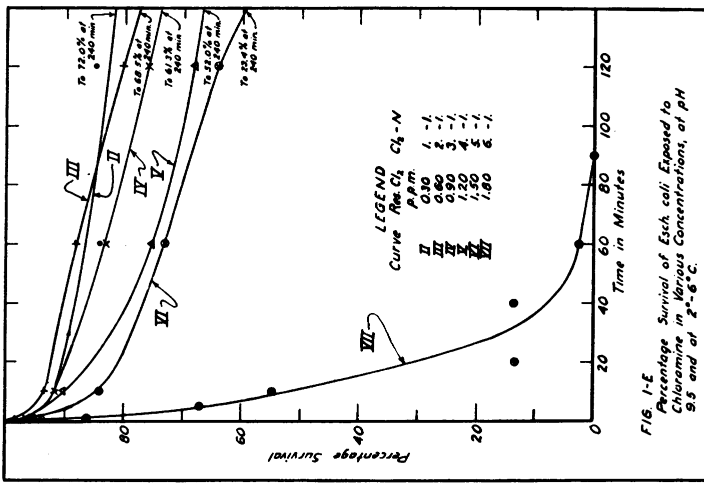

FIG. 1-E
Percentage Survival of Esch. coli Exposed to Chloramine in Various Concentrations, at pH 9.5 and at 2°-6°C.

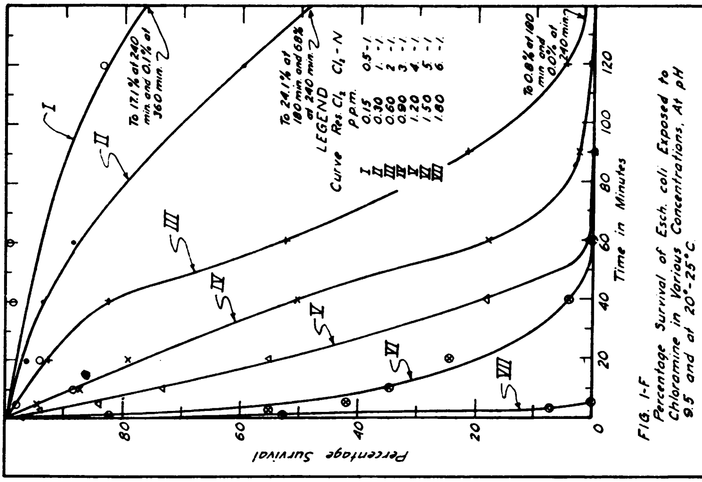

FIG. 1-F
Percentage Survival of Esch. coli Exposed to Chloramine in Various Concentrations, At pH 9.5 and at 20°-25°C.

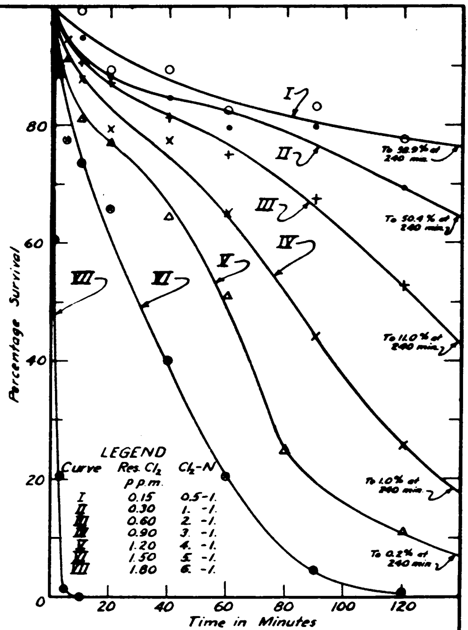

FIG. 1-G
Percentage Survival of Eber. typhosa Exposed to Chloramine in Various Concentrations at pH 8.5 and at 2°-6°C.

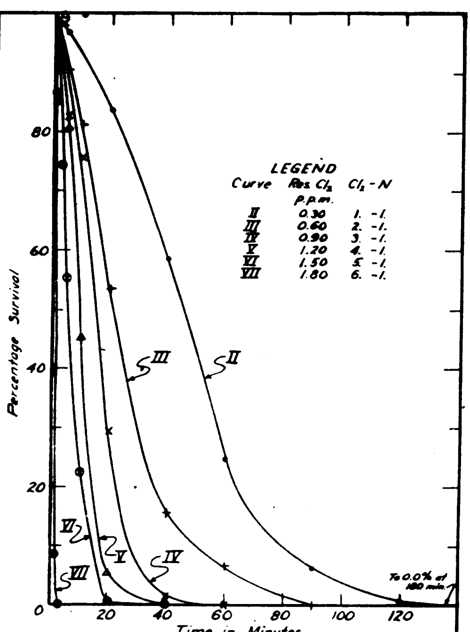

FIG 1-H
Percentage Survival of Eber. typhosa Exposed to Chloramine in Various Concentrations at pH 8.5 and at 20°-25°C.

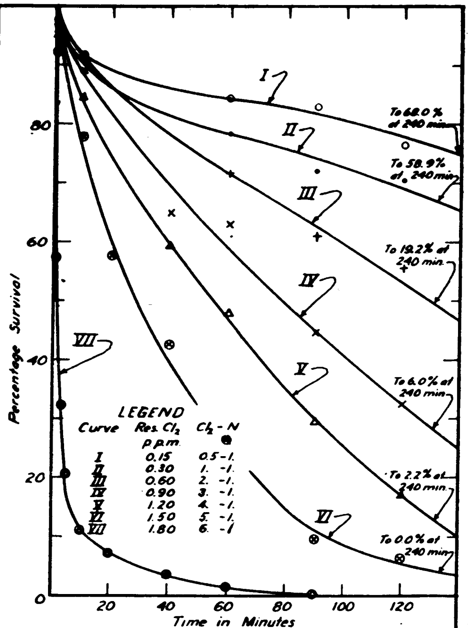

FIG. 1-I
Percentage Survival of Sh. sonnei Exposed to Chloramine in Various Concentrations, at pH 8.5 and at 2°-6°C.

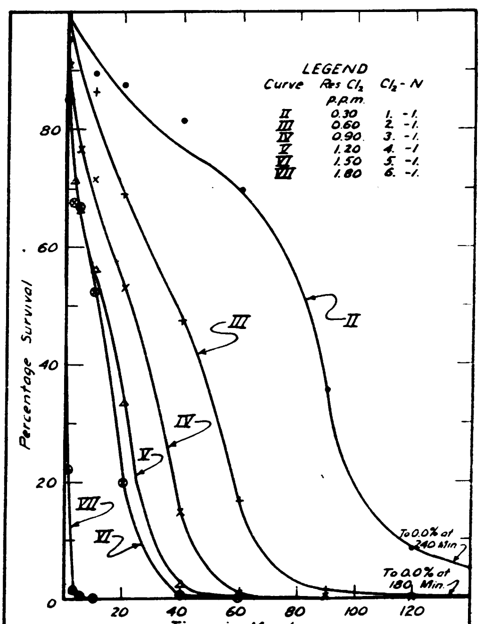

FIG. 1-J
Percentage Survival of Sh. sonnei Exposed to Chloramine in Various Concentrations at pH 8.5 and at 20°-25°C.

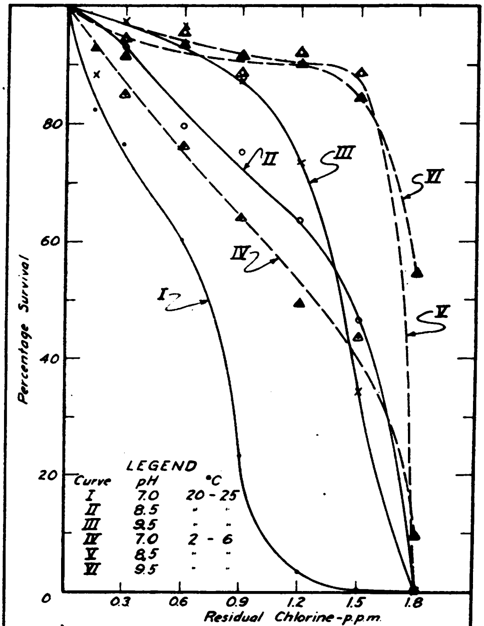

FIG. II-A
Survival of Esch. coli at pH 7.0, 8.5 and 9.5, at 2°-6°C and at 20°-25°C after Exposure to Chloramine in Various Concentrations for 10 Minutes

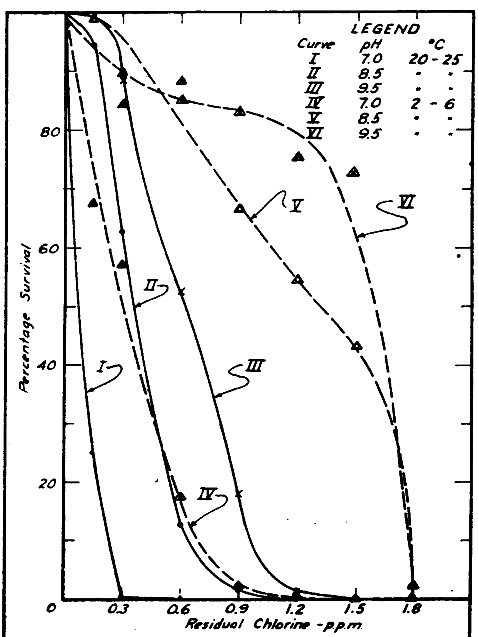

FIG. II-B
Survival of Esch. coli at pH 7.0, 8.5 and 9.5, at 2°-6°C and at 20°-25°C after Exposure to Chloramine in Various Concentrations for 60 Minutes

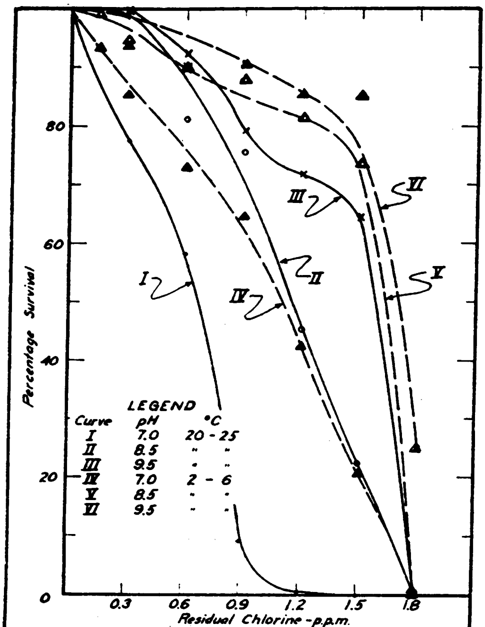

FIG. II-C
Survival of Eber. typhosa at pH 7.0, 8.5 and 9.5, at 2°-6°C and 20°-25°C after Exposure to Chloramine in Various Concentrations for 10 Minutes

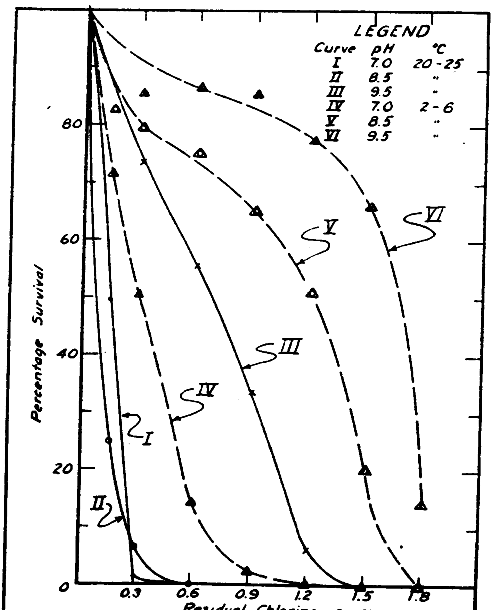

FIG. II-D
Survival of Eber. typhosa at pH 7.0, 8.5 and 9.5, at 2°-6°C. and 20°-25°C. after Exposure to Chloramine in Various Concentrations for 60 Minutes

The marked effect of the hydrogen-ion concentration on the bactericidal efficiency of chloramine (or on the extent of availability of the chloramine present) is indicated quite definitely. It is evident that the pH effect becomes more marked with increased periods of exposure, for the ratios of the amounts of chloramine required to produce a 50-percent kill of *Esch. coli* at pH 7.0 and at 8.5 are greater for the 60-minute period of exposure at both temperature ranges. When *Esch. coli* were exposed to the same residuals at pH 7.0 and 8.5, and a 100-percent kill was used as a criterion, two to six times (avg. 3.4) longer exposure periods were required at pH 8.5. A further increase in pH (8.5 to 9.5) requires approximately another twofold to fourfold increase in the exposure time. Similarly, to obtain a 100-percent kill of *Esch. coli* in the same exposure interval at pH 8.5 required 1.5 to 3 times (avg. 2.3) the residual needed at pH 7.0. Further shift of the pH from 8.5 to 9.5 again required a 1.3-fold increase in residual.

EFFECT OF TEMPERATURE

The effect of variations in temperature on the bactericidal efficiency of chloramine has been illustrated in figures 3A and 3B. Here again, to avoid confusion, limited data only are presented. In figure 3A the average results obtained after 60 minutes' exposure in waters of pH 8.5 for *Esch. coli*, *Eber. typhosa*, and *S. sonnei*, at 20° to 25° C. and at 2° to 6° C., curves I, II, and III, and IV, V, and VI, respectively, are plotted against residual chlorine in parts per million. Thus to observe the effects of temperature, when all other variables are held constant, comparison may be made of (*a*) curves I and IV for *Esch. coli*, (*b*) curves II and V for *Eber. typhosa*, and (*c*) curves III and VI for *S. sonnei*. The marked effect of a 20° temperature differential is quite apparent. It is approximately the same for each of the three genera shown. The greatest differences are observed when the kills are in the range of 35 to 95 percent of the initial number. When the comparisons are based on a 100-percent kill, or zero survival, and the results obtained at pH values of 7.0 and 9.5 (table 9) as well as at pH 8.5, it is noted that (*a*) with a given concentration of chloramine approximately nine times (range of ratios 1–18) the exposure times were required at the lower temperature, and (*b*) with the same exposure times approximately 2.5 times (range of ratios, 1–4) as much chloramine was needed to produce a 100-percent kill at the lower temperature.

In figure 3B results are presented which were obtained with *S. sonnei* (the most resistant of the various pathogens studied), in waters of pH 8.5 after exposures for 10 and 60 minutes, respectively, at the two temperature ranges. The average data for the 10-minute observations are shown in curves I and II, and for the 60-minute results in curves III and IV. The temperature effects are similar to those observed with *Esch. coli.* with the trends more consistently defined for the 60-minute exposure period, as would be expected. It may be noted also that a very rapid initial decrease, with low chloramine concentration, was indicated for *S. sonnei* at the low temperature which was not observed at the higher temperature. The same effect was observed with *Eber. typhosa* (fig. 3A). Although data to establish this theory are not available, it is thought that this accentuated initial decrease may have been brought about by the shock induced by the sudden transfer of a suspension of bacteria grown at 37° C. to a temperature of 2° C. With the heavier dosages of chloramine, this reduction, possibly induced by shock, would be concealed by the more extensive kills produced by the chloramine.

VARIATIONS IN GENUS RESISTANCE

In this study the chloramine resistance of 2 strains each of 4 genera, *Escherichia*, *Aerobacter*, *Pseudomonas*, and *Eberthella*, and of 13 strains of 1 genus, *Shigella*, was investigated. In figures 4A, 4B, and 4C variations in their resistance to chloramine are shown, by plotting the average percentages of survival of the various genera against residual chlorine in parts per million as chloramine. Only results obtained after an exposure period of 10 minutes, and at the higher temperature range, are presented in these figures. Additional data for other exposure periods and for the lower temperature, if desired, may be found in tables 1 to 7 and similarly plotted. Only one exposure period could be shown in the figures without confusion and the 10-minute period offered the maximum variations. Data obtained in waters at pH 7.0, 8.5, and 9.5 are shown in figures 4A, 4B, and 4C, respectively. It should be noted that in figure 4B average results obtained with 4 strains of *S. sonnei* are presented which are not represented in figures 4A and 4C as these strains were secured toward the end of the study and were tested at pH 8.5 only.

At pH 7.0, as illustrated in figure 4A, the *A. aerogenes* strains were definitely the most resistant and *S. dysenteriae* the least resistant of the five genera studied. *Esch. coli, Ps. pyocyanea* and *Eber. typhosa* results are in very close agreement, with pyocyanea and typhosa possibly slightly more resistant than coli with chloramine residuals of about 0.7 p. p. m. or less, and less resistant with larger residuals. At pH 8.5 (fig. 4B), *S. dysenteriae* again is the most sensitive. The other genera tested, including *S. sonnei*, all showed approximately the same resistance. However, in this connection the following points should be emphasized: (*a*) *P. pyocyanae* at pH 8.5 were more resistant with chloramine residuals greater than about 1.2 p. p. m.; (*b*) with the exception of (*a*), *Esch. coli* strains were more resistant than any of the other genera studied, and (*c*) *S. sonnei*, in contrast

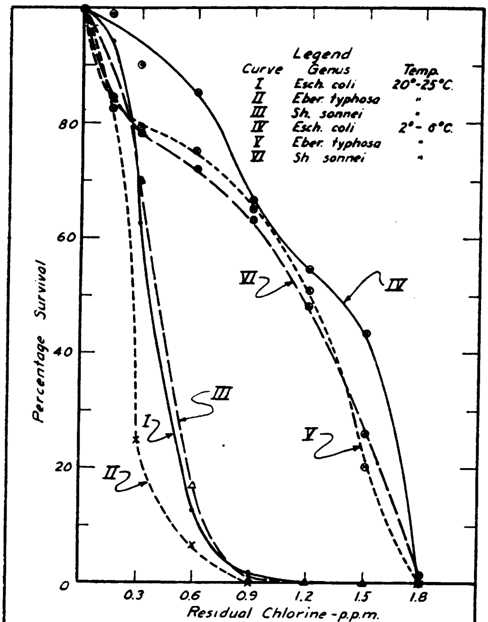

FIG. III-A
Percentage Survival of Esch. coli, Eber. typhosa and Sh. sonnei Exposed 60 Minutes to Chloramine in Various Concentrations at pH 8.5, at 2°-6°C. and 20°-25°C.

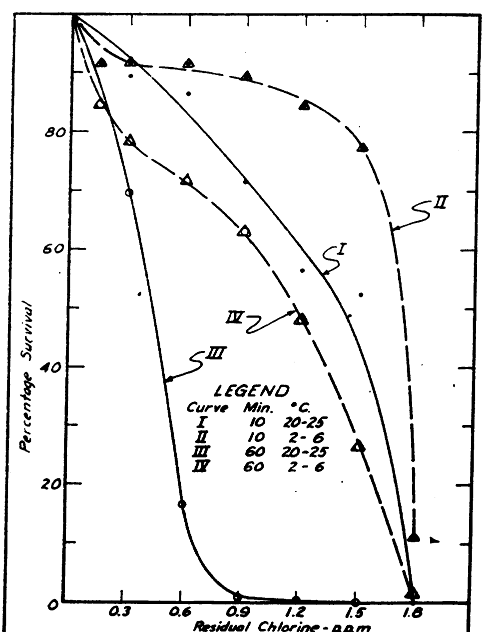

FIG. III-B
Survival of Sh. sonnei at pH 8.5 at 2°-6°C. and 20°-25°C. after Exposure to Chloramine in Various Concentrations for 10 and 60 Minutes

with the fellow-member of its genus, *S. dysenteriae*, was practically as resistant as *Esch. coli* throughout the range of chloramine concentrations used. At pH 9.5 (fig. 4C), the trends were about the same as at pH 7.0 and 8.5, with the exception that *S. dysenteriae*, though still remaining the most sensitive genus at the lower chloramine concentrations, appears to be more resistant with the largest concentration, 1.8 p. p. m.

EFFECT OF EXCESS NITROGEN

In the results discussed heretofore the nitrogen content of the waters used was kept constant at 0.3 p. p. m. and the chlorine content was varied so that Cl_2:N ratios of 0.5:1 to 6.0:1, were obtained in all series. In a few series of tests with *Esch. coli* these ratios were extended to 10:1. In some natural waters the nitrogen content may exceed considerably the usual amounts of chlorine added in practical water treatment and observations were made on the effect of excessive amounts of nitrogen on the bactericidal efficiency of the chloramine produced. Eighteen series of tests were made with *Esch. coli* in waters at pH 7.0, 8.5, and 10.5 with Cl_2:N ratios varying from 1:1 to 1:25. These waters were held at 20° to 25° C, and there was a contact period of 1 hour for Cl_2 and N, before the test bacteria were added to the water. The results are presented in table 8.

Study of these results indicates that in waters at pH 7.0 and 8.5 there was a definite tendency for the larger amounts of nitrogen to reduce slightly the percentage of kill. At most of the time intervals of examination this tendency was consistent, increasing the reduction slightly with each increment of nitrogen. Although this tendency as observed was consistent, in no instance was there a marked difference. The apparent effect was to slow up the rate of kill slightly so that at pH 7.0, for instance, a 100-percent kill was observed with the 1:1 ratio after 3 hours, and with the 1:7 and the 1:25 ratios a resistant minority persisted not only after 3 hours, but also after 4 hours of exposure.

In waters at pH 10.5 increased amounts of nitrogen after long periods of exposure appeared to enhance rather than to reduce the percentage of kill. Consequently, it would appear logical to include with Cl_2:N ratios in which the N exceeds the Cl_2 by 7 times, or more, that (*a*) the effect on the bactericidal efficiency of the chloramine produced was not marked; (*b*) in waters of pH 7.0 to 8.5 the efficiency decreased slightly with nitrogen increases; and (*c*) in waters of pH 10.5 the efficiency increased slightly with nitrogen increases.

EFFECT OF CONTACT TIME OF CL_2 AND NH_3

As has been pointed out previously in this report, a contact period of 1 hour for the chlorine and ammonia nitrogen, before the suspen-

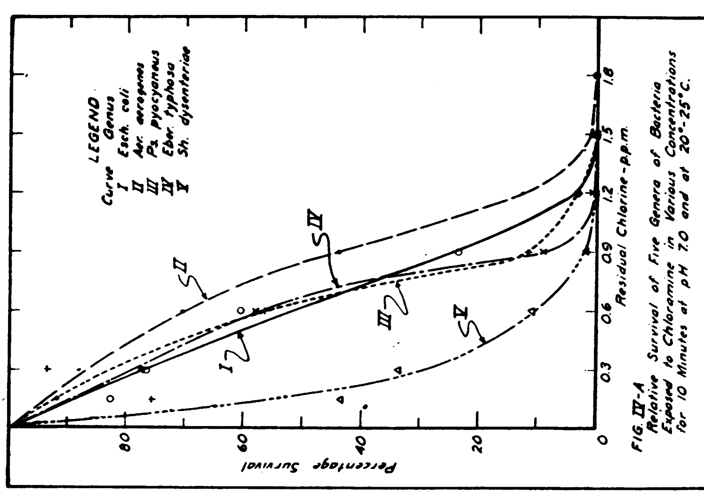

FIG. IV-A Relative Survival of Five Genera of Bacteria Exposed to Chloramine in Various Concentrations for 10 Minutes at pH 7.0 and at 20°-25°C.

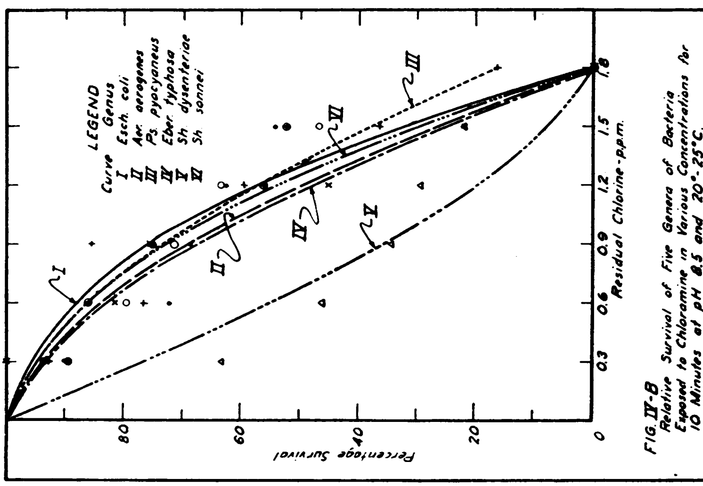

FIG. IV-B Relative Survival of Five Genera of Bacteria Exposed to Chloramine in Various Concentrations for 10 Minutes at pH 8.5 and 20°-25°C.

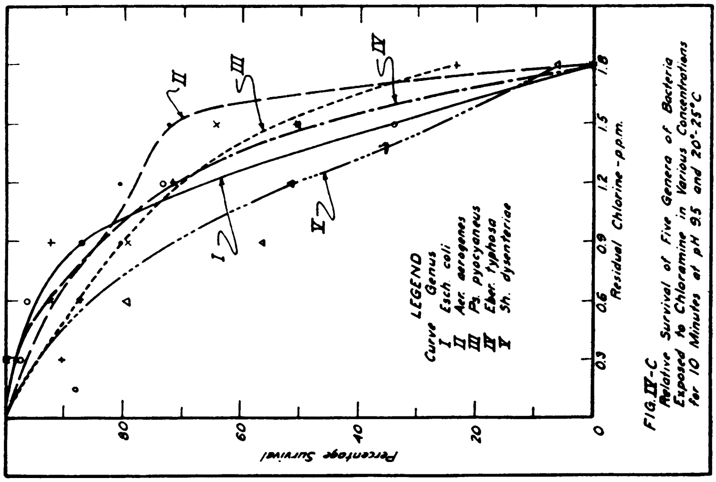

FIG. IV-C Relative Survival of Five Genera of Bacteria Exposed to Chloramine in Various Concentrations for 10 Minutes at pH 9.5 and 20°-25°C sions of test bacteria were added, was made the standard procedure for the routine tests of this study. This procedure was adopted to make sure that the chloramine-formation reaction was complete before the bacteria were added, i. e., to insure that all bactericidal action observed could be attributed to chloramines and not to free chlorine. Such a procedure was not in accord with the conditions observed in normal practice where the bacteria, and usually the ammonia nitrogen, are in the water before the chlorine is added. The procedure followed in our routine studies would be duplicated in normal practice only when extraneous pollution was introduced into the finished water, either in the clear well or in the distribution system.

These considerations introduced questions concerning (*a*) the validity of the practical application of the results of this study, and (*b*) the relative bactericidal efficiency of chloramines as freshly formed and after prolonged storage in water as occurs in a distribution system. To obtain information on these points 42 series of tests at 20° to 25° C. were made with *Esch. coli* in waters at pH 7.0, 8.5, and 9.5 when the contact periods for chlorine and ammonia nitrogen, before the addition of the test bacteria, were varied as follows: (*a*) Zero contact, i. e., the bacteria and the ammonia nitrogen were added to the water first and then, after mixing, the chlorine was introduced; (*b*) 1-hour contact, (*c*) 20-hour contact; and (*d*) 68-hour contact.

A careful study of the results indicates very little difference in the bactericidal action under the four conditions if contributing factors are considered. With zero contact time the average extent of bacterial kill was approximately 10 percent greater. However, this was not the case in all instances. Apparently the reaction between chlorine and ammonia nitrogen occurs almost instantaneously, as has been indicated by Moore, et al. (*3*) so that little opportunity was offered under this condition for free chlorine to act as such. The extent of the bacterial kills in waters of 20-hour contact was slightly lower than that of the 1-hour, and after 68 hours, still lesser kills were observed, when judged on a basis of the initial chloramine concentrations. It should be noted, however, that after 20 hours' storage the chloramine residuals were slightly reduced before the bacteria were added, and after 68 hours a considerable reduction (15–25 percent) had occurred. Consequently, if the percentage of bacterial kill results was set back so that the extent of kills was based on equivalent residuals at the time the bacteria were exposed, approximately the same efficiencies were observed under all the conditions.

TIME REQUIRED TO PRODUCE A 100-PERCENT KILL

Data compiled from the preceding tables are presented in table 9 showing the time required to produce a 100-percent kill of the several genera of bacteria studied, when exposed to chloramine at the various hydrogen-ion concentrations and temperatures used. Sections of these data from table 9 have been plotted to illustrate certain factors. For instance, in figure 5A the time required to produce a 100-percent kill of *Esch. coli* exposed to chloramine in various concentrations at six pH values at room temperature is shown, and in figure 5B similar data for three genera of bacteria obtained at one pH, 8.5, and at two temperatures, 2° to 6° C. and 20° to 25° C., are presented. Additional data could not be shown in these figures without confusion. If desired, similar figures may be prepared, illustrating the various genera studied and the other conditions of pH and temperature. The *sonnei* strains were selected to represent the *Shigella* genus as they were the most resistant of the six *Shigella* species tested.

It is noted from Figure 5A and the results in table 9 that, in general, as the pH was increased, longer periods of time were required to produce a 100-percent kill if the residual chlorine was the same, or greatly increased amounts of chlorine must be used to obtain 100-percent kills in the same time interval. Thus at 2° to 6° C., the average time required to produce a 100-percent kill of *Esch. coli* with chlorine residuals in the range of 0.9 to 1.5 p. p. m. was 90 minutes at pH 7.0, 360 minutes at pH 8.5, and 1,440 minutes at pH 9.5, respectively. This constituted approximately a fourfold increase in the time required for each pH shift studied, 7.0 to 8.5 and 8.5 to 9.5. At room temperature, 20° to 25° C., the increases in time required were not so great, being about 3.0 times for the pH range 7.0 to 8.5, and 1.8 times for 8.5 to 9.5, with an initial requirement of 20–25 minutes for a 100-percent kill at pH 7.0 with a residual of 1.2 p. p. m. Similarly, to obtain a 100-percent kill in the same interval of time of exposure required, when the pH was shifted from 7.0 to 8.5, an increase in residual chlorine of 1.5–3.0 times (avg. 2.3), and a further change from pH 8.5 to 9.5 required an additional 1.3-fold increase in chlorine dosage. One exception to these generalizations is noted: At pH 9.5 with a chlorine residual of 1.8 p. p. m. the 100-percent kill was observed in 5 minutes, whereas a longer time, 20 minutes, was required for this chlorine concentration at pH 7.8 and 8.5.

Comparing the results obtained with the three genera at 20° to 25° C., as given in figure 5B and in table 9, it is noted that *S. sonnei* was slightly more sensitive than *Esch. coli* with the smallest and largest amounts of chlorine used. With the other four intermediate chlorine concentrations, 0.6, 0.9, 1.2, and 1.5 p. p. m., *S. sonnei* was slightly more resistant. A similar variation at other concentrations

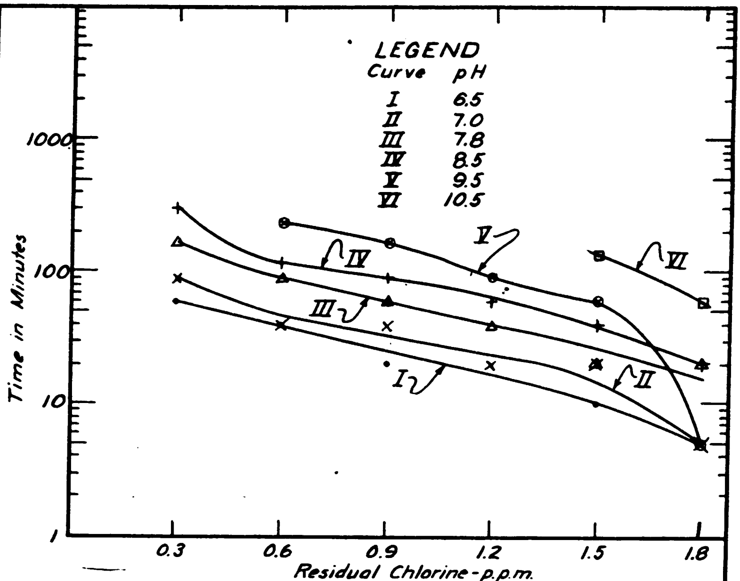

FIG. V-A
Time Required to Produce 100 Percent Kill of Esch. coli when Exposed to Chloramine in Various Concentrations at Various pH Values and at 20°-25°C.

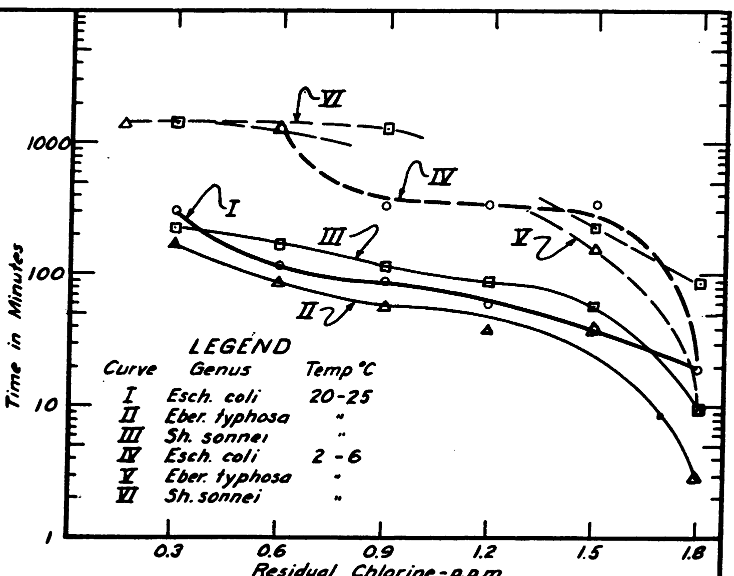

FIG. V-B
Time Required to Produce 100 Per Cent Kill of Various Genera of Bacteria when Exposed to Chloramine in Various Concentrations at pH 8.5 and at Two Temperature Ranges.

may be noted for the results obtained at 2° to 6° C. At this temperature, however, the differences were very slight, possibly within the limits of experimental error, with *sonnei* again appearing to be more resistant.

In this connection it is noted that if the results for *A. aerogenes* (table 9) had been used in figure 5B, the sonnei strains would have been more resistant only with the 1.8 p. p. m. concentration. This favors the retention of aerogenes strains as members of the bacterial criteria of water quality.

RELATIVE EFFICIENCY OF FREE CHLORINE AND CHLORAMINE

Although this report presents data on the bactericidal action of chloramines only, preceding reports in this series, (*1*) and (*5*), have presented rather extensive data on (*a*) the influence of pH and temperature on the survival of coliforms and enteric pathogens exposed to free chlorine, and (*b*) a special study of the relative resistance of *Esch. coli* and *Eber. typhosa* to free chlorine and chloramines. Consequently, it seems appropriate at this point to contrast briefly the relative bactericidal efficiencies of free chlorine and chloramine for the several genera of bacteria studied under comparable conditions, utilizing for this purpose not only the data presented at this time but also the data which have been given in the two preceding reports.

Using *Esch. coli* as the test organism, a comparison of the bactericidal efficiency of free chlorine and chloramine under the same conditions indicates that to obtain (*a*) a 100-percent kill during the same time interval requires about 25 times as much chloramine as free chlorine, and (*b*), a 100-percent kill with the same amount of residual chlorine (as measured by O. T.) requires about 60 to 144 times (avg. 94) longer exposure to chloramine. To illustrate, in waters at pH 8.5 and 2° to 6° C., 100-percent kills of *Esch. coli* were obtained in 20 minutes, with a residual of 0.065 p. p. m. using free chlorine, or 1.8 p. p. m. using chloramine, and at the same pH and at 20° to 25° C., in 60 minutes with 0.05 p. p. m. of free chlorine or 1.2 p. p. m. of chloramine. When similar comparisons, using the same amounts of free chlorine and chloramine, were made in waters at pH 9.5, kills of *Esch. coli* of 100 percent were produced at 2° to 6° C., by 0.9 p. p. m. of free chlorine or chloramine in 10 and 1,440 minutes, and at 20° to 25° C. in the same manner, 0.9 p. p. m. required only 3 and 180 minutes respectively. Because of the wide variations in the relative efficiency of free chlorine and chloramine, it was possible to make these comparisons only in waters at pH 8.5 and 9.5 where the bactericidal action of both is retarded enough to provide for reliable observations and comparisons.

When like comparisons were made using results obtained with *Eber. typhosa* as the test organism, about 15 times as much chloramine as free chlorine was required to obtain 100-percent kills in the same time interval, and an average of 110 times longer periods of exposure with chloramine if the same O. T. residuals were used. These results are in fair agreement for the ratios given for *Esch. coli* with an indication that *Eber. typhosa* organisms are slightly more susceptible to chloramine, or perhaps less susceptible to free chlorine, than *Esch. coli.* Other comparisons to fit the particular needs of the reader may be made by selecting appropriate data from the tables of these three reports.

SUMMARY

Supplementing previous reports providing data on the bactericidal efficiency of free chlorine for coliforms and enteric pathogens, similar results demonstrating the bactericidal properties of the chloramines are now presented. The results represent the averages from 193 series of experiments conducted at (*a*) pH 6.5, 7.0, 7.8, 8.5, 9.5, and 10.5; (*b*) two temperature ranges, 2° to 6° C. and 20° to 25° C.; (*c*) various ratios of chlorine and ammonia nitrogen, and with species of *Escherichia*, *Aerobacter*, *Pseudomonas*, *Eberthella*, and *Shigella*. The materials and procedures used are fully described and the factors concerned in the use of chloramine are briefly discussed.

The results suggest the following conclusions:

1. The length of the time of exposure of the bacteria in water to chloramine and the amount of chloramine present are primary factors governing the rate of bacterial kills. Under favorable conditions, i. e., at pH 7.0 and a temperature of 20° to 25° C., 100-percent kills cannot be expected in less than 20 minutes with chloramine residuals of about 1.2 p. p. m.

2. The hydrogen-ion concentration has a pronounced effect on the bactericidal activity of chloramine, the activity being diminished with each decrease in hydrogen-ion concentration. For instance, if under given conditions at room temperature, 0.6 p. p. m. of chloramine at pH 7.0 produced a 100-percent kill in 40 minutes, then at pH 8.5, under otherwise identical conditions, approximately 120 minutes would be required, and at pH 9.5, 240 minutes, or to produce a 100-percent kill in 40 minutes at pH 8.5, the chloramine residual would need to be increased to about 1.5 p. p. m.

3. A lowering of temperature retards the bactericidal activity of chloramine. A reduction of 20 degrees in temperature (20°–25° C. to 2°–6° C.) requires 9 times the exposure period, or 2.5 times as much chloramine to produce a 100-percent kill. Thus, when the effect of a high pH water is superimposed on the effect of low temperatures, very marked retardation of bactericidal activity must be anticipated.

4. Under certain conditions some strains of *Eber. typhosa* and *S. sonnei* appear to be slightly more resistant than some strains of *Esch. coli.* However, they were not found any more resistant than the strains of *A. aerogenes* studied.

5. The presence of excessive amounts of ammonia nitrogen (Cl_2:N ratios to 1:25) did not markedly reduce the bactericidal efficiency of the resultant chloramines.

6. The duration of the contact time (0 to 68 hours), of the chloramine components, chlorine and ammonia, did not alter the bactericidal properties of the chloramine.

7. Chloramines are much less efficient as bactericidal agents than free chlorine. Thus, to obtain a 100-percent kill with the same period of exposure required about 25 times as much chloramine as free chlorine, and to obtain the same kill with the same amounts of chlorine and chloramine under the same conditions required approximately 100 times the exposure period for the chloramine.

REFERENCES

(*1*) Butterfield, C. T.; Wattie, Elsie; Megregian, S.; and Chambers, C. W.: Influence of pH and temperature on the survival of coliforms and enteric pathogens when exposed to free chlorine. Pub. Health Rep., **59**: 1837 (1943). Reprint No. 2530.

(*2*) Weber, Geo. R., and Levine, Max: Factors affecting germicidal efficiency of chlorine and chloramine. Am. J. Pub. Health, **34**: 719 (1944).

(*3*) Moore, W. A.: Megregian, S.; and Ruchhoft, C. C.: Some chemical aspects of the ammonia-chlorine treatment of water. J. Am. Water Works Assoc., **35**: 1929 (1943).

(*4*) Moore, W. A.: Use of p-aminodimethylaniline as an indicator for free chlorine. J. Am. Water Works Assoc., **35**: 427 (1943).

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INCIDENCE OF HOSPITALIZATION, DECEMBER 1945

Through the cooperation of the Hospital Service Plan Commission of the American Hospital Association, data on hospital admissions among members of Blue Cross Hospital Service Plans are presented monthly. These plans provide prepaid hospital service. The data cover hospital service plans scattered throughout the country, mostly in large cities.

Item	December	
	1944	1945
1. Number of plans supplying data	77	81
2. Number of persons eligible for hospital care	15,924,479	18,915,067
3. Number of persons admitted for hospital care	114,320	145,954
4. Incidence per 100 persons, annual rate, during current month (daily rate × 365)	84.7	90.8
5. Incidence per 1,000 persons, annual rate, for the 12 months ended December 31, 1945	103.2	106.7
6. Number of plans reporting on hospital days	22	27
7. Days of hospital care per case discharged during month [1]	7.96	8.98

[1] Days include entire stay of patient in hospital whether at full pay or at a discount.

DEATHS DURING WEEK ENDED JANUARY 12, 1946

[From the Weekly Mortality Index, issued by the Bureau of the Census, Department of Commerce]

	Week ended Jan. 12, 1946	Corresponding week, 1945
Data for 93 large cities of the United States:		
Total deaths	11,668	9,912
Average for 3 prior years	10,642	
Total deaths, first 2 weeks of year	23,596	19,698
Deaths under 1 year of age	620	661
Average for 3 prior years	699	
Deaths under 1 year of age, first 2 weeks of year	1,264	1,253
Data from industrial insurance companies:		
Policies in force	67,121,498	66,922,444
Number of death claims	13,283	14,780
Death claims per 1,000 policies in force, annual rate	10.3	11.5
Death claims per 1,000 policies, first 2 weeks of year, annual rate	10.3	9.8

PREVALENCE OF DISEASE

No health department, State or local, can effectively prevent or control disease without knowledge of when, where, and under what conditions cases are occurring

UNITED STATES

REPORTS FROM STATES FOR WEEK ENDED JANUARY 19, 1946

Summary

The incidence of influenza decreased in all geographic sections of the country except the West North Central. A total of 21,110 cases was reported, as compared with 32,635 last week, 3,993 and 47,143, respectively, for the corresponding weeks of 1945 and 1944, and a 5-year (1941–45) median of 4,387. Of the 13 States reporting more than 195 cases each, only two reported increases—Kansas, from 253 to 818, and Oklahoma, 1,768 to 2,164. The other 11 States reported an aggregate of 16,646 cases, as compared with 27,345 for the preceding week. The total for the year to date is 101,786, as compared with 12,712 and 239,498, respectively, for the corresponding periods of 1945 and 1944. The total for the period November 11, 1945, to January 19, 1946, is 444,500, as compared with 566,444 for the corresponding period of 1943–44.

Cumulative figures for the year to date for diphtheria and poliomyelitis are above those for both the corresponding period of last year and the 5-year median, while those for meningococcus meningitis, scarlet fever, smallpox, typhoid fever, and whooping cough are below. The figure for measles, 13,573, is above that for the same period of last year, but below the 5-year median, 25,839.

Of 13 cases of smallpox reported during the week, 8 occurred in Idaho.

A total of 10,401 deaths was recorded during the week in 93 large cities of the United States, as compared with 11,670 last week, 9,656 and 10,461 for the corresponding weeks of 1945 and 1944, respectively and a 3-year (1943–45) average of 10,091. The total to date is 33,999, as compared with 29,354 for the corresponding period last year.

Telegraphic morbidity reports from State health officers for the week ended Jan. 19, 1946, and comparison with corresponding week of 1945 and 5-year median

In these tables a zero indicates a definite report, while leaders imply that, although none was reported, cases may have occurred.

Division and State	Diphtheria			Influenza			Measles			Meningitis, meningococcus		
	Week ended—		Median 1941–45	Week ended—		Median 1941–45	Week ended—		Median 1941–45	Week ended—		Median 1941–45
	Jan. 19, 1946	Jan. 20, 1945		Jan. 19, 1946	Jan. 20, 1945		Jan. 19, 1946	Jan. 20, 1945		Jan. 19, 1946	Jan. 20, 1945	
NEW ENGLAND												
Maine	1	0	0	2	------	5	5	6	29	0	2	2
New Hampshire	0	0	0	------	------	------	7	------	6	0	0	0
Vermont	2	0	0	77	------	------	12	2	28	0	0	0
Massachusetts	6	3	3	------	------	------	209	43	364	10	2	2
Rhode Island	0	0	0	2	------	1	------	------	17	1	1	1
Connecticut	2	2	2	22	3	8	39	46	65	1	2	2
MIDDLE ATLANTIC												
New York	18	12	18	[1] 43	[1] 3	[1] 15	573	118	719	26	27	27
New Jersey	1	5	8	56	2	18	55	15	478	9	6	6
Pennsylvania	25	6	10	16	4	4	656	52	1,214	18	12	12
EAST NORTH CENTRAL												
Ohio	30	11	8	35	8	29	18	5	96	13	5	5
Indiana	17	4	8	76	13	16	61	23	67	2	7	7
Illinois	4	1	13	22	5	34	438	51	177	13	16	8
Michigan [2]	18	19	14	18	1	5	430	31	176	5	5	5
Wisconsin	1	3	3	196	8	101	60	23	421	4	3	1
WEST NORTH CENTRAL												
Minnesota	8	11	1	3	------	2	7	16	16	3	2	2
Iowa	6	3	3	------	------	15	329	39	95	0	1	1
Missouri	8	4	7	33	4	12	113	8	45	9	18	5
North Dakota	6	3	2	28	3	41	------	2	19	2	0	1
South Dakota	0	0	2	------	------	------	33	7	11	0	0	0
Nebraska	2	1	1	61	4	51	13	4	10	2	3	1
Kansas	8	2	2	818	2	17	187	12	135	1	5	5
SOUTH ATLANTIC												
Delaware	0	0	1	------	------	------	4	6	7	0	1	1
Maryland [2]	26	12	5	26	14	27	33	15	19	2	4	4
District of Columbia	0	0	2	3	2	6	10	2	17	0	2	2
Virginia	23	5	8	1,835	278	763	172	24	194	11	8	8
West Virginia	4	4	4	488	8	38	25	18	58	8	3	3
North Carolina	21	12	17	------	------	31	23	14	169	3	7	7
South Carolina	6	4	7	1,811	775	775	53	4	70	1	1	1
Georgia	8	7	7	170	59	101	41	4	64	3	6	2
Florida	9	7	7	8	4	13	21	26	26	3	5	3
EAST SOUTH CENTRAL												
Kentucky	6	7	6	72	3	21	226	5	38	6	5	3
Tennessee	17	6	6	187	57	81	50	48	49	14	4	4
Alabama	4	6	10	2,164	175	433	11	21	72	4	8	4
Mississippi [2]	8	5	5	------	------	------	------	------	------	3	6	3
WEST SOUTH CENTRAL												
Arkansas	15	11	10	490	143	186	38	12	61	8	4	1
Louisiana	11	6	7	2,253	3	8	5	11	18	6	4	4
Oklahoma	3	8	9	461	126	138	20	19	19	3	3	2
Texas	39	71	58	6,437	2,094	2,094	215	111	111	10	11	10
MOUNTAIN												
Montana	1	1	1	102	35	35	13	2	54	1	0	0
Idaho	2	0	0	105	2	2	69	4	4	1	0	0
Wyoming	0	0	0	------	------	70	10	3	10	1	0	0
Colorado	4	0	6	93	11	77	109	15	158	0	1	0
New Mexico	3	4	3	86	6	6	------	10	15	1	1	0
Arizona	4	4	2	356	97	103	4	8	64	0	2	0
Utah [2]	0	0	0	1,976	4	105	52	32	32	2	0	0
Nevada	0	0	0	------	------	------	40	1	1	0	1	0
PACIFIC												
Washington	9	2	2	------	1	12	296	50	60	3	2	2
Oregon	6	10	1	136	12	53	35	72	102	7	0	0
California	35	32	20	343	24	112	670	387	273	20	16	16
Total	427	314	314	21,110	3,993	4,387	5,490	1,427	9,234	240	222	222
3 weeks	1,320	1,053	1,014	101,786	12,712	12,712	13,573	3,861	25,839	691	711	711

[1] New York City only.
[2] Period ended earlier than Saturday.

Telegraphic morbidity reports from State health officers for the week ended Jan. 19, 1946, and comparison with corresponding week of 1945 and 5-year median—Con.

Division and State	Poliomyelitis			Scarlet fever			Smallpox			Typhoid and paratyphoid fever [3]		
	Week ended—		Median 1941–45	Week ended—		Median 1941–45	Week ended—		Median 1941–45	Week ended—		Median 1941–45
	Jan. 19, 1946	Jan. 20, 1945		Jan. 19, 1946	Jan. 20, 1945		Jan. 19, 1946	Jan. 20, 1945		Jan. 19, 1946	Jan. 20, 1945	
NEW ENGLAND												
Maine	0	1	0	19	58	26	0	0	0	0	1	0
New Hampshire	0	0	0	3	15	12	0	0	0	0	0	0
Vermont	1	1	0	13	1	7	0	0	0	0	0	0
Massachusetts	0	0	0	173	328	328	0	0	0	2	0	1
Rhode Island	0	0	0	11	15	15	0	0	0	0	0	0
Connecticut	2	0	0	34	63	63	0	0	0	1	0	0
MIDDLE ATLANTIC												
New York	4	5	2	297	576	385	0	0	0	0	2	4
New Jersey	3	0	1	87	107	112	0	0	0	3	3	0
Pennsylvania	1	0	0	137	331	285	0	0	0	1	4	4
EAST NORTH CENTRAL												
Ohio	0	0	1	228	237	311	1	0	0	2	1	2
Indiana	1	0	0	89	132	115	0	1	2	0	2	2
Illinois	1	3	2	159	334	265	0	0	1	1	0	2
Michigan [2]	0	0	0	145	236	195	0	0	0	1	0	1
Wisconsin	0	1	1	123	175	175	0	0	0	0	0	0
WEST NORTH CENTRAL												
Minnesota	0	1	0	52	95	95	0	0	0	0	0	0
Iowa	4	0	0	42	106	63	0	0	0	4	0	1
Missouri	1	1	1	41	121	86	0	0	1	0	1	1
North Dakota	0	0	0	9	36	36	0	0	0	0	0	0
South Dakota	0	1	0	15	33	31	0	0	0	0	1	0
Nebraska	0	0	0	55	60	38	0	0	1	0	0	0
Kansas	1	0	0	71	142	94	0	0	1	0	0	0
SOUTH ATLANTIC												
Delaware	0	0	0	1	12	14	0	0	0	0	0	0
Maryland [2]	0	1	0	56	142	68	0	0	0	2	1	1
District of Columbia	0	0	0	12	59	28	0	0	0	0	0	0
Virginia	1	0	0	72	86	48	0	0	0	0	1	2
West Virginia	0	0	0	34	65	64	0	0	0	0	5	1
North Carolina	0	1	1	33	72	66	0	1	0	4	0	0
South Carolina	0	0	0	10	7	11	0	0	0	0	1	1
Georgia	0	1	0	7	45	24	0	0	0	2	1	2
Florida	1	0	0	5	5	5	0	0	0	1	2	1
EAST SOUTH CENTRAL												
Kentucky	0	0	0	35	50	56	0	0	0	1	0	1
Tennessee	0	0	1	50	62	88	0	1	0	1	0	2
Alabama	0	1	1	9	17	23	0	0	0	0	0	0
Mississippi [2]	2	0	0	13	30	13	0	1	1	1	1	0
WEST SOUTH CENTRAL												
Arkansas	2	1	0	14	23	9	1	1	0	0	0	0
Louisiana	6	0	2	11	15	5	1	0	0	4	2	7
Oklahoma	0	1	0	25	31	26	1	0	0	3	1	2
Texas	3	1	1	103	181	82	0	0	1	3	11	6
MOUNTAIN												
Montana	2	0	0	2	14	20	0	0	0	2	0	0
Idaho	0	0	0	10	64	15	8	2	0	2	2	0
Wyoming	0	0	0	6	7	7	0	0	0	0	0	0
Colorado	0	0	0	51	82	38	1	0	0	0	1	1
New Mexico	1	0	0	17	47	6	0	0	0	1	1	1
Arizona	0	1	0	2	20	8	0	2	0	4	2	1
Utah [2]	1	0	1	43	45	45	0	0	0	0	0	0
Nevada	0	0	0	0	1	0	0	0	0	0	0	0
PACIFIC												
Washington	2	2	2	57	81	38	0	0	0	0	3	2
Oregon	1	0	0	24	43	19	0	0	0	0	0	1
California	10	3	1	206	431	194	0	0	0	2	1	2
Total	51	27	27	2,711	4.938	3,981	13	9	20	48	51	61
3 weeks	152	111	103	7,816	13,849	10,749	22	30	41	129	132	174

[2] Period ended earlier than Saturday.
[3] Including paratyphoid fever reported separately as follows: Massachusetts 2; Connecticut 1; Maryland 1; Georgia 1; Texas 1.

Telegraphic morbidity reports from State health officers for the week ended Jan. 19, 1946, and comparison with corresponding week of 1945 and 5-year median—Con.

Division and State	Whooping cough: Week ended— Jan. 19, 1946	Whooping cough: Week ended— Jan. 20, 1945	Whooping cough: Median 1941–45	Week ended Jan. 19, 1946: Dysentery: Amebic	Dysentery: Bacillary	Dysentery: Unspecified	Encephalitis, infectious	Rocky Mt. spotted fever	Tularemia	Typhus fever, endemic	Undulant fever
NEW ENGLAND											
Maine	16	41	41								
New Hampshire	12	10	2								
Vermont	12	47	34								2
Massachusetts	111	91	206	2	2						
Rhode Island	69	25	25								
Connecticut	42	54	54								3
MIDDLE ATLANTIC											
New York	258	239	451	6	1		2		1		5
New Jersey	164	94	140			1			1		1
Pennsylvania	141	220	330								
EAST NORTH CENTRAL											
Ohio	92	134	208		2		1				1
Indiana	24	14	16				1		1		
Illinois	82	100	133						4		6
Michigan [2]	129	75	349		7						5
Wisconsin	71	98	115				1				2
WEST NORTH CENTRAL											
Minnesota	10	43	43	3							2
Iowa	7	10	28	1							
Missouri	6		9			1					1
North Dakota		8	8								
South Dakota	1	2	5								
Nebraska	5	1	9								
Kansas	14	45	45				1				2
SOUTH ATLANTIC											
Delaware		1	1								
Maryland [2]	12	60	60			1					1
District of Columbia	10	6	14								
Virginia	70	46	89	2		32			7		1
West Virginia	14	29	59								
North Carolina	58	135	146						3	3	
South Carolina	53	82	60		6				1	4	
Georgia	6	15	16		1				2	11	7
Florida	14	17	20							4	2
EAST SOUTH CENTRAL											
Kentucky	11	33	33	2					3		
Tennessee	20	7	33						4	3	
Alabama	7	13	15	1						5	
Mississippi [2]									1		
WEST SOUTH CENTRAL											
Arkansas	3	41	24	23	3				2	2	
Louisiana			3	2					5	2	
Oklahoma	6	10	13			1					
Texas	146	193	140	22	274	108				14	33
MOUNTAIN											
Montana	2	25	16								
Idaho	4	7	7				1				
Wyoming		5	5								
Colorado	32	14	33	1							
New Mexico	12	11	12				1				
Arizona	14	19	24			29					
Utah [2]	15	7	30								
Nevada	7		1								
PACIFIC											
Washington	61	31	47								2
Oregon	10	9	10								1
California	123	251	251	2	13					1	1
Total	1,976	2,418	4,135	67	309	173	8	0	35	49	78
Same week, 1945	2,418			42	658	83	4	1	37	74	76
Average, 1943–45	2,825			30	325	48	7	[4] 0	21	[4] 51	
3 weeks: 1946	5,504			135	1,164	436	21	0	87	191	194
1945	6,526			89	2,230	557	17	1	119	243	200
Average, 1943–45	7,871		[4] 12,037	77	1,152	271	24	[4] 1	77	[4] 172	

[2] Period ended earlier than Saturday.
[4] 5-year median, 1941–45.

Leprosy: California, 1 case.

WEEKLY REPORTS FROM CITIES

City reports for week ended January 12, 1946

This table lists the reports from 86 cities of more than 10,000 population distributed throughout the United States, and represents a cross section of the current urban incidence of the diseases included in the table.

	Diphtheria cases	Encephalitis, infectious, cases	Influenza		Measles cases	Meningitis, meningococcus, cases	Pneumonia deaths	Poliomyelitis cases	Scarlet fever cases	Smallpox cases	Typhoid and paratyphoid fever cases	Whooping cough cases
			Cases	Deaths								
NEW ENGLAND												
Maine:												
Portland	0	1	------	0	1	0	1	0	6	0	0	13
New Hampshire:												
Concord	0	0	------	0	------	0	0	0	1	0	0	------
Vermont:												
Barre	0	0	------	0	------	0	0	0	0	0	0	------
Massachusetts:												
Boston	4	0	------	2	17	1	40	0	45	0	1	19
Fall River	0	0	------	0	------	1	0	0	5	0	0	5
Springfield	0	0	------	0	3	0	1	0	16	0	0	6
Worcester	0	0	------	0	12	1	19	0	12	0	0	13
Rhode Island:												
Providence	0	0	5	0	1	0	7	0	8	0	0	65
Connecticut:												
Bridgeport	0	0	1	0	1	1	6	0	1	0	0	------
Hartford	0	0	------	0	------	1	2	0	4	0	0	5
New Haven	0	0	2	1	------	0	3	0	0	0	0	6
MIDDLE ATLANTIC												
New York:												
Buffalo	0	0	1	3	13	4	4	0	8	0	0	54
New York	8	1	44	4	156	14	150	3	161	0	0	64
Rochester	0	0	------	1	3	0	5	0	7	0	2	5
Syracuse	0	0	------	0	410	2	3	0	8	0	0	8
New Jersey:												
Camden	0	0	------	0	1	0	3	0	4	0	0	5
Newark	0	0	3	0	5	1	10	0	11	0	0	25
Trenton	0	0	3	1	0	0	3	0	2	0	0	------
Pennsylvania:												
Philadelphia	2	0	15	8	169	2	41	0	44	0	0	38
Pittsburgh	3	0	5	4	2	2	19	0	8	0	0	5
Reading	0	0	1	4	1	0	5	0	1	0	0	17
EAST NORTH CENTRAL												
Ohio:												
Cincinnati	1	0	5	0	------	3	17	0	7	0	0	2
Cleveland	1	0	4	3	2	6	20	0	20	0	0	23
Columbus	5	0	4	4	3	0	6	0	9	0	0	1
Indiana:												
Fort Wayne	0	0	------	1	2	0	3	0	0	0	0	------
Indianapolis	2	0	------	0	25	0	8	0	16	0	0	6
South Bend	0	0	------	0	------	0	0	0	2	0	0	------
Terre Haute	0	0	------	0	1	0	4	0	1	0	0	------
Illinois:												
Chicago	0	0	11	3	407	18	62	0	60	0	0	38
Springfield	0	0	------	1	2	0	6	0	3	0	0	2
Michigan:												
Detroit	3	1	5	4	145	1	11	0	41	0	0	44
Flint	0	0	------	0	34	0	3	0	4	0	0	------
Grand Rapids	0	0	------	1	6	0	3	0	6	0	0	5
Wisconsin:												
Kenosha	0	0	------	0	------	0	0	0	1	0	0	------
Milwaukee	0	0	------	0	24	1	13	0	22	0	0	13
Racine	0	0	------	3	1	1	0	0	1	0	0	2
Superior	0	0	------	0	1	0	0	0	0	0	0	11
WEST NORTH CENTRAL												
Minnesota:												
Duluth	0	0	------	1	------	0	2	0	9	0	0	2
Minneapolis	1	0	------	0	1	1	8	0	15	0	0	2
Missouri:												
Kansas City	0	0	2	1	48	0	14	0	11	0	0	2
St. Joseph	0	0	------	0	37	0	0	0	2	0	0	------
St. Louis	3	0	23	4	19	2	11	0	17	0	1	4

City reports for week ended January 12, 1946—Continued

	Diphtheria cases	Encephalitis, infectious, cases	Influenza Cases	Influenza Deaths	Measles cases	Meningitis, meningococcus, cases	Pneumonia deaths	Poliomyelitis cases	Scarlet fever cases	Smallpox cases	Typhoid and paratyphoid fever cases	Whooping cough cases
WEST NORTH CENTRAL—continued												
Nebraska:												
Omaha	4	0	------	0	5	0	4	0	5	0	0	------
Kansas:												
Topeka	1	0	------	0	10	1	1	0	5	0	0	------
Wichita	0	0	1	0	7	0	1	0	3	0	0	2
SOUTH ATLANTIC												
Delaware:												
Wilmington	0	0	------	0	1	0	9	0	1	0	0	------
Maryland:												
Baltimore	22	0	23	4	13	0	25	0	25	0	0	26
Cumberland	0	1	------	0	------	0	1	0	0	0	0	------
Frederick	0	0	------	0	------	0	0	0	0	0	0	------
District of Columbia:												
Washington	0	0	2	0	8	0	7	0	14	0	1	9
Virginia:												
Lynchburg	0	0	------	1	------	0	1	0	2	0	0	------
Richmond	1	0	5	4	1	4	7	0	9	0	1	3
Roanoke	0	0	------	0	------	0	0	0	1	0	0	------
West Virginia:												
Charleston	0	0	------	0	------	0	0	0	0	0	0	------
Wheeling	0	0	------	0	------	0	0	0	1	0	0	1
North Carolina:												
Raleigh	0	0	------	0	------	0	6	0	0	0	0	------
South Carolina:												
Charleston	0	0	115	0	------	0	2	0	4	0	0	------
Georgia:												
Atlanta	0	0	51	3	------	0	7	0	0	0	0	3
Brunswick	0	0	------	0	------	0	0	0	0	0	0	------
Savannah	0	0	12	3	------	0	2	0	2	0	0	------
Florida:												
Tampa	0	0	1	0	20	0	5	0	1	0	1	------
EAST SOUTH CENTRAL												
Tennessee:												
Memphis	1	0	7	6	12	3	24	0	13	0	0	8
Nashville	0	0	------	2	28	2	2	0	0	0	0	1
Alabama:												
Birmingham	0	0	89	4	------	2	8	1	6	0	0	------
Mobile	1	0	66	3	------	1	6	0	2	0	0	------
WEST SOUTH CENTRAL												
Arkansas:												
Little Rock	0	0	5	0	1	0	2	0	0	0	0	------
Louisiana:												
New Orleans	2	0	9	1	------	5	11	0	5	0	4	------
Shreveport	0	0	------	0	------	0	3	0	1	0	0	------
Texas:												
Dallas	4	0	1	3	1	1	6	0	8	0	0	------
Galveston	0	0	------	0	------	0	1	0	1	0	0	------
Houston	1	0	------	0	1	2	3	0	4	0	1	------
San Antonio	3	0	6	5	2	0	11	0	2	0	0	------
MOUNTAIN												
Montana:												
Billings	0	0	------	1	------	0	1	0	0	0	0	------
Great Falls	0	0	------	0	------	0	1	0	0	0	0	------
Helena	0	0	------	0	------	0	0	0	1	0	0	------
Missoula	0	0	50	0	------	0	0	0	0	0	0	------
Idaho:												
Boise	0	0	1	0	1	0	0	0	0	0	0	------
Colorado:												
Denver	1	0	12	0	14	0	13	0	8	0	0	15
Pueblo	0	0	------	0	------	0	2	0	3	0	0	------
Utah:												
Salt Lake City	0	0	------	0	9	0	0	1	7	0	0	------

City reports for week ended January 12, 1946—Continued

	Diphtheria cases	Encephalitis, infectious, cases	Influenza		Measles cases	Meningitis, meningococcus, cases	Pneumonia deaths	Poliomyelitis cases	Scarlet fever cases	Smallpox cases	Typhoid and paratyphoid fever cases	Whooping cough cases
			Cases	Deaths								
PACIFIC												
Washington:												
Seattle	1	0	------	1	69	1	3	0	4	0	0	13
Spokane	0	0	4	0	41	0	2	0	3	0	0	7
Tacoma	0	0	------	2	31	0	1	0	3	0	0	12
California:												
Los Angeles	1	0	85	7	36	4	10	4	31	0	1	10
Sacramento	1	0	2	1	24	0	2	0	3	0	0	1
San Francisco	1	0	17	0	161	2	10	0	12	0	0	4
Total	78	4	698	105	2,049	91	713	9	789	0	13	625
Corresponding week, 1945	61	------	145	36	352	------	478	------	1,492	0	13	687
Average, 1941-45	70	------	2,467	[1] 122	[2] 2,326	------	[1] 661	------	1,150	2	12	831

[1] 3-year average, 1943-45.
[2] 5-year median, 1941-45.

Dysentery, amebic.—Cases: Rochester 1; Cleveland 1.
Dysentery, baccillary.—Cases: Bridgeport 1; Detroit 3; Los Angeles 4.
Dysentrey, unspecified.—Cases: San Antonio 7.
Tularemia.—Cases: Memphis 1.
Typhus fever, endemic.—Cases: Birmingham 1; Mobile 7; Little Rock 1; New Orleans 3; San Antonio 1.

Rates (annual basis) per 100,000 population, by geographic groups, for the 86 cities in the preceding table (estimated population, 1943, 33,969,400)

	Diphtheria case rates	Encephalitis, infectious, case rates	Influenza		Measles, case rates	Meningitis, meningococcus case rates	Pneumonia, death rates	Poliomyelitis, case rates	Scarlet fever, case rates	Smallpox, case rates	Typhoid and paratyphoid fever, case rates	Whooping cough, case rates
			Case rates	Death rates								
New England	10.5	2.6	20.9	7.8	91	13.1	206.5	0.0	256	0.0	2.6	345
Middle Atlantic	6.0	0.5	33.3	11.6	352	11.6	112.5	1.4	118	0.0	0.9	102
East North Central	7.3	0.6	17.6	12.2	397	18.2	94.9	0.0	117	0.0	0.0	89
West North Central	20.3	0.0	58.6	13.5	286	9.0	92.4	0.0	151	0.0	2.3	27
South Atlantic	39.0	1.7	354.6	25.4	73	6.8	122.1	0.0	102	0.0	5.1	71
East South Central	11.8	0.0	956.1	88.5	236	47.2	236.1	5.9	124	0.0	0.0	53
West South Central	28.7	0.0	60.3	25.8	14	23.0	106.2	0.0	60	0.0	14.3	0
Mountain	7.9	0.0	500.4	7.9	191	0.0	135.0	7.9	151	0.0	0.0	119
Pacific	6.3	0.0	170.8	17.4	573	11.1	44.3	6.3	89	0.0	1.6	74
Total	12.0	0.6	107.4	16.2	315	14.0	109.7	1.5	121	0.0	2.0	96

FOREIGN REPORTS

CANADA

Provinces—Communicable diseases—Week ended December 22, 1945.—During the week ended December 22, 1945, cases of certain communicable diseases were reported by the Dominion Bureau of Statistics of Canada as follows:

Disease	Prince Edward Island	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Total
Chickenpox		8		139	305	45	85	99	107	788
Diphtheria		1	6	34	14	3		1	5	64
Dysentery:										
Bacillary				1						1
Unspecified					3					3
German measles				7	25		3	7	7	49
Influenza		6			64	9				79
Measles		2	47	184	357	2	2	18	57	669
Meningitis, meningococcus				1	1					2
Mumps			1	61	75	17	24	62	53	293
Poliomyelitis		2								2
Scarlet fever		6	7	50	88	16	10	21	16	214
Tuberculosis (all forms)		5	4	78	35	17	29	45	41	254
Typhoid and paratyphoid fever				10					1	11
Undulant fever								1	1	2
Venereal diseases:										
Gonorrhea		6	25	76	125	58	58	41	121	510
Syphilis		12	4	95	113	7	8	27	62	328
Whooping cough		25	1	86	31	6		9		158

NEW ZEALAND

Notifiable diseases—4 weeks ended December 1, 1945.—During the 4 weeks ended December 1, 1945, certain notifiable diseases were reported in New Zealand as follows:

Disease	Cases	Deaths	Disease	Cases	Deaths
Cerebrospinal meningitis	20	3	Poliomyelitis	1	
Diphtheria	75	3	Puerperal fever	7	
Dysentery:			Scarlet fever	173	
Amebic	7		Tetanus	2	1
Bacillary	4		Trachoma	3	
Erysipelas	9		Tuberculosis (all forms)	243	70
Food poisoning	85		Typhoid fever	12	2
Malaria	13		Undulant fever	6	
Ophthalmia neonatorum	1				

REPORTS OF CHOLERA, PLAGUE, SMALLPOX, TYPHUS FEVER, AND YELLOW FEVER RECEIVED DURING THE CURRENT WEEK

NOTE.—Except in cases of unusual incidence, only those places are included which had not previously reported any of the above-mentioned diseases, except yellow fever, during recent months. All reports of yellow fever are published currently.

A table showing the accumulated figures for these diseases for the year to date is published in the PUBLIC HEALTH REPORTS for the last Friday in each month.

Plague

British East Africa—Uganda.—For the week ended January 12, 1946, 5 fatal cases of plague were reported in Uganda, British East Africa.

Madagascar.—Plague has been reported in Madagascar as follows: December 1–10, 1945, 5 cases; December 11–20, 1945, 18 cases.

Smallpox

Sudan (French).—Smallpox has been reported in French Sudan as follows: December 1–10, 1945, 130 cases; December 11–20, 1945, 35 cases; December 21–31, 1945, 307 cases.

Venezuela.—For the month of December 1945, 54 cases of smallpox (alastrim) were reported in Venezuela. States reporting the highest incidence are Miranda 16, and Sucre 12.

Typhus Fever

Belgian Congo.—Typhus fever has been reported in Belgian Congo as follows: Week ended December 22, 1945, 122 cases, 11 deaths; week ended December 29, 1945, 102 cases.

Greece.—For the week ended December 22, 1945, 19 cases of typhus fever were reported in Greece.

Turkey.—For the week ended January 12, 1946, 38 cases of typhus fever were reported in Turkey, including cases reported in ports as follows: Izmir 5, Kocaeli 7, Balikesir 3, Istanbul 6, Zonguldak 1, Trabzon 1, Icel 1, Erzurum 1.

Yellow Fever

Venezuela—Trujillo State.—During the week ended January 12, 1946, 1 confirmed case of yellow fever was reported in the municipality of Sabana Grande, and 1 confirmed case was reported in the municipality of Motatan, both in the State of Trujillo, Venezuela.

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