THE CHEMICAL AND BACTERIAL COMPOSITION OF THE SEWAGE DISCHARGED INTO BOSTON HARBOR FROM THE SOUTH METROPOLITAN DISTRICT.

WITH SPECIAL REFERENCE TO DIURNAL AND SEASONAL
VARIATIONS.

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INTRODUCTION.

In any problem of sewage disposal the composition of the sewage to be treated is the first and most essential factor. A few haphazard analyses are not sufficient. Diurnal and seasonal variations must be determined and the total amount of organic matter to be handled estimated with some degree of accuracy. At the Sanitary Research Laboratory of the Institute of Technology we have based our ideas of the efficiency of our various experimental filters upon the studies outlined below—studies which included daily analyses extending over a period of nearly a year, and six special 24 series of hourly samples. With the exception of the Lawrence results, no fuller set of analyses has probably been made for any American city. We have thought therefore that a somewhat full discussion of the data might prove suggestive as to methods of approach, as well as of absolute value in defining the character of the Boston sewage studied.

STATISTICS OF CONTRIBUTORY AREA.

The entire metropolitan district of eastern Massachusetts covers nearly 200 square miles of territory and includes at present some 24 separate cities and towns. The sewage from this large area is discharged by two main sewers into Boston harbor, the region north of the Charles discharging continuously off Deer Island, while the sewage of the South Metropolitan District is stored in tanks at Moon Island and discharged into the harbor on the

ebb tide. (See map.) A third main sewer is now under construction which will relieve the Moon Island outlet, carrying the flow by gravity from the higher parts of the South Metropolitan District to a point of discharge farther out in the harbor. The South Metropolitan District, as at present constituted, includes the city of Boston (with the exception of East Boston, Charlestown, and the harbor islands); the cities of Newton, Waltham, and Quincy, and the towns of Brookline, Watertown, Milton, Hyde Park, and Dedham.

One large metropolitan interceptor receives the sewage from Newton, Waltham, Brookline, and Watertown, and another drains Milton, Quincy, Hyde Park, and Dedham. Both discharge into a main trunk sewer which receives directly most of the sewage of the city of Boston. Statistics for the metropolitan district as given in the reports of the Metropolitan Water and Sewerage Board omit all discharges entering the trunk sewer itself and not passing through one of the two metropolitan interceptors; but we have collected in Table 1 the data for the whole sewerage system discharging at Moon Island, combining with the figures given in the second annual report of the Metropolitan Water and Sewerage Board of January 1, 1903, statistics obtained from the office of the sewer division of the street department of the city of Boston, through the courtesy of Mr. E. S. Dorr, engineer in charge. The present total population (1903), is calculated by geometrical ratio from the censuses of 1895 and 1900; and the contributing population is estimated by assuming that it bears to the total population the same relation which the number of connections bears to the total number of dwelling-houses as stated in the assessor's records.

The Sewage Experiment Station of the Massachusetts Institute of Technology is situated at 786 Albany Street, Boston, at the point indicated by a star on the map. A $2\frac{1}{2}$ inch pipe connects the station with the trunk sewer of the South Metropolitan District just below the junction of the Albany Street interceptor and above the junctions of the South Boston and Dorchester intercepting sewers, into which not only those districts and a small portion of West Roxbury, but Milton, Hyde Park, Dedham,

TABLE 1.

STATISTICS OF THE SOUTH METROPOLITAN SYSTEM DISCHARGING AT MOON ISLAND.

Districts	Miles of Local Sewer Connected	Area Served Sq. Mi.	Number of Connections with Local Sewers	Estimated Present Total Population	Estimated Population Now Contributing Sewage	Estimated Number of Persons Served by Each House Connection
Boston—						
Wards 6, 7, 8, 9, 10, 11, 12..	64.18	3.60	15,562	169,200	169,200	10.8
South Boston—						
Wards 13, 14, 15.....	45.52	1.92	5,267	64,700	47,830	9.1
Roxbury—						
Wards 17, 18, 19, 21 (22)..	96.76	3.79	6,731	121,900	63,570	9.4
West Roxbury—						
Wards (22), 23.....	85.80	12.49	3,356	41,400	24,730	7.4
Dorchester—						
Wards 16, 20, 24.....	185.15	8.64	8,845	98,400	70,360	8.0
Brighton—						
Ward 25.....	59.60	4.28	2,405	22,400	14,350	6.0
Brookline.....	53.61	6.81	2,758	23,000	19,000	6.9
Newton.....	94.85	18.03	4,569	37,200	26,900	5.9
Watertown.....	30.41	4.04	1,467	10,700	7,900	5.4
Waltham.....	38.25	13.63	2,594	25,500	22,050	8.5
Milton.....	3.39	12.59	78	7,300	430	5.5
Hyde Park.....	17.11	4.57	609	14,100	5,360	8.8
Dedham.....	3.32	9.40	17	7,200	95	5.0
Quincy.....	35.93	12.56	952	26,500	5,300	5.6
Totals.....	813.88	116.35	55,210	669,500	577,065	8.1

TABLE 2.

STATISTICS OF THE AREA ABOVE THE SEWAGE EXPERIMENT STATION.

Districts	Miles of Local Sewer Connected	Area Served	Number of Connections with Local Sewers	Estimated Present Total Population	Estimated Population Now Contributing Sewage	Estimated Number of Persons Served by Each House Connection
Boston—						
Wards 6, 7, 8, 9, 10, 11, 12..	64.18	3.60	15,562	169,200	169,200	10.8
Roxbury—						
Wards 17, 18, 19, 21 (22) ..	96.76	3.79	6,731	121,900	63,570	9.4
West Roxbury—						
Wards (22), 23.....	81.88	3.57	3,221	39,800	23,800	7.4
Brighton.....	59.60	4.28	2,405	22,400	14,350	6.0
Brookline.....	53.61	6.81	2,758	23,000	19,000	6.9
Newton.....	94.85	18.03	4,569	37,200	26,900	5.9
Watertown.....	30.41	4.04	1,467	10,700	7,900	5.4
Waltham.....	38.25	13.63	2,594	25,500	22,050	8.5
Totals.....	519.54	57.75	39,407	449,700	346,770	8.9

and Quincy discharge. The statistics for the area contributing the sewage actually analyzed are shown in Table 2. The population served appears to be about 350,000, a little more than one-half the total for the South Metropolitan District.

CALCULATION OF THE FLOW.

The first question to be settled concerned the variations in the sewage to be treated at different hours of the day and night; and in order to measure this factor we have made six sets of hourly analyses at different seasons of the year and under various weather conditions. In order to obtain an average analysis of the sewage flowing for 24 hours either one of two methods may be employed. Samples may be taken at short intervals, the volume of each sample being proportionate to the amount of sewage flowing at the time. Then if all the samples be mixed the result is a true average of the whole flow. A second and more convenient method is to take samples at regular intervals during the test and analyze each one separately. Then it is possible to calculate a "weighted average" by multiplying each analysis by the flow at the time of sampling, adding up the results and dividing by the total flow. Either method necessitates some knowledge of the hourly variation in the sewage flow.

We were unable to make meter measurements of the flow of sewage during the 24-hour runs, and it was impossible to make other gaugings on account of the size and the flat grade of the sewer. We were therefore forced to fall back upon indirect computations, which, though rough, possess sufficient comparative value for the weighting of hourly analyses.

The total length of the sewer between our intake and the pumping station at Dorchester is 11,514 feet. The sewer is circular in section, the diameter of the upper 6,874 being 9 feet, and of the remainder 10 feet 6 inches; it was built to a uniform slope of 1 in 2,500. At the point at which the sewer is enlarged from 9 feet to 10 feet 6 inches in diameter there enters from the north the South Boston interceptor, a sewer of circular section 6 feet in diameter, and at a point about 1,000 feet below this there enters from the south the Dorchester interceptor of

5 feet circular section. In the office of the Boston Main Drainage Works, on Massachusetts Avenue, directly opposite the point at which our intake enters the sewer, is installed an automatic gauge which records upon a revolving drum the elevation of the sewage. The pen of this indicator is operated by a float in a well, the latter being connected by a six-inch pipe with the sewer. At the pumping station in Dorchester a similar gauge is in operation at a point just above the screens. The permanent records of these gauges are preserved by the Sewer Division, to whose courteous officials we are indebted for their use and for other valuable assistance. We have also been allowed to examine and make use of the pump-log kept at the Dorchester station. We have therefore, for use in calculating the flow past our intake during any hour, the total amount pumped during that time, and the depth of the sewage at each end of the system at the beginning and end of the hour.

Considering the system below us as a reservoir we have a known amount flowing out (the amount pumped); and a known change in level from which we can calculate the amount flowing in. The calculation is complicated by the presence of the two intercepting sewers previously mentioned which enter the system below us; but one of these enters at too high a grade to affect the storage capacity, and the other stands full for too long a distance back materially to influence it. We shall therefore use in calculating our weighted analyses of sewage for 24 hours the total flow in the sewer as measured by the pump records, corrected for the storage in the system as indicated by the change in level. In comparing our monthly averages of daily analyses with one another we shall multiply each set by the total flow for the month.

In calculating the hourly flow we have first taken the recorded depth at each end of the system at the beginning and at the end of the hour, and calculated the volume of the layer of sewage included between these two surfaces. We have assumed the surfaces to be plane and taken as the cross-section of the layer of sewage the cross-section of the middle-point. The whole volume had to be divided into two parts, one in the nine-foot sewer and the other in the ten-foot-six sewer. The maximum observed

hourly variation in the amount of sewage in the sewer was but 10 per cent of the amount pumped in one hour and was generally less than two per cent. It was therefore necessary to calculate the storage value with an accuracy of only 10 per cent to avoid

TABLE 3.
FLOW OF SEWAGE -- MILLION GALLONS PER HOUR.

TIME	July 1903 22 23	Aug. 1903 13 14	Nov. 1903 16 17	Dec. 1903 22 23	Feb. 1904 17 18	April 1904 12 13
9-10 A. M.	.....	.....	5.65	6.54	6.06	4.57
10-11 "	5.64	4.86	6.20	5.35	5.96	4.57
11-12 "	5.63	4.57	5.98	4.57	4.45	4.57
12- 1 P. M.	5.78	4.86	5.96	4.27	4.45	4.57 4.57
1- 2 "	5.65	4.71	5.96	4.57	5.96	4.57 4.57
2- 3 "	5.64	4.66	5.96	5.96	5.96	4.57 4.57
3- 4 "	5.44	4.83	5.96	5.96	5.96	4.57 4.57
4- 5 "	5.42	4.78	6.38	5.96	5.96	4.57
5- 6 "	5.42	4.68	6.07	5.96	5.96	4.57
6- 7 "	5.66	4.27	5.96	5.96	5.96	4.57
7- 8 "	7.23	4.53	5.96	5.96	5.96	4.57
8- 9 "	5.96	4.40	5.96	5.96	5.96	4.57
9-10 "	5.96	4.37	5.96	5.93	5.96	4.57
10-11 "	5.96	4.31	5.96	5.93	5.96	4.57
11-12 "	5.96	3.88	5.96	5.93	5.96	4.57
12- 1 A. M.	5.96	4.57	5.96	5.93	5.96	4.57
1- 2 "	5.96	4.46	5.96	5.65	5.96	4.57
2- 3 "	5.55	4.45	5.96	5.65	5.96	4.57
3- 4 "	5.55	4.57	5.96	5.85	5.92	4.57
4- 5 "	5.46	4.45	5.96	5.85	5.92	4.57
5- 6 "	5.83	4.50	5.96	5.85	5.92	4.57
6- 7 "	3.35	4.69	5.96	5.85	5.91	4.57
7- 8 "	4.86	4.45	5.96	5.85	5.90	4.57
8- 9 "	4.96	4.84	5.96	6.37	6.04	4.57

an error in the final result greater than one per cent. These calculated changes in the volume of the sewage from hour to hour were then applied as corrections to the quantities pumped as calculated from the pump records. If the height of sewage increased during the hour the correction was added; if it decreased, the correction was subtracted. In Table 3 are given the resulting hourly total flows into the system for the six days on which

we make our tests. They represent the flow past our intake plus the amount of sewage entering the system by the two intercepting sewers previously mentioned.

With regard to the absolute amount of sewage flowing past Albany Street the following data are available:

Messrs. R. G. Hartshorne and L. T. Howard, M. I. T., '04, carried out as a graduating thesis a study entitled "Measurement of the Flow in the Main Intercepting Sewer of Boston." This

TABLE 4.
FLOW OF SEWAGE IN MOON ISLAND SEWER AT ALBANY STREET.
(Hartshorne and Howard).

DATE	TIME	MEASUREMENTS			PUMP RECORDS CUBIC FEET PER SECOND	RATIO	
		Mean Velocity	Area	Cubic Feet Per Second			
P.M.							
April	18.....	1:53- 2:50	2.04	57.2	116.8	222.9	.52
	18.....	2:55- 3:51	2.12	58.6	124.0	222.9	.55
	20.....	3:00- 4:14	1.93	63.6	122.8	225.4	.54
	25.....	2:17- 3:26	2.17	55.3	120.0	226.9	.53
	25.....	3:34- 4:37	2.11	55.6	117.0	226.9	.52
A.M.							
May	5.....	8:54- 9:46	1.41	63.6	89.9	164.7	.55
	5.....	9:56-10:45	1.60	63.6	101.7	165.0	.62
	14.....	7:40- 7:59	3.20	37.3	119.3	222.4	.54
	14.....	8:04- 8:31	3.26	38.2	124.5	218.6—227.9	.54
	14.....	8:47- 9:04	3.38	40.7	131.8	228.3	.60
						55.1	

investigation was made under the direction of the late Mr. K. S. Sweet, Instructor in Civil Engineering, whose untimely death we, who knew him, still mourn. Messrs. Hartshorne and Howard have permitted us to use their figures comparing the results of meter measurements made in the sewer at a point just below our intake with the total amount pumped as obtained from the pump-logs of the sewer division. In making these measurements a large Haskell meter was used, with a long pitch wheel and electrical connections with a buzzer. A system of multiple point measurements was adopted. By use of a stop watch the time required to make a certain number of revolutions, either 10 or 20, was noted. In this way any clogging of the meter could be

instantly detected and remedied. Eight per cent was the maximum error allowed for in the calculation, but the actual error was undoubtedly much less. The following table, based upon the figures obtained, is calculated to show the ratio between the flow past our intake and the total amount pumped.

The results shown in Table 4 indicate a remarkably constant ratio between the amount flowing at Albany Street and the pumpage at the end of the sewer, a ratio of 50 to 60 per cent. The residue must be accounted for by slip of the pumps and by the contribution of the lower intercepting sewers. The concordance of the results obtained in the measurements seem to us to warrant the assumption that the sewage flowing by Albany Street represents from 50 to 60 per cent of the total entering the Moon Island sewer. At any rate the contribution of our sewer appears to be a constant factor of the whole.

METHODS OF SAMPLING AND ANALYSIS.

In the first (July, 1903) series of analyses samples were taken from the petcock of the pump, but the difficulty of obtaining anything like a representative sample in this way is very great. In the later runs our pump was run continuously for the 24 hours, pumping at a rate of about 1500 gallons per hour. Some two-thirds of this amount was wasted, the remainder being delivered into a tank of 540 gallons capacity at such a rate that it was nearly filled in one hour. At each hour the sewage was diverted into a second tank, that in the first tank was thoroughly mixed by stirring, and a half gallon sample bottle was filled from the tank by means of a cock at its mid-depth. The bottle was filled rather slowly and the sewage kept well stirred during the operation. Each sample therefore represents very closely the average composition of the sewage flowing during one hour. The advantage of this procedure is clearly indicated by the smoothness of the curves on diagrams II-VI as compared with diagram I. Analyses were made immediately after the collection of the sample.

The following determinations were carried out on each sample: free and albuminoid ammonia, nitrites, oxygen consumed, chlorine

and dissolved oxygen. The samples were also examined bacteriologically and the following groups of organisms counted; on lactose gelatin at 20° C. the total number of organisms, the number of liquefiers and of acid formers; on lactose agar at 37° the total number and the number of acid formers; and on agar at 20° the number of facultative anaërobes.

The chemical analyses were made according to the methods now generally employed in this country as described for example by Richards and Woodman (1904.) We have used permanent standards for the ammonia readings as suggested by Jackson (1900). All ammonia and nitrite values are reported in terms of nitrogen, and all the chemical results are expressed in parts per million. We have adopted the plan of reporting the dissolved oxygen in parts rather than in per cent of saturation. While the latter method of expression may have had some significance in the study of surface waters it has no value whatever in connection with sewage work or with filtration work in general. Owing to a change in the temperature of the water during treatment the results expressed in per cent of saturation may show an increase in oxygen while there is in reality a marked decrease. For the oxygen consumed determination we used the Kübel method, boiling for two minutes.

In the bacteriological work we have followed the methods proposed by the Committee on Standard Methods of the American Public Health Association. The anaërobic counts were made in the earlier part of the work after the method of Wright (1901), later by a method proposed by Rickards (1904). Both methods are the same in principle, the oxygen being absorbed by pyrogallate of potassium.

GENERAL RESULTS OF THE EXPERIMENTS.

The analyses reported in Tables 5-10 represent six sets, each of 24 hourly samples. The first two series, of July and August, 1903, were intended to be typical of summer conditions. During the July run heavy rain fell while the August run was in fair weather. The third series in November represents late autumn conditions, and the fourth and fifth in December and

DIAGRAM II.

DIAGRAM I.

DIAGRAM IV.

DIAGRAM III.

DIAGRAM VI.

DIAGRAM V.

TABLE 5.

Parts per Million.

No.		NITROGEN AS					OXYGEN CONSUMED	OXYGEN DISSOLVED	CHLORINE	NUMBER OF BACTERIA IN ONE CUBIC CENTIMETER					
		Free Ammonia	Albuminoid Ammonia			Nitrates				Lactose Gelatin at 20°			Lactose Agar at 37°		Anærobic Lactose Agar at 20°
			Total	Solution	Suspension					Acid	Liquefiers	Total	Acid	Total	
33	July 22	14.0	5.7	3.8	1.9	0.08	0.62	—	3,700	50,000	—	300,000	—	100,000	500,000
34	10 A. M.	12.5	3.7	3.5	0.2	0.08	—	—	2,800	50,000	—	1,000,000	100,000	500,000	2,300,000
35	12	12.5	5.3	2.8	2.5	0.10	—	—	2,800	250,000	200,000	1,700,000	350,000	950,000	1,000,000
36	1 P. M.	15.0	6.1	2.7	3.4	0.08	0.83	—	2,800	850,000	150,000	3,500,000	1,100,000	1,850,000	1,000,000
37	2	18.0	5.5	3.4	2.1	0.11	—	—	1,300	550,000	150,000	2,600,000	500,000	1,050,000	1,500,000
38	3	14.0	5.8	3.4	2.4	0.10	—	—	1,700	400,000	200,000	3,900,000	650,000	2,100,000	2,000,000
39	4	14.0	5.8	2.0	3.8	0.10	1.03	—	280	300,000	—	3,300,000	100,000	12,000,000	2,100,000
40	5	14.0	5.8	2.3	3.5	0.14	—	—	260	550,000	150,000	4,600,000	300,000	800,000	1,400,000
41	6	13.0	5.2	2.8	2.4	0.16	—	—	360	1,000,000	150,000	8,800,000	100,000	17,000,000	1,900,000
42	7	18.0	5.0	2.8	2.2	0.17	0.53	—	678	400,000	—	3,700,000	1,300,000	9,200,000	2,600,000
43	8	11.0	9.0	2.2	6.8	0.10	—	—	871	2,000,000	1,000,000	6,000,000	1,500,000	4,000,000	—
44	9	13.0	4.7	1.9	2.8	0.07	—	—	543	—	—	2,000,000	2,500,000	12,500,000	500,000
45	10	8.0	4.4	2.2	2.2	0.08	0.48	—	2,840	—	—	3,500,000	500,000	2,000,000	1,000,000
46	11	9.0	3.5	1.2	2.3	0.13	—	—	5,100	10,000,000	1,000,000	15,000,000	500,000	1,000,000	1,000,000
47	12	9.0	2.6	1.4	1.2	0.12	—	—	4,890	—	—	1,000,000	—	1,000,000	—
48	July 23	10.5	2.8	1.4	1.4	0.13	0.78	—	3,990	—	—	500,000	—	500,000	—
49	1 A. M.	11.0	2.8	1.3	1.5	0.05	—	—	3,330	200,000	200,000	1,400,000	200,000	650,000	—
50	2	8.0	3.6	0.8	2.8	0.15	—	—	1,500	—	—	1,500,000	—	1,000,000	650,000
51	3	7.2	3.4	0.9	2.5	0.15	0.53	—	632	—	—	1,000,000	—	1,500,000	1,500,000
52	4	7.2	3.4	0.9	2.5	0.15	—	—	632	—	—	1,000,000	—	1,500,000	1,000,000
53	5	7.2	1.3	0.8	0.5	0.17	—	—	280	200,000	100,000	600,000	150,000	350,000	900,000
54	6	7.0	1.9	1.1	0.8	0.15	—	—	440	200,000	150,000	1,100,000	150,000	550,000	700,000
55	7	8.8	2.4	1.6	0.8	0.20	2.03	—	400	200,000	50,000	800,000	150,000	300,000	700,000
56	8	15.0	4.5	2.4	2.1	0.10	—	—	720	400,000	300,000	5,000,000	400,000	1,000,000	2,000,000
56	9	—	—	—	—	—	2.53	—	—	5,900,000	2,000,000	40,250,000	2,400,000	17,700,000	16,300,000
Averages.....		11.7	4.3	2.1	2.2	0.11	1.09	43	1,805	1,400,000	414,000	4,710,000	682,000	3,733,000	2,010,000
Weighted averages		11.8	4.4	2.1	2.3	0.12	0.98	45	2,100	1,370,000	428,900	4,620,000	701,500	3,000,000	1,978,000

TABLE 6.
Parts per Million.

No.	TIME	NITROGEN AS					OXYGEN CONSUMED	OXYGEN DISSOLVED	CHLORINE	NUMBER OF BACTERIA IN ONE CUBIC CENTIMETER							
		Free Am- monia	Albuminoid Ammonia			Ni- trates				Ni- trites	Lactose Gelatin at 20°			Lactose Agar at 37°		Anaerobic Lactose Agar at 20°	
			Total	Solu- tion	Sus- pen- sion						Acid	Liquefiers	Total	Acid	Total		
August 13 A. M.																	
128	9:30-10:30	22.5	7.7	4.8	2.9	0.16	0.63	52	—	234	200,000	200,000	1,000,000	600,000	1,600,000	700,000	
129	10:30-11:30	24.0	7.7	4.7	3.0	0.14	—	57	—	236	700,000	100,000	2,000,000	450,000	900,000	1,150,000	
130	11:30-12:30	22.5	7.8	4.7	3.1	0.14	—	57	—	280	700,000	100,000	2,300,000	900,000	1,400,000	2,150,000	
P. M.																	
131	12:30-1:30	22.5	7.7	4.4	3.3	0.14	—	56	—	420	1,200,000	400,000	3,300,000	300,000	1,400,000	2,400,000	
132	1:30-2:30	21.0	6.7	3.2	3.5	0.06	0.45	55	—	1,920	1,000,000	350,000	4,350,000	600,000	700,000	1,800,000	
133	2:30-3:30	18.0	5.7	2.8	2.9	0.08	—	48	—	2,430	1,050,000	50,000	2,900,000	450,000	1,600,000	2,050,000	
134	3:30-4:30	16.0	5.0	2.7	2.3	0.10	—	41	—	2,550	2,900,000	500,000	5,700,000	600,000	1,750,000	2,450,000	
135	5:30-6:15	15.0	5.4	2.7	2.7	0.10	—	51	—	2,180	1,150,000	300,000	4,100,000	1,150,000	2,900,000	2,500,000	
136	6:15-7:00	14.5	5.1	2.8	2.3	0.10	0.43	48	—	1,830	1,500,000	300,000	3,200,000	600,000	1,900,000	800,000	
137	7:00-7:45	14.0	5.0	2.2	2.8	0.06	—	43	—	1,560	—	—	5,600,000	1,200,000	2,350,000	2,600,000	
138	7:45-8:30	13.0	4.9	3.1	1.8	0.06	—	42	—	1,200	1,150,000	250,000	5,020,000	1,600,000	2,200,000	900,000	
139	8:30-9:30	9.5	4.3	4	1.9	0.10	—	46	—	760	750,000	250,000	2,650,000	400,000	750,000	2,000,000	
140	9:30-10:30	12.5	3.4	5	0.9	0.12	0.55	34	—	220	—	—	—	300,000	950,000	1,400,000	
141	10:30-11:30	13.0	3.5	2.0	1.5	0.08	—	27	—	220	—	100,000	1,800,000	200,000	450,000	1,600,000	
142	11:30-12:30	14.5	4.9	1.9	3.0	0.08	—	40	—	380	—	—	—	700,000	1,300,000	2,000,000	
August 14 A. M.																	
143	12:30-1:30	12.5	3.7	1.9	1.8	0.10	—	28	—	760	—	—	—	250,000	350,000	1,500,000	
144	1:30-2:30	12.5	2.4	0.9	1.5	0.12	0.40	29	—	1,420	50,000	—	600,000	100,000	700,000	800,000	
145	2:30-3:30	12.0	2.0	1.5	0.5	0.14	—	21	—	1,600	—	—	1,500,000	200,000	700,000	450,000	
146	3:30-4:30	6.5	2.0	1.4	0.6	0.14	—	17	—	1,520	—	—	400,000	—	100,000	400,000	
147	4:30-5:30	7.0	2.2	1.5	0.7	0.16	—	16	—	1,540	—	—	300,000	200,000	300,000	550,000	
148	5:30-6:30	7.0	3.1	2.4	0.7	0.12	0.75	8	—	1,480	50,000	50,000	500,000	350,000	400,000	600,000	
149	6:30-7:30	8.0	2.5	2.0	0.5	0.14	—	15	—	1,560	—	—	300,000	200,000	1,100,000	1,100,000	
150	7:30-8:30	14.0	5.2	2.6	2.6	0.14	—	22	—	1,670	300,000	100,000	2,400,000	200,000	1,750,000	1,250,000	
151	8:30-9:30	18.5	6.7	3.9	2.8	0.16	—	34	—	954	400,000	400,000	1,850,000	450,000	1,150,000	700,000	
Averages.....		14.6	4.8	2.7	2.1	0.11	0.54	37	..	1,206	873,000	223,000	2,465,000	519,000	1,195,000	1,410,000	
Weighted averages		14.7	4.8	2.7	2.1	0.11	0.64	37	..	1,213	860,000	232,000	2,480,000	520,000	1,220,000	1,415,000	

TABLE 7.
Parts per Million

No.	Time	Nitrogen as					Oxygen Consumed	Oxygen Dissolved	Chlorine	Number of Bacteria in one Cubic Centimeter						
		Free Am- monia	Albuminoid Ammonia		Ni- trates	Lactose Gelatin at 20°				Lactose Agar at 37°		Anaerobic Lactose Agar at 20°				
			Total	Solu- tion		Sus- pen- sion				Ni- trites	Acid		Lique- fiers	Total	Acid	Total
November 16																
	A. M.															
428	9:00-10:00	20.0	8.8	3.4	5.4	0.14	44	2.30	3,050	—	—	270,000	270,000	—		
429	10:00-11:00	19.0	8.5	4.0	4.5	0.80	46	1.50	2,400	50,000	0	690,000	690,000	1,910,000		
430	11:00-12:00	20.0	8.8	4.2	4.6	8.80	62	1.40	1,560	60,000	0	400,000	440,000	1,810,000		
P. M.																
431	12:00-1:00	25.0	7.7	4.8	2.9	0.90	67	1.10	1,750	30,000	0	500,000	560,000	1,870,000		
432	1:00-2:00	25.0	11.0	4.2	6.8	0.85	67	1.30	1,670	20,000	0	230,000	250,000	1,910,000		
433	2:00-3:00	22.0	10.5	4.0	6.5	0.68	68	0.70	1,100	60,000	0	300,000	320,000	3,160,000		
434	3:00-4:00	25.0	6.7	4.8	1.9	0.10	72	1.00	1,000	100,000	0	550,000	500,000	2,410,000		
435	4:30-5:50	22.5	9.5	4.2	5.3	0.80	88	1.30	340	20,000	0	470,000	260,000	1,630,000		
436	7:00	12.5	7.3	3.4	3.9	0.00	93	—	360	70,000	0	540,000	360,000	750,000		
437	7:00-8:00	17.5	9.3	2.4	6.9	0.02	108	—	440	50,000	0	310,000	280,000	1,120,000		
438	8:00-9:00	13.0	7.3	2.4	4.9	0.00	74	—	600	40,000	0	360,000	260,000	1,120,000		
439	9:00-10:00	12.5	8.3	2.8	5.5	0.01	50	—	900	40,000	0	390,000	210,000	1,120,000		
440	10:00-11:00	12.0	6.0	2.3	3.7	0.00	77	—	1,780	30,000	0	330,000	140,000	1,710,000		
441	11:00-12:00	10.0	6.1	1.9	4.2	0.00	66	—	2,300	80,000	0	450,000	960,000	690,000		
November 17																
	A. M.															
442	12:00-1:00	8.5	8.5	5.5	3.0	0.00	57	—	2,300	20,000	0	330,000	80,000	160,000		
443	1:00-2:00	9.3	3.3	1.3	2.0	0.00	50	—	1,900	20,000	0	190,000	60,000	250,000		
444	2:00-3:00	9.5	2.9	1.3	1.6	0.00	53	—	1,600	40,000	0	160,000	50,000	50,000		
445	3:00-4:00	10.0	3.0	1.3	1.7	0.00	43	—	1,520	20,000	0	130,000	50,000	460,000		
446	4:00-5:00	10.5	2.6	.9	1.7	0.00	45	—	1,280	—	0	40,000	50,000	360,000		
447	5:00-6:00	10.5	7.6	1.5	6.1	0.00	88	—	1,100	—	0	40,000	140,000	1,070,000		
448	6:00-7:00	7.5	4.5	1.3	3.2	0.10	43	—	1,020	40,000	0	120,000	60,000	1,460,000		
449	7:00-8:00	8.5	4.5	1.9	2.6	0.60	41	—	1,290	—	0	80,000	160,000	890,000		
450	8:00-9:00	12.5	4.3	2.0	2.3	0.80	41	—	1,860	30,000	0	40,000	90,000	340,000		
Averages.....													270,000	288,000	1,188,000	
Weighted averages													271,000	288,000	1,193,000	

TABLE 8.
Parts per Million

No.	TIME	NITROGEN AS					OXYGEN CONSUMED	OXYGEN DISSOLVED	CHLORINE	NUMBER OF BACTERIA IN ONE CUBIC CENTIMETER						
		Free Ammonia	ALBUMINOID AMMONIA			Nitrates				Lactose Gelatin at 20°			Lactose Agar at 37°		Anaerobic Lactose Agar at 20°	
			Total	Solubility	Suspension					Acid	Liquefiers	Total	Acid	Total		
December 22																
543	9:30-10:30	20.0	5.7	3.6	2.1	0	1.80	72	3.40	600	180,000	—	230,000	360,000	380,000	420,000
544	10:30-11:30	17.5	7.0	3.6	3.4	0	0.40	66	3.50	860	160,000	10,000	410,000	240,000	300,000	430,000
545	11:30-12:30	18.5	5.5	3.5	2.0	0	0.40	49	3.30	1,200	200,000	10,000	280,000	300,000	340,000	410,000
P. M.																
546	12:30-1:30	15.0	5.5	3.4	2.1	0	1.80	46	3.50	2,500	290,000	5,000	380,000	830,000	840,000	200,000
547	1:30-2:30	17.5	5.8	2.9	2.9	0	0.60	61	3.00	2,800	400,000	5,000	420,000	370,000	500,000	360,000
548	2:30-3:30	14.5	6.2	3.0	3.2	0	1.00	62	3.50	3,200	400,000	10,000	420,000	760,000	790,000	360,000
549	3:30-4:30	18.0	6.1	3.7	2.4	0	0.20	41	4.00	2,700	350,000	15,000	430,000	430,000	540,000	220,000
550	5:00-6:00	18.0	6.3	2.9	2.9	0	0.20	53	3.30	2,200	310,000	—	410,000	320,000	430,000	230,000
551	6:00-7:00	13.0	6.9	4.0	2.9	0.05	0.20	63	14.70	1,790	180,000	—	210,000	280,000	310,000	370,000
552	7:00-8:00	10.0	4.9	2.9	2.0	0.05	0.20	57	8.40	240	130,000	—	140,000	70,000	100,000	320,000
553	8:00-9:00	8.5	4.7	2.2	2.5	0.10	0.20	50	9.70	190	190,000	5,000	190,000	50,000	60,000	370,000
554	9:00-10:00	10.0	5.5	2.3	2.2	0	0.10	50	12.10	490	260,000	10,000	280,000	210,000	250,000	400,000
555	10:00-11:00	14.0	4.5	2.4	2.1	0	0.10	39	10.30	600	200,000	—	200,000	100,000	120,000	330,000
556	11:00-12:00	10.0	4.7	2.6	2.1	0.05	1.00	—	6.50	710	100,000	—	110,000	110,000	130,000	520,000
December 23																
A. M.																
557	12:00-1:00	11.5	3.5	1.7	1.8	0.20	0.10	26	12.00	660	40,000	—	50,000	5,000	50,000	410,000
558	1:00-2:00	10.0	2.2	1.6	0.6	0.05	0.10	22	10.60	640	50,000	—	70,000	100,000	100,000	100,000
559	2:00-3:00	7.5	2.1	1.0	1.1	0	0.10	21	7.40	670	100,000	5,000	100,000	70,000	80,000	270,000
560	3:00-4:00	6.5	1.5	0.9	0.6	0	0.20	19	16.50	760	20,000	—	30,000	70,000	70,000	220,000
561	4:00-5:00	3.5	5.0	4.2	0.8	0	0.20	21	15.10	980	40,000	—	40,000	40,000	40,000	130,000
562	5:00-6:00	7.0	2.0	0.8	1.2	0	0.30	14	7.80	900	10,000	—	10,000	50,000	50,000	210,000
563	6:00-7:00	7.5	3.3	1.6	1.7	0	0.20	16	6.50	1,000	30,000	—	40,000	5,000	20,000	1,860,000
564	7:00-8:00	10.1	4.2	2.9	1.3	0	0.20	28	6.00	260	160,000	—	160,000	—	10,000	5,550,000
565	8:00-9:00	15.0	5.0	2.9	2.1	0	0.20	45	4.60	180	80,000	—	100,000	20,000	50,000	260,000
Averages.....																
Weighted averages																
Averages.....																
Weighted averages																
Averages.....																
Weighted averages																

TABLE 9.

Parts per Million

No.	TIME	NITROGEN AS					OXYGEN CONSUMED	OXYGEN DISSOLVED	CHLORINE	NUMBER OF BACTERIA IN ONE CUBIC CENTIMETER						
		Free Ammonia	Albuminoid Ammonia		Nitrites	Nitrates				Lactose Gelatin at 20°			Lactose Agar at 37°		Anaerobic Lactose Agar at 20°	
			Total	Solution						Suspension	Acid	Liquefiers	Total	Acid		Total
	February 16	17.5	8.0	3.5	4.5	0.02	—	61	4.80	1,500	55,000	0	60,000	100,000	180,000	475,000
610	11:30 A.M.	15.5	6.9	3.0	3.9	0.02	—	25	4.90	1,900	5,000	0	45,000	55,000	90,000	365,000
611	12:30 P.M.	17.5	6.6	3.4	3.2	—	—	52	3.60	2,200	10,000	10,000	135,000	55,000	110,000	430,000
612	1:30	15.0	6.7	3.2	3.5	0.02	—	61	—	2,500	30,000	10,000	80,000	50,000	95,000	485,000
613	2:30	17.0	7.7	3.8	3.9	0.02	—	57	5.00	2,400	40,000	5,000	185,000	130,000	200,000	195,000
614	3:30	16.0	6.3	3.6	2.7	0.00	—	60	—	2,400	115,000	10,000	300,000	170,000	335,000	475,000
615	4:30	20.0	5.0	3.6	1.4	0.00	—	46	4.70	1,000	110,000	5,000	400,000	185,000	310,000	305,000
616	5:30	30.0	4.7	2.7	2.0	0.00	—	42	—	540	330,000	5,000	430,000	70,000	145,000	325,000
617	6:30	17.5	4.7	3.0	1.7	0.00	—	48	3.00	440	590,000	45,000	820,000	100,000	155,000	650,000
618	7:30	15.0	4.9	2.6	2.3	0.02	—	30	—	400	340,000	35,000	1,400,000	185,000	200,000	400,000
619	8:30	12.5	4.6	2.4	2.2	0.02	—	24	4.20	700	85,000	0	245,000	130,000	190,000	390,000
620	9:30	10.0	3.1	1.6	1.5	—	—	27	—	600	315,000	10,000	420,000	100,000	175,000	180,000
621	10:30	10.0	3.5	2.1	1.4	—	—	22	5.00	600	120,000	5,000	235,000	125,000	165,000	215,000
622	11:30	10.0	3.2	1.6	1.6	0.02	—	16	—	1,400	180,000	30,000	230,000	115,000	215,000	225,000
623	12:30 A.M.	9.0	2.3	1.0	1.3	0.02	—	15	6.90	800	115,000	5,000	135,000	70,000	145,000	185,000
624	1:30	6.5	2.2	1.1	1.1	0.01	—	11	—	700	60,000	15,000	190,000	20,000	65,000	145,000
625	2:30	4.5	1.8	1.1	0.7	0.01	—	9	8.20	500	0	0	20,000	35,000	45,000	130,000
626	3:30	4.5	1.8	0.9	0.9	0.01	—	10	9.00	600	20,000	5,000	60,000	15,000	25,000	150,000
627	4:30	4.5	1.8	0.9	0.9	0.01	—	11	9.30	440	90,000	0	130,000	10,000	30,000	195,000
628	5:30	11.5	3.1	1.9	1.2	0.00	—	28	—	300	65,000	5,000	170,000	35,000	65,000	100,000
629	6:30	4.5	2.7	2.0	0.7	0.04	—	41	—	400	40,000	0	85,000	135,000	400,000	100,000
630	7:30	10.0	5.3	3.7	1.6	0.00	—	41	—	280	50,000	10,000	115,000	95,000	135,000	115,000
631	8:30	10.0	8.0	6.0	2.0	0.00	—	46	—	480	70,000	0	115,000	110,000	145,000	115,000
632	9:30	14.0	9.0	6.2	2.8	0.02	—	31	—	300	110,000	25,000	200,000	145,000	190,000	290,000
633	10:30	11.5	5.2	3.0	2.2	0.04	—	74	—	974	122,700	9,800	258,400	93,300	158,750	278,500
Averages		12.9	4.9	2.8	2.1	0.01	—	35	5.72	951	122,000	8,800	261,000	93,500	156,000	294,000
Weighted averages		12.8	4.9	2.8	2.1	0.01	—	35	5.73	951	122,000	8,800	261,000	93,500	156,000	294,000

TABLE 10.

Parts per Million

No.	Time	Nitrogen as					Oxygen Consumed	Oxygen Dissolved	Chlorine	Number of Bacteria in One Cubic Centimeter						
		Free Ammonia	Albuminoid Ammonia			Nitrates				Lactose Gelatin at 20°				Lactose Agar at 37°		Anaerobic Lactose Agar at 20°
			Total	Solubility	Suspension					Nitrates	Acid	Liquefiers	Total	Acid	Total	
673	April 12 12:30 P. M.	4.5	5.0	2.2	2.8	—	44	5.6	500	158,000	75,000	350,000	6,500,000	6,800,000	230,000	
674	1:30	5.0	4.2	2.6	1.6	—	34	4.8	400	—	—	—	6,000,000	6,300,000	400,000	
675	2:30	9.0	3.5	2.6	0.9	—	59	5.7	300	60,000	40,000	300,000	140,000	430,000	150,060	
676	3:30	8.5	8.0	3.4	4.6	0.01	53	3.9	300	—	—	—	930,000	1,000,000	230,000	
677	4:30	—	—	—	—	0.01	54	3.4	200	60,000	30,000	700,000	350,000	380,000	315,000	
678	5:30	9.0	4.7	2.8	1.9	0.00	51	4.4	—	160,000	40,000	415,000	270,000	300,000	280,000	
679	6:30	9.0	4.5	2.4	2.1	0.00	66	6.1	380	105,000	65,000	615,000	1,200,000	340,000	340,000	
680	7:30	5.0	3.7	2.3	1.4	—	40	6.4	620	200,000	30,000	630,000	150,000	420,000	380,000	
681	8:30	8.0	3.3	2.0	1.3	—	47	6.9	770	85,000	10,000	260,000	450,000	490,000	305,000	
682	9:30	9.0	2.7	2.1	0.6	—	42	9.1	1,810	65,000	0	380,000	300,000	530,300	420,000	
683	10:30	10.0	4.7	1.6	3.1	—	39	8.5	2,390	90,000	20,000	260,000	200,000	240,000	120,000	
684	11:30	7.5	2.5	1.6	0.9	—	28	4.9	1,490	30,000	0	150,000	160,000	180,000	190,000	
685	April 13 12:30 A. M.	7.5	2.2	1.4	0.8	—	24	16.1	1,600	50,000	0	200,000	210,000	240,000	160,000	
686	1:30	9.0	2.7	1.6	1.1	—	31	10.1	2,820	55,000	25,000	250,000	200,000	230,000	235,000	
687	2:30	10.0	2.7	1.4	1.3	—	34	11.3	2,310	85,000	20,000	230,000	390,000	410,000	315,000	
688	3:30	7.5	1.1	0.8	0.3	—	17	9.9	1,740	55,000	0	255,000	140,000	160,000	140,000	
689	4:30	10.0	1.5	1.0	0.5	—	23	2.3	1,280	30,000	5,000	150,000	35,000	55,000	230,000	
690	5:30	7.5	1.9	0.8	1.1	—	14	4.5	800	10,000	15,000	65,000	80,000	85,000	120,000	
691	6:30	7.5	1.4	1.3	0.1	—	23	4.2	500	5,000	25,000	100,000	90,000	110,000	110,000	
692	7:30	9.5	1.8	1.5	0.3	—	22	5.9	540	10,000	0	95,000	110,000	130,000	70,000	
693	8:30	5.0	2.5	1.6	0.9	0.00	27	3.7	920	35,000	0	55,000	120,000	120,000	175,000	
694	9:10	10.0	3.7	2.8	0.9	0.00	39	8.9	1,560	130,000	10,000	195,000	230,000	240,000	250,000	
695	10:30	13.0	3.5	2.2	1.3	—	31	8.8	2,100	0	0	55,000	90,000	90,000	30,000	
696	11:30	17.5	2.2	2.0	0.2	—	32	4.5	2,400	320,000	15,000	550,000	150,000	160,000	355,000	
697	12:30 P. M.	17.5	2.5	2.2	0.3	0.00	29	—	2,700	900,000	30,000	1,300,000	930,000	980,000	—	
698	1:30	15.4	4.0	2.4	1.6	—	31	5.3	2,200	750,000	150,000	2,000,000	580,000	680,000	—	
699	2:30	6.5	3.0	2.2	0.8	—	30	4.3	2,000	—	—	—	—	—	—	
700	3:30	15.0	2.7	2.0	0.7	—	32	3.0	1,000	650,000	5,000	1,080,000	550,000	590,000	—	
Average for 24 hrs.		8.6	3.2	1.9	1.3	0.003	36	6.6	1,205	85,600	28,300	283,600	799,800	837,500	231,300	
Average for 28 hrs.		9.0	3.2	2.0	1.2	0.003	36	5.3	1,320	219,000	32,600	497,000	741,600	806,400	231,300	
Weighted average, 28 hrs.		9.0	3.2	2.0	1.2	0.003	36	5.3	1,320	219,000	32,600	477,000	741,600	806,400	231,310	

February, are typical of winter weather. Considerable snow and rain fell during the November run. Finally the last series (in April), followed heavy rain and spring thaws.

The analyses recorded in detail in Tables 5-10 are plotted in graphic form in Diagrams I-VI. Inspection of the curves shows, first, the general relation of the day and night flow. The nitrogenous bodies, indicated by the ammonias, and the carbonaceous constituents as measured by the oxygen consumed, rise to a maximum between 11:30 A. M. and 2:30 P. M., and fall to a minimum between 3 and 6 A. M. The curves for the dissolved oxygen naturally exhibit a reciprocal relation the amount increasing regularly from early evening to 6 or 7 A. M. The curves are most even and show the widest diurnal variation in the winter runs when the surface water was largely excluded and in the August series during the dry summer period.

Bacteriological analyses of sewage have never been carried out with so much detail so far as we are aware, and they bring out several points of interest. First, the enormous diurnal variations in warm weather are strikingly manifest in the diagrams of the July and August tests. The maximum occurs not at 11:30 A. M. when the organic constituents are highest, but from four to six hours later, at 4:30 P. M. We are inclined to attribute this mainly to the fact that the large amount of organic matter which passes in the morning is from the adjacent regions of Boston proper, and is comparatively fresh and undecomposed, while that arriving in the afternoon comes from the upper part of the system, so that the bacteria present have had time to multiply. The fact that the other four curves indicate no such enormous increase shows the important effect of the seasonal variations of temperature upon the multiplication of bacteria. The diurnal variation is, however, clearly shown even in December and February, although the absolute numbers are so small that the differences are somewhat obscured by the scale of our diagrams.

The effects of dilution with rainwater are shown with great clearness by the curves for the April analyses. The actual amount of nitrogenous matter present was much lower than at any other time, while the values for oxygen consumed remained as

high as in August and February, and not far below the July and December figures. This is attributable to the fact that while street washings are poor in nitrogen as compared with domestic sewage, they contain considerable carbonaceous matter derived from horse droppings, etc. The normal diurnal variations are, of course, somewhat obscured in the presence of much surface water, and this phenomenon is also evident in the April analyses.

GENERAL DIURNAL VARIATIONS IN THE COMPOSITION OF BOSTON SEWAGE.

Fuller (1903) and others have emphasized the importance of the hourly variations in the composition of sewage, and Goodnough and Johnson (1899) have published numerous series of analyses which bring out with clearness the extent of the variations. The absurdity of calculating sewage purification on the basis of analyses made during parts of the day when the sewage has twice its normal strength must be obvious, and yet this solecism is still commonly committed. Not only the hourly analyses but the hourly variations in flow should be considered; and in each of our tables there is given first the crude average for each constituent, and second, the true average corrected by weighting each analysis according to the amount of sewage flowing. In our case the correct average differs but little from the crude average, since the Moon Island sewer is usually full and shows but little variation in flow. Under other conditions, however, this allowance for hourly variations in flow would become of great importance.

We have calculated for the principal features of the analyses in Tables 5-10 the ratios which each hourly figure bear to the general average for the day, and have averaged the results obtained for each hour in the six different tests. The final figures in Table 11 probably form a fairly correct measure of the hourly variations in Boston sewage, and bring out some points not made clear in the diagrams. The maximum of albuminoid ammonia and oxygen consumed is seen to fall between 10 A. M. and 2 P. M., while the free ammonia is highest between 1 P. M. and 8 P. M. The latter thus follows the bacteria which is natural, since in all water and sewage analyses free ammonia, the product of bacterial decom-

position, and the bacteria which form it, are found to vary together. The dissolved oxygen is highest at 4 to 5 A. M., when ammonia, oxygen consumed, and bacteria alike reach their minimum. For purposes of comparison we have calculated similar

TABLE 11.

RATIO OF ANALYSES FOR EACH HOUR TO THE AVERAGE ANALYSIS OF THE TWENTY-FOUR HOURS (AVERAGE OF SIX SERIES).

TIME	FREE AMMONIA	ALBUMINOID AMMONIA		OXYGEN CONS.	OXYGEN DISS.	CHLORINE	BACTERIA		
		Total	Susp.				Gela- tin, 20°	Agar, 37°	Ana- erobic
10 A. M.	1.29	1.33	1.35	1.31	1.26	1.15	.77	.89	.60
11 "	1.27	1.27	1.19	1.19	.84	1.12	.81	.98	1.13
12 Noon.	1.25	1.24	1.21	.98	1.35	1.17	.85	.70	1.04
1 P. M.	1.35	1.25	1.21	1.20	.96	1.61	1.04	1.17	1.11
2 "	1.40	1.29	1.49	1.31	1.17	1.71	1.05	.81	1.22
3 "	1.21	1.22	1.29	1.21	.94	1.71	1.14	1.42	1.16
4 "	1.31	1.07	1.03	1.09	.64	1.66	1.49	1.80	1.31
5 "	1.16	1.02	1.11	1.00	.84	1.18	1.09	1.15	1.02
6 "	1.38	1.07	.97	1.12	.74	1.06	1.43	1.64	.82
7 "	1.14	1.04	.96	1.20	1.18	.71	1.30	1.35	1.16
8 "	.92	1.20	1.42	1.00	.90	.52	1.90	.97	.86
9 "	.81	1.02	1.05	1.09	1.21	.58	.91	1.11	.95
10 "	.91	.97	.93	.96	1.13	.95	1.08	.72	.64
11 "	.97	.80	.75	.96	.80	1.30	1.67	.77	.98
12 Midnight.	.75	.95	.94	.90	.74	1.33	1.10	2.25	.93
1 A. M.	.76	.86	.82	.71	1.07	1.04	.55	1.22	.85
2 "	.80	.61	.53	.74	1.21	.78	.48	.38	.40
3 "	.68	.83	1.06	.72	1.11	.63	.40	.47	.49
4 "	.52	.46	.51	.69	1.64	.57	.73	.30	.57
5 "	.75	.64	.56	.66	1.42	.90	.57	.21	.55
6 "	.62	.76	.79	.82	1.13	.40	.65	.59	.64
7 "	.63	.77	.67	.71	1.11	.47	.77	.67	1.24
8 "	.87	1.06	.91	.92	1.15	.56	.61	.63	.73
9 "	.95	1.15	.94	.93	1.04	1.04	2.18	1.31	.59

ratios for the six 24-hour runs reported by Goodnough and Johnson (1899), as Fuller (1903) has done for one of them. The results are presented in Table 12. Representing only a single series, the variations are less even than in our own table; yet they suggest distinct differences between the sewages studied. Marlborough, Spencer, and Natick sewages appear to be most concentrated in the afternoon, which is probably due to the length of the sewers above the point at which samples were taken.

TABLE 12.

RATIO OF ANALYSES AT DIFFERENT HOURS TO THE AVERAGE ANALYSIS OF THE
TWENTY-FOUR HOURS, IN SIX MASSACHUSETTS COMMUNITIES.

Spencer—June, 1898.

HOUR	RATE OF FLOW	RESIDUE ON EVAPORATION			NITROGEN AS		OXYGEN CON- SUMED	CHLO- RINE
	Gals. per 24 hrs.	Total	Dissolved	Suspended	Free Ammonia	Albuminoid Ammonia		
8-9 A.M.	1.13	1.18	1.02	1.68	2.25	1.94	1.44	.90
10-11 " "	.98	1.77	1.30	3.20	2.20	1.58	1.58	1.35
12-1 P.M.	1.29	1.11	1.03	1.36	1.85	1.49	1.35	.96
2-3 " "	1.20	1.47	1.27	2.07	1.76	1.49	1.90	1.06
4-5 " "	1.18	1.16	1.54	0.00	1.76	1.17	1.24	2.33
6-7 " "	1.06	.85	.94	.58	1.68	.86	.76	.96
8-9 " "	.97	.97	.96	.98	1.63	1.12	.96	.88
10-11 " "	.90	.83	.81	.89	.97	.66	.84	.65
12-1 A.M.	.90	.53	.65	.15	.53	.33	.27	.59
2-3 " "	.80	.52	.68	.05	.21	.15	.21	.56
4-5 " "	.76	.48	.63	.03	.12	.14	.16	.55
6-7 " "	.97	.59	.73	.18	.87	.34	.39	.69

Brockton—Outlet of Main Sewer, June, 1898

8-9 A.M.	...	.35	.53	1.10	1.80	1.63	.24	.42
10-11 " "	...	1.35	1.09	1.74	1.62	2.07	1.74	.82
12-1 P.M.	...	1.20	1.30	1.07	1.70	1.54	1.60	1.24
2-3 " "	...	1.30	1.37	1.21	1.66	1.44	1.34	1.45
4-5 " "	...	1.51	1.45	1.61	1.40	1.44	1.41	1.72
6-7 " "	...	1.02	1.13	.86	1.16	1.06	1.34	.89
8-9 " "	...	.91	1.06	.70	1.32	1.10	1.03	1.01
10-11 " "	...	1.15	1.40	.79	1.04	1.04	1.17	1.96
12-1 A.M.	...	1.17	.92	1.52	.81	1.08	.90	.85
2-3 " "	...	1.31	.68	2.25	.59	.48	.68	.64
4-5 " "	...	.38	.57	.94	.37	.30	.32	.55
6-7 " "	...	.33	.52	.49	.24	.16	.25	.45

Framingham—Main Sewer, June, 1898.

9-10 A.M.	...	1.32	1.29	1.40	1.87	1.77	1.69	1.25
11-12 " "	...	1.03	1.07	.94	1.45	1.26	1.16	1.04
1-2 P.M.	...	1.63	1.30	2.50	1.34	1.49	1.59	1.00
3-4 " "	...	1.31	1.20	1.60	1.14	1.70	.23	1.24
5-6 " "	...	1.04	.97	1.23	1.45	1.13	1.12	.76
7-8 " "	...	1.13	1.03	1.40	1.48	1.19	1.18	.86
9-10 " "	...	.82	.66	1.23	.67	.98	.82	.63
11-12 " "	...	.57	.69	.28	.78	.43	.49	.77
1-2 A.M.	...	.47	.63	.05	.25	.26	.20	.60
3-4 " "	...	.50	.67	.08	1.34	.21	.19	.58
5-6 " "	...	.97	1.22	.34	.23	.34	.31	1.58
7-8 " "	...	1.20	1.30	.98	1.22	1.23	1.00	1.46

TABLE 12.—Continued.

Marlborough—Main Sewer, June, 1898.

Hour	Rate of Flow	Residue on Evaporation			Nitrogen as		Oxygen Consumed	Chlorine
	Gals. per 24 hrs.	Total	Dissolved	Suspended	Free Ammonia	Albuminoid Ammonia		
9-10 A.M. . .	1.03	.76	.79	.68	1.08	.84	.58	.75
11-12 " . .	1.13	1.57	1.58	1.55	2.51	1.71	1.55	2.55
1- 2 P.M. . .	1.10	1.15	1.06	1.36	1.65	1.95	1.19	.96
3- 4 " . .	1.17	1.36	1.19	1.78	1.12	1.35	1.72	1.09
5- 6 " . .	1.27	1.46	1.14	2.30	1.19	1.69	1.96	.94
7- 8 " . .	1.05	.97	.99	.94	.93	1.01	1.26	.79
9-10 " . .	1.02	.99	1.09	.75	.86	.87	.91	1.28
11-12 " . .	.94	.86	.92	.72	.82	.75	.78	.82
1- 2 A.M. . .	.90	.70	.97	.48	.59	.48	.52	.67
3- 4 " . .	.80	.57	.74	.14	.26	.24	.29	.57
5- 6 " . .	.77	.54	.69	.16	.86	.10	.12	.52
7- 8 " . .	.85	.53	.73	.00	.76	.07	.12	.56

Natick—Main Sewer, June, 1898.

9-10 A.M. . .	...	.97	1.02	.40	2.35	1.47	.64	1.26
11-12 " . .	...	1.26	1.20	1.97	1.69	1.45	1.25	1.73
1- 2 P.M. . .	...	.99	1.02	.77	1.47	1.62	1.41	.94
3- 4 " . .	...	1.10	1.02	2.00	.70	.68	1.68	.96
5- 6 " . .	...	1.22	1.02	3.27	1.10	1.24	1.28	1.10
7- 8 " . .	...	1.18	1.04	2.75	1.35	1.73	2.23	.91
9-10 " . .	...	.99	1.06	.19	.90	.70	1.18	1.14
11-12 " . .	...	.85	.93	.05	.57	1.05	.59	.89
1- 2 A.M. . .	...	.87	.94	.14	.57	.51	.43	.79
3- 4 " . .	...	.86	.94	.10	.33	.23	.30	.77
5- 6 " . .	...	.84	.90	.29	.43	.75	.36	.75
7- 8 " . .	...	.86	.94	.05	.78	.70	.89	.79

Gardner—July, 1898.

9-10 A.M. . .	1.24	1.43	1.26	1.80	1.50	1.80	1.58	.99
11-12 " . .	1.16	1.60	1.59	1.62	1.57	1.55	1.67	1.14
1- 2 P.M. . .	1.23	1.29	1.31	1.25	1.07	1.07	1.10	1.27
3- 4 " . .	1.16	1.42	1.14	2.04	1.13	1.41	1.41	1.20
5- 6 " . .	1.07	1.23	1.37	.93	1.16	.99	.92	2.17
7- 8 " . .	1.03	.97	1.05	.79	1.41	1.17	1.10	1.16
9-10 " . .	.92	.67	.76	.49	.84	.66	.85	.75
11-12 " . .	.85	.84	.76	1.01	.98	.87	.99	.77
1- 2 A.M. . .	.74	.35	.43	.16	.35	.31	.22	.53
3- 4 " . .	.70	.28	.39	.06	.08	.15	.16	.38
5- 6 " . .	.77	.32	.44	.08	.16	.14	.19	.38
7- 8 " . .	1.14	.69	.74	.59	1.01	.87	.82	.61

By comparison with the tables above, it appears that the diurnal variations in Boston sewage are less wide than those characteristic of smaller towns. This is natural, since the long sewers of the larger system must tend to equalize local variations.

The practical conclusion of this work is, of course, the derivation of a constant by which the true composition of the sewage for 24 hours may be deduced from analyses made at a given time,—in the case of our experiments during the late morning. Reference to Table 11 shows that the ammonia and oxygen consumed ratios for Boston in the morning hours from 10 A. M. till noon range not far from 1.25 while the bacterial ratios on gelatin and agar are approximately .8. In using our routine daily analyses made on samples collected at this time as a measure of the average composition of the sewage this factor may be used as a correction.

MONTHLY VARIATIONS IN THE COMPOSITION OF BOSTON SEWAGE.

Our data for the study of seasonal variations consist of a series of daily analyses made during the last six months of 1903 and during April, May, and June, 1904. The examinations were unfortunately interrupted from January to March 1904. Averages of the analyses by months are shown in Table 13 with the pumpage at Moon Island in billion gallons per month as a correction factor. It must be noted that this is the total flow from the whole South Metropolitan system, not merely that which passes Albany Street; but the relative proportion of the latter must by months be practically constant. The crude average is first shown in the table, and next the corrected average, obtained by multiplying the analyses for each month by the flow for that month and dividing the sum by the total flow.

The monthly variations are better seen by a comparison of the ratios as they are shown in Table 14. The seasonal differences are much less important than those which subsist between the night and day flows; yet there is a well marked minimum in May, followed by a steady rise, culminating in November or December. The strength of the sewage bears a general inverse relation to the amount flowing, although from October to December both flows and analyses were high.

TABLE 13.
BOSTON SEWAGE—MONTHLY AVERAGE OF DAILY SAMPLES.

DATE	FLOW, BILLION GALLONS.	NITROGEN AS						OXYGEN CONSUMED, TOTAL
		Albuminoid NH ₃			Free NH ₃	Ni- trites	Ni- trates	
		Total	Solu- tion	Sus- pension				
April, 1904	4.0	5.2	2.8	2.3	15.8	.09	.00	41
May, 1904	4.2	5.7	2.5	3.2	14.9	.14	.00	31
June, 1904	3.8	7.0	3.0	4.0	19.8	.22	.48	43
July, 1903	3.4	6.3	3.2	3.0	18.2	.12	.48	47
August, 1903	3.3	7.1	3.8	3.3	22.4	.12	.00	45
September, 1903	3.4	6.3	3.0	3.2	21.4	.18	.00	45
October, 1903	3.8	6.3	3.4	2.9	20.5	.80	...	51
November, 1903	3.8	6.1	3.0	3.2	22.3	.20	...	53
December, 1903	4.2	6.6	3.6	3.0	24.0	.42	...	50
Crude average ...	3.8	6.3	3.1	3.1	19.9	.26	.16	45
Average corrected for flow	...	6.2	3.1	3.1	19.9	.26	.15	45
Final ave. cor. for diurnal variation		5.0	2.5	2.5	15.9	.21	.12	36

In the last line of Table 13 we have applied the diurnal variation factor, dividing the corrected averages above by 1.25.

TABLE 14.
BOSTON SEWAGE—RATIO OF MONTHLY ANALYSES TO GENERAL AVERAGE.

MONTH	FLOW	ALBUMINOID AMMONIA			FREE AMMONIA	OXYGEN CONSUMED
		Total	Solution	Suspension		
April, 1904	105	83	90	74	79	91
May, 1904	115	91	80	103	74	69
June, 1904	100	115	96	128	100	95
July, 1903	89	99	104	97	91	104
August, 1903	87	113	120	107	112	100
September, 1903	89	99	97	104	107	100
October, 1903	100	100	108	93	103	113
November, 1903	100	97	95	101	112	118
December, 1903	115	105	116	95	120	111
Nine months	100	100	100	100	100	100

For comparison we have calculated the monthly ratios for four other cities and towns, which are given in Table 15. The original analyses for Andover and Lawrence were obtained from the report of the Massachusetts State Board of Health for 1901

(Clark, 1902); the Worcester figures were taken from the reports of the superintendent of sewers from 1900 to 1903 (average of the four years), and the Brockton analyses from the reports of the City Engineer for 1900 and 1901 (average for the two years). All show October and November to be much higher than the other months. September is also high except at Andover; January and February are well above the average at Worcester; and January, February, and March at Lawrence. The minimum in each case occurs in April or May. There is, then, a yearly cycle in the composition of sewage as definite, if not as wide in range, as the diurnal cycle.

TABLE 15.

RATIOS OF THE MONTHLY AVERAGES OF SEWAGE ANALYSES TO THE YEARLY AVERAGE, FOR FOUR MASSACHUSETTS COMMUNITIES.

Andover—1901.

MONTH	FREE AMMONIA	ALBUMINOID AMMONIA			CHLORINE	OXYGEN CONSUMED	BACTERIA
		Total	Soluble	Suspended			
January ...	.80	.43	.65	.17	.97	.51	1.21
February..	.75	.98	.26	1.84	1.11	.72	.87
March.....	1.02	1.10	1.18	1.00	.98	1.47	1.47
April.....	.73	.81	1.16	.39	1.02	.98	.87
May.....	.80	1.17	.99	1.38	.87	1.16	1.26
June.....	.90	.93	1.15	.68	1.20	.77	.66
July.....	1.00	1.57	.87	2.40	1.02	1.51	.25
August....	.70	.40	.52	.25	.70	.50	.02
September.	1.00	.50	.78	.17	.95	.53	.31
October ...	1.36	1.21	1.39	1.00	1.07	1.25	1.52
November .	1.57	1.74	.83	1.63	1.20	1.63	2.89
December .	1.18	1.17	1.26	1.06	.90	1.01	.68

Worcester—1899-1903.

January ...	1.01	1.06	1.18	1.00	.99	1.15	....
February..	1.05	1.06	1.27	.94	.92	1.14	....
March.....	.75	.84	.89	.82	.76	.86	....
April.....	.64	.66	.67	.65	.74	.82	....
May.....	.87	.81	.82	.84	.88	.85	....
June.....	.93	.91	.84	.91	.98	.88	....
July.....	.95	1.04	.95	1.10	1.17	.99	....
August....	.94	1.04	1.00	1.07	1.17	.99	....
September.	1.32	1.24	1.25	1.12	1.33	1.05	....
October ...	1.14	1.19	1.05	1.28	1.14	1.14	....
November .	1.21	1.23	1.14	1.29	1.09	1.20	....
December .	.82	.94	.96	.93	.84	.91	....

TABLE 15—Continued.

Brookton—1900-1902.

MONTH	FREE AMMONIA	ALBUMINOID AMMONIA			CHLORINE	OXYGEN CONSUMED	BAC- TERIA
		Total	Soluble	Suspended			
January ...	1.60	.99	.95	1.02	.84	.83	....
February ..	.93	.89	1.03	.80	.78	.90	....
March	.81	.67	.94	.56	.67	.84	....
April	.89	.78	.84	.75	.77	.79	....
May	.85	.93	1.00	.90	.79	.87	....
June	.80	1.00	.93	1.05	1.06	1.99	....
July	.99	1.02	1.09	.91	1.47	1.16	....
August	.96	.98	.91	1.01	1.42	1.07	....
September ..	1.30	1.38	1.18	1.53	1.43	1.27	....
October ...	1.21	1.33	1.11	1.48	1.08	1.25	....
November ..	1.21	1.17	1.13	1.17	.89	1.13	....
December .	.94	.85	.92	.81	.86	.88	....

Lawrence—Sewage at Experiment Station—1901.

January ...	1.21	1.25	1.40	1.12	.79	1.20	.62
February ..	.99	1.06	1.12	1.02	.62	1.12	8.00
March	.80	1.12	1.10	1.14	.64	1.41	.52
April	1.02	.97	1.14	.80	.89	.95	.50
May	.81	.74	.73	.75	.97	.80	.30
June	1.03	.90	1.00	.80	1.28	.93	.48
July	.79	.76	.80	.73	1.36	.80	.23
August	1.14	.91	.87	.96	1.03	.83	.09
September ..	1.06	.77	.66	.89	1.37	.80	.11
October ...	1.14	1.18	1.00	1.33	1.20	1.07	.14
November ..	1.24	1.44	1.34	1.53	1.24	1.31	.17
December .	.75	.89	.91	.89	.62	.80	.14

THE AVERAGE COMPOSITION OF BOSTON SEWAGE.

In estimating the strength of a sewage to be purified, both hourly and monthly fluctuations must be taken into account. The error due to seasonal variations is ordinarily eliminated by a series of analyses of day samples covering the entire year; and a correction for diurnal variation may be made with sufficient accuracy by applying a factor obtained from a series of hourly examinations. In the case of Boston sewage we have seen that analyses made between 10 A. M. and 1 P. M. bear to the average for the day the relation of 1.25 to 1.00. In the last line of Table 13 the corrected average of our daily analyses has been divided by the factor 1.25; and we believe that this fairly represents the general composition of the sewage passing the station at Albany

Street. In our daily analyses the months of January, February, and March are omitted and the results are so far imperfect; but since in the results for other cities, summarized in Table 15, these three months taken together do not depart far from the yearly average, we are inclined to believe this error not a very serious one.

To check this general representative analysis we have compared it in Table 16 with the straight average of the results of the six 24-hour examinations; and the agreement is seen to be close enough for any practical purposes. The representative analysis must of course be nearer the truth than the average of the daily samples of day flow or the average of six days, necessarily subject to individual variation.

TABLE 16.
BOSTON SEWAGE—AVERAGE COMPOSITION OBTAINED BY VARIOUS METHODS.

	NITROGEN AS						OXY- GEN CON- SUMED
	Albuminoid NH ₃			Free NH ₃	Ni- trites	Ni- trates	
	Total	Diss.	Susp.				
A. Average of daily analyses.	6.2	3.1	3.1	19.9	.26	.15	45
B. Average of six 24-hour runs	4.8	2.6	2.2	12.5	.09	.68	42.9
Representative analysis cor- rected by factor for diurnal variation	5.0	2.5	2.5	15.9	...	...	36

Figures for nitrites and nitrates cannot, of course, be corrected by the factor 1.25, since their diurnal distribution is quite different. It will be noted that the nitrates were more than four times as high in the 24-hour runs as in the regular day analyses, while the nitrites were much lower. This is explained by the fact that nitrates are most abundant during the night hours, when the sewage contains free oxygen. During the day, when organic matter is present in large amount, the nitrates are reduced, appearing in part as nitrites.

For purposes of comparison we have prepared Tables 17–19, showing the composition of sewages in a number of English, American, and German cities. The analyses are of differing value, some representing only a few samples, some a long series, the

data upon which they are based being stated in footnotes. In the case of Lawrence, analyses are available for a considerable series of years, and in Table 20 we have cited the figures obtained at five-year intervals in order to illustrate the increase often noticeable in the strength of sewage from year to year.

TABLE 17.
COMPOSITION OF SEWAGES—ENGLISH CITIES.
Parts per Million.

CITY	SOLIDS		NITROGEN AS				OXYGEN CON- SUMED 4 HRS. AT 80° F.	CHLO- RINE
	Total	Soluble	Free NH ₃	Organic Nitrogen (Kjel- dahl)	Alb. Ammonia			
					Total	Soluble		
Huddersfield	1061.	715.	10.7	—	6.0	—	99.0	123.
Leeds	1680.	1334.	23.6	—	11.3	—	126.0	—
Leicester	1680.	1045.	....	—	14.2	—	107.0	—
London (North).....	1353.	870.	39.0	—	4.3	—	80.0	132.
London (South) ...	1501.	1093.	34.5	—	4.3	—	67.0	267.
Manchester	1310.	940.	24.0	—	6.0	—	118.0	170.
Belfast	1848.	143.	21.3	15.3	8.9	—	90.1	679.
Sutton	1628.	804.	114.3	—	8.85	—	57.1	114.
Aylesbury	1191.	824.	68.4	—	7.8	—	57.4	123.
Blackburn	1076.	602.	28.2	—	3.4	—	35.8	81.
Exeter	544.	299.	37.7	—	2.1	—	20.2	50.
Saltley	2190.	1455.	41.6	39.1	15.6	—	134.3	125.
Rea	1886.	1340.	35.0	48.3	15.2	—	173.8	245.
Hockley	2155.	1451.	33.7	59.7	16.7	—	140.4	216.
Aston	1832.	948.	51.7	92.8	19.5	—	133.3	203.
Dublin	1523.	1190.	32.4	—	40.1	—	87.8	201.

Huddersfield.—CAMPBELL, K. F., 1900, 1902. Average of five 24-hour tests with mean analysis of sewage from Aug. 1898 to Feb. 1900. Sewers on the combined plan.

Leeds.—HARDING, 1902. Mean analyses from Nov. 1898 to June 1900. Sewers on combined plan.

Leicester.—MAWBEE, E. G., 1903. Average of analyses made from Sept. 1898 to Sept. 1899. Combined plan.

London—Northern Outfall.—DIBDIN, 1884. Average analyses for 1893. CRIMP, S., 1893. Average analyses for 1893. DIBDIN, 1893. Average analyses for 1894. CLOWES, 1902. Sept. 1898, April 1899, Nov. 1900 to Aug. 1901.

London—Southern Outfall.—DIBDIN, 1893. Average for years 1893 to 1894. CLOWES, 1902. Nov. 1899 to July 1900.

Manchester.—MANCHESTER, CITY OF, 1901. Period from May 16, 1900, to Jan. 24, 1901. Four daily samples per week, made up of hourly samples, which were mixed in equal portions.

Belfast.—LETTA, 1903. Twelve analyses, Jan. to June 1902.

Sutton.—DIBDIN, 1902. Twenty-seven analyses, Feb. 1897 to Aug. 1898.

Aylesbury.—DIBDIN, 1902.—Fifteen analyses.

Blackburn.—DIBDIN, 1902. Seventeen analyses.

Exeter.—DIBDIN, 1903. Twelve analyses.

Saltley.—REA, HOCKLEY AND ASHTON, WATSON, 1903. One analysis each.

Dublin.—CAMERON, 1903.

TABLE 18.
COMPOSITION OF SEWAGE—CONTINENTAL CITIES.
Parts per Million.

CITY	SOLIDS		NITROGEN AS						OXY.CONSUMED		CHLO- RINE
	Total	Soluble	Free NH ₃	Organic N		Alb. NH ₃		Total	Soluble		
				Total	Soluble	Total	Soluble				
(a) Halle..	3388.	2794.	89.	97.	59.					715.	
Breslau ..	1178.	773.	73.							182.	
(b) Halle..	2458.	1633.		55.	21.					209.	
(a) Berlin.		695.	60.						294.	164.	
Hamburg	1133.	922.	35.			5.06		54.	290.	312.	
Cristiania	1097.	639.	19.	31.				62.		167.	
Paris.....	630.		16.							50.	
Zürich ...	607.	480.	8.	33.	18.					22.	
(b) Berlin.	2172.	1088.	*	*						264.	
Frankfurt	2062.	898.	63.	54.	11.			126.	—	30.	

* Nitrogen as Free NH₃ + Soluble Organic N (by Kjeldahl) = 108.8.

Halle (a).—3 analyses. KÖNIG, 1887. With water closets.

Halle (b).—5 analyses. KÖNIG, 1887. No water closets.

Breslau.—Average 72 analyses. KÖNIG, 1887.

Berlin (a).—Average 14 analyses. BRUCH, 1899.

(b).—30 analyses. KÖNIG, 1898.

Hamburg.—Average of analyses from Sept. 1898 to March 1899. DUNBAR, 1899. Oxygen consumed by Kubel method.

Cristiania, Norway, 1902. Average 41 analyses during 1900-1901.

Paris.—Single analysis, 1900. STEURNAGLE, 1900; HOLST, 1902.

Zürich.—4 analyses. KÖNIG, 1887. No water closets.

Frankfort, 1891. Eight analyses. LEPSIUS, 1891.

TABLE 19.
COMPOSITION OF SEWAGES—AMERICAN CITIES.
Parts per Million.

CITY	SOLIDS		NITROGEN AS			TOTAL OXYGEN CONSUMED	CHLO- RINE
	Total	Soluble	Free Am- monia	Alb. Ammonia			
				Total	Soluble		
Brockton, Mass.....	482.	381.	2.9	5.36	3.43	80.7	83.0
Framingham, Mass.....	1031.	364.	21.9	8.46	3.17	97.9	64.2
Gardner, Mass.....	508.	240.	24.7	8.12	3.18	57.3	42.0
Leicester, Mass.....	747.	602.	29.3	6.86	3.73	21.6	56.2
Marlborough, Mass.....	520.	341.	33.3	6.68	3.19	58.8	60.7
Medfield, Mass.....	825.	696.	9.6	7.40	5.93	67.3	87.8
Natick, Mass.....	349.	297.	12.5	2.58	1.59	29.3	57.0
Spencer, Mass.....	293.	168.	13.4	3.91	1.61	32.9	30.8
Newport, R. I.....	—	—	17.2	8.14	—	59.9	164.7
Plainfield, N. J.....	530.	374.	31.7	12.8	—	58.25	49.6
Worcester, Mass.....	870.	553.	15.7	5.97	2.23	93.0	80.9
Berlin, Ont.....	—	—	20.9	16.74	—	499.5	61.0

DATA FOR TABLE 19.

Brockton, Framingham, Gardner, Leicester, Marlborough, Medfield, Natick, Spencer.—

Average of 12 monthly analyses during 1899. MASS. STATE BOARD OF HEALTH, 1900.

Newport, R. I.—Average of daily analyses from June 2 to Oct. 13, 1894.

Plainfield, N. J.—By ROLPH.

Worcester, Mass.—Average of 48 monthly averages of weekly analyses of sterilized daily samples, during 1900-1903 inclusive. The total solids are for the year 1901 only.

Eddy, 1900-1903.

Berlin, Ont.—Average of daily analyses from June 26 to Sept. 4, 1902. AMYOT, 1902.

TABLE 20.

YEARLY AVERAGE ANALYSES OF SEWAGE AT LAWRENCE, MASS.

Parts per Million.

YEAR	FREE AMMONIA	ALBUMINOID AMMONIA		OXYGEN CONSUMED (Kubel, 2 Min.)	BACTERIA PER 1 C.C.
		Total	Soluble		
1888	15.5	6.8	1.6	—	1,000,000
1893	26.8	6.3	3.1	34.5	923,000
1898	29.9	5.8	2.9	32.2	1,862,000
1902	44.9	7.2	3.1	40.6	3,377,400

Compiled from the Annual Reports of the Massachusetts State Board of Health.

Table 19 shows that in American sewages the free ammonia ranges from 3 to 30 parts and averages somewhere near 15 parts; figures for albuminoid ammonia vary from 2 to 15 parts and average near 7; oxygen consumed analyses lie between 20 and 100 parts and average about 60. Judged by these standards, Boston sewage is seen to be relatively strong in free ammonia and weak in albuminoid ammonia and oxygen consumed. The European sewages appear to be several times as strong as the American sewages in all constituents.

In Table 21 we have calculated the total amount of the various constituents in Boston sewage, multiplying the average daily analyses in Table 13 by the flow obtained from the pump records at Dorchester. We have assumed that the flow at Albany Street is 55 per cent of the total pumpage at Dorchester for the reasons previously cited, and the first column of Table 21 thus represents the estimated flow past the experiment station. The other figures are obtained by multiplying the analytical data in Table 13 by the estimated flow. The totals for the nine months are corrected by dividing by the factor 1.25; and finally the results are expressed in grams per capita per day.

TABLE 21.

BOSTON SEWAGE.

Total Amount of Various Constituents.

DATE	FLOW BILLIONS OF LITERS	THOUSANDS OF KILOGRAMS				
		Nitrogen as				Oxygen Consumed Total
		Albuminoid Ammonia			Free NH ₃	
		Total	Soluble	Suspended		
April, 1904.....	8.3	43	23	20	130	340
May, 1904.....	8.8	50	22	28	130	270
June, 1904.....	7.9	55	24	31	160	340
July, 1903.....	7.1	44	23	21	130	330
August, 1903....	6.9	49	26	23	150	310
September, 1903..	7.1	44	21	23	150	320
October, 1903....	7.9	50	26	24	160	400
November, 1903...	7.9	48	23	25	180	420
December, 1903...	8.8	58	32	26	210	440
Total, Nine Months	70.7	441	220	221	1,400	3,170
Total corrected for Diurnal Variation		352	176	176	1,120	2,536
Grams per Capita Daily		3.7	1.8	1.8	12.	27.

The values obtained are higher than those given for any other American sewage with which we are acquainted. Fuller (1903) offers as approximate average amounts of the various constituents in grams per capita daily, 15 for oxygen consumed, 7 for free ammonia, and 2.5 for albuminoid ammonia. Our figures are respectively 27, 12, and 3.7, from 55 per cent to 70 per cent higher. The analysis of Boston sewage as we have seen corresponds well with that of other American cities; its higher per capita content is due to the fact that its per capita flow is higher. The total amount of sewage pumped at Dorchester from July, 1903, to June, 1904, inclusive, was 46,000,000,000 gallons, which, with a contributing population of 477,000, makes a daily per capita flow of 264 gallons. Even using the total population of the South Metropolitan District, 669,000, we get a daily per capita flow of 188. Fuller's figures were all much lower than this,

the per capita flow at Framingham being 73, at Gardner 100, at Marlborough 113, and Worcester 115. The per capita flow appears to increase with the size of the community, as is the case with the per capita consumption of water, and it is natural that a city like Boston, with a considerable transient population, should exhibit this phenomenon to a marked degree.

It is at any rate evident that in dealing with cities of the first rank our estimates of per capita yield of polluting material must be materially modified; and we gain a new idea of the vastness of a problem which involves the treatment of 1,400,000 kilograms of nitrogen in the form of free ammonia in one only of the principal sewers of a city in a single year.

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