DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Water-Supply Paper 496

THE INDUSTRIAL UTILITY OF PUBLIC WATER SUPPLIES IN THE UNITED STATES

BY

W. D. COLLINS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1923

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY

PURCHASER AGREES NOT TO RESELL OR DISTRIBUTE THIS COPY FOR PROFIT.—PUB. RES. 57, APPROVED MAY 11, 1922

CONTENTS.

ILLUSTRATIONS.

THE INDUSTRIAL UTILITY OF PUBLIC WATER SUPPLIES IN THE UNITED STATES.

By W. D. Collins.

INTRODUCTION.

EFFECTS OF MINERAL CONSTITUENTS ON THE VALUE OF WATER.

Nearly everyone is familiar with the difficulty of using soap with "hard" water. This difficulty, which is probably the most widely known of the ill effects of dissolved mineral matter in water, is not only troublesome in the home but is still more troublesome in commercial laundries. The ill effect of the mineral constituents that produce the hardness goes even further, for it interferes with the bleaching and dyeing of fabrics and with other operations, in which the substances naturally dissolved in the water may react with the chemicals used in the processes employed.

Less widely recognized but probably of greater industrial consequence are the effects of the use of bad water in steam boilers. These effects include foaming, corrosion, and the formation of scale. Large and continuous expenditures are necessary to overcome these effects and to provide for inspections to prevent disaster from the failure of boilers that have been weakened by the use of water containing undesirable mineral constituents.

In addition to these two classes of industries there are still others that can not neglect the consideration of the mineral constituents of the water they use. The manufacture of soft drinks, bakery products, and other foods may be affected by the water used. There are limits to the quantities of dissolved material that can be permitted in the water used in the manufacture of many chemicals, of paper, and of a large number of other articles, though that fact may not be known even to many who are engaged in their manufacture. Some industries have grown up in localities where the water contained little dissolved mineral matter, so that they encountered no difficulties from these constituents, but when the processes used were tried in places where the water contained more mineral matter attention had to be given to the quality of the water.

EXTENT OF INDUSTRIAL AND DOMESTIC USE OF WATER.

Most of the industrial establishments in the United States are in cities containing more than 25,000 inhabitants. Some large plants are in smaller places, but their total output is small compared with the total output of the plants in the larger cities.

When the census of 1920 was taken, 25.9 per cent of the total population of the United States lived in 68 places of more than 100,000 inhabitants and 9.8 per cent in 219 places of 25,000 to 100,000 inhabitants, a total of 35.7 per cent in 287 places of more than 25,000 inhabitants. The rural population amounted to 48.6 per cent, and only 15.6 per cent lived in the 2,500 places having 2,500 to 25,000 inhabitants. Thus it appears that analyses of water from the public supplies of 287 places will show the chemical character of the water used by nearly 36 per cent of the population of the United States. These analyses, however, represent much more than 36 per cent of the water used in industrial processes.

ANALYSES OF WATER FROM PUBLIC SUPPLIES.

SOURCES OF ANALYSES.

The analyses in Table 6 (pp. 28–59) represent water supplied at the 287 places, each having a population of more than 25,000. Analyses are given also for 20 smaller places, in order that every State may be represented by at least two cities. Table 1 shows the sources of the analyses:

TABLE 1.—*Sources and types of analyses used in this report.*

Source.	Type.			Cities supplied.	Population supplied (thousands).
	Series of analyses.	Single complete analyses.	Single partial analyses.		
United States Geological Survey water-resources laboratory (made for this report)	1	65	5	56	9,727
Published reports of United States Geological Survey	35	12	0	53	5,294
State or municipal laboratories (board of health, State geological survey, etc.)	1	36	61	86	7,289
Waterworks laboratories	27	33	2	73	13,416
Commercial laboratories	0	44	6	39	3,031
	64	190	74	307	38,757

The largest number of individual analyses thus tabulated are those in the series of published analyses made by the United States Geological Survey. These 35 series of analyses include about 30 in each series, or 1,050 in all. Practically all the 27 series of analyses made by waterworks laboratories are analyses of monthly composite samples, 12 in a year, making 324 analyses, which, supplemented by the 33 single analyses, make 357 in all from the waterworks laboratories.

The 106 analyses made for this report include the series of 36 analyses of Washington tap water shown in Table 2, below. For these analyses a sample of definite volume was collected each day from the clear-water basin at the filtration plant, and from these samples 3 composite samples were made each month, the composite samples including 10, 10, and 10 daily samples for months with 30 days, 10, 10, and 11 for the months with 31 days, and 10, 9, and 9 for February. The analyses thus represent the average water obtained by a consumer using the same quantity each day. In order to show the real average composition of the water of the city supply the volumes of daily samples should have been proportional to the quantity of water used each day. To show the average composition of the dissolved material carried by Potomac River from which the supply is obtained, the daily samples should have been proportional to the discharge of the river.

TABLE 2.—*Mineral analyses of Washington city water supply.*

[Parts per million. Analyses by Margaret D. Foster.]

Dates of collection of sample (1921).	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$ (calculated).
Jan. 1-10	84	5.5	8.6	0.15	17	3.9	3.3		48	17	2.3	6.0	58
Jan. 11-20	83	4.0	7.5	.08	18	4.1	3.8		55	15	2.6	4.3	62
Jan. 21-31	89	3.2	9.4	.08	18	4.2	2.4	1.4	56	15	2.6	3.1	62
Feb. 1-10	88	3.3	9.5	.08	18	4.2	2.8	1.2	55	16	2.7	3.1	62
Feb. 11-19	86	3.1	9.6	.07	18	4.1	2.5	1.4	54	15	2.8	3.3	62
Feb. 20-28	85	3.1	8.2	.08	18	4.1	2.2	1.3	51	16	2.8	2.8	62
Mar. 1-10	83	3.0	7.7	.06	18	4.1	2.3	1.4	52	15	2.8	2.8	62
Mar. 11-20	77	3.0	8.1	.06	15	3.6	2.1	1.0	39	17	2.6	3.2	52
Mar. 21-31	79	3.3	6.4	.05	17	3.8	2.2	1.2	47	16	2.5	3.0	58
Apr. 1-10	84	3.2	6.7	.05	19	4.2	2.4	1.2	57	15	2.8	2.5	65
Apr. 11-20	90	3.4	5.8	.05	21	4.8	2.9	1.7	65	15	2.8	2.5	72
Apr. 21-30	96	2.2	5.2	.04	23	5.5	3.0	1.5	72	18	2.9	2.2	80
May 1-10	94	3.1	5.5	.04	22	5.0	2.4	1.9	68	18	3.1	2.5	75
May 11-20	76	3.6	7.1	.04	16	3.8	2.1	1.6	47	14	2.3	2.9	56
May 21-31	75	3.1	9.2	.09	15	3.7	2.1	1.3	43	14	2.3	3.3	53
June 1-10	87	3.4	8.6	.09	19	4.1	2.7	1.4	53	18	2.6	3.3	64
June 11-20	95	2.1	7.8	.03	21	4.9	2.4	1.3	64	16	3.0	2.9	73
June 21-30	105	2.1	4.2	.03	26	5.7	2.3	1.2	85	16	3.2	2.1	88
July 1-10	117	2.4	4.4	.02	28	6.2	2.3	.9	88	22	3.5	2.5	95
July 11-20	122	5.6	7.7	.07	27	6.3	3.4	1.4	77	27	3.3	3.1	93
July 21-31	118	7.5	5.8	.07	26	6.0	3.2	1.4	74	26	3.5	3.3	90
Aug. 1-10	120	6.0	5.0	.08	26	6.1	3.6	.9	83	21	3.2	2.5	90
Aug. 11-20	111	6.7	7.0	.08	23	5.7	3.5	1.2	69	23	3.1	2.8	81
Aug. 21-31	113	7.6	6.4	.06	24	6.2	3.5	1.0	74	21	3.3	2.5	85
Sept. 1-10	125	8.8	4.9	.06	28	7.1	3.7	1.4	93	22	4.1	1.0	99
Sept. 11-20	121	2.1	4.4	.12	28	7.5	3.8	1.0	98	20	4.3	1.4	101
Sept. 21-30	126	1.7	5.3	.12	30	7.0	3.5	1.9	98	22	4.3	1.9	104
Oct. 1-10	117	3.1	6.9	.12	27	6.3	3.4	1.7	80	24	3.8	2.9	93
Oct. 11-20	124	3.9	6.3	.12	29	6.6	3.4	1.8	92	21	4.0	3.2	100
Oct. 21-31	134	2.0	4.3	.08	32	7.5	3.9	2.0	104	24	4.5	1.9	111
Nov. 1-10	140	3.1	3.8	.10	34	8.1	3.6	2.2	110	26	5.0	1.4	118
Nov. 11-20	145	3.5	5.5	.07	34	8.1	4.3	1.6	109	28	5.5	1.9	118
Nov. 21-30	132	3.6	4.6	.06	31	6.8	3.9	1.6	95	29	5.3	1.9	105
Dec. 1-10	112	3.8	6.2	.07	25	6.0	2.9	1.8	74	24	4.2	2.3	87
Dec. 11-20	90	3.6	7.2	.08	18	4.5	2.8	.8	43	24	2.9	4.6	63
Dec. 21-31	89	3.3	7.3	.08	18	4.8	2.8	.7	51	20	2.7	4.8	65
Average	103	3.8	6.6	.07	23	5.4	3.0	1.4	70	20	3.3	2.8	80

The daily samples taken for the 35 series of analyses reported in published water-supply papers were combined for analysis in the same way as the Washington samples, except that most of the composites were made up of 10 daily samples without adjustment to form a composite at the end of each month.

The analyses made in the laboratories of State boards of health and other public laboratories, except waterworks laboratories, and the analyses made by private laboratories amount to 148, of which 67 are incomplete.

ACCURACY OF ANALYSES.

The analyses were made by well-established methods, and the results have been examined carefully for indications of possible inaccuracies. There is little doubt of the accuracy of the analyses of the samples examined, and in general the samples were as representative as any that could be obtained.

The mineral content of the water of many municipal supplies varies so much from day to day that in addition to an analysis giving average results analyses giving maximum and minimum results are necessary to show the probable range in the quantities of the several constituents.

The water supplied to some cities for which no satisfactory analyses are available is represented by the analysis or analyses of that supplied to another city that uses water of practically the same kind. The analysis of a sample from Chicago is used for a number of other cities that are supplied with water from Lake Michigan. Analyses for Cincinnati, Ohio, serve for several other cities using water from Ohio River.

The analyses of river waters made by the United States Geological Survey from 1905 to 1912 have been used for a number of cities. At practically all these cities the river water is treated with chemicals and filtered. Although the treatment changes the composition of the water slightly, the older analyses usually show the probable composition of the water well enough for all practical purposes.

Incomplete or partial analyses are given of the waters from a number of municipal supplies, most of which contain only small quantities of dissolved mineral matter. The exact composition of the dissolved solids in these waters is of comparatively little importance. In nearly all of them the constituents are present in practically the same proportions as in the water of some neighboring supply that contains about the same total quantity of dissolved solids.

EXPRESSION OF RESULTS.

In accordance with the long established practice of the United States Geological Survey the analyses are given in parts per million of the radicles determined. In a number of the analyses the quantities of some of the constituents have been calculated, and in all the analyses in which calcium and magnesium are given the hardness is calculated. In all the others the hardness reported was determined. The complete analyses include determinations of total dissolved solids, loss on ignition, silica, iron, calcium, magnesium, sodium and potassium together, bicarbonate, sulphate, chloride, nitrate, and total hardness (calculated). Each of these determinations is discussed in succeeding paragraphs with reference to its reliability and its significance.

TOTAL DISSOLVED SOLIDS.

The results given under "Total solids" show approximately the total quantity of mineral matter in each water analyzed. The quantity of total solids is determined by weighing the residue obtained by evaporating a given quantity of water. The weight of this residue after it has been heated one hour at 180° C. is very nearly that of dissolved material. In many laboratories it is customary to heat the residue to only 103° or 105° before weighing, but the weight is then too high. The determinations of total solids were not reported for some analyses, but if enough other determinations were reported the quantity of total solids was taken as the sum of the constituents, the bicarbonate being calculated as carbonate. If silica was not determined it was assumed to be 10 or 20 parts per million, according to the quantity of total solids.

LOSS ON IGNITION.

In analyses of water made to show its sanitary condition the loss on ignition is sometimes supposed to represent the amount of organic matter in the water, and the residue after ignition, the "fixed residue," to be the mineral matter in the water. As indicated above, however, the residue at 103° or 105° represents much more than the dissolved mineral matter. Sometimes its weight includes that of considerable water. The so-called "fixed residue" is frequently less than the total dissolved mineral matter. Most residues from the evaporation of water do not lose much weight when ignited gently after they have been heated for one hour at 180°.

The loss on ignition reported in the tables indicates the relation of the quantity of total solids to the quantity of mineral matter in solution in the water, a quantity that is practically always between that of the determined total solids and that of the residue after ignition. In most of the analyses in which the loss on ignition is not given it is probably not over 10 per cent of the total solids.

MINERAL CONSTITUENTS DETERMINED.

Silica.—Silica is dissolved from practically all rocks. Its state in natural water is not definitely known, but in reports of analyses it is assumed to be in the colloidal state, taking no part in the equilibrium between the acids and the bases.

A survey of the analyses in this report shows that few of the waters examined contained over 30 parts per million of silica. Several samples of river water analyzed by the United States Geological Survey contained more silica, but although these samples were filtered through asbestos or paper before analysis some of them contained fine suspended clay that could not be removed by such filtration. Coagulation with aluminum sulphate makes possible the removal of this fine silt by sedimentation and filtration, so that the effluents of filter plants contain less silica than untreated waters filtered through paper, and in considering the Geological Survey's analyses of river waters used for a city supply that is filtered after the use of a coagulant it must be borne in mind that the quantity of silica is reduced by the filtration. The silica in most filtered waters is not so high as 10 parts per million, and in some it is less than 5.

As an insoluble constituent the silica in water contributes to the formation of boiler scale, and it sometimes helps to cement the other materials into a hard scale. Its presence or absence is said to have an effect on some of the exchange-silicate water-softening materials. On the whole, however, silica is of comparatively little importance in the waters of public supplies.

Iron (iron and aluminum oxides).—Iron is dissolved from practically all rocks and is frequently dissolved from iron pipes in sufficient quantity to be objectionable.

Iron is reported in all the analyses made by the United States Geological Survey and in most of the others. The figures given as iron in some analyses represent, as is shown by a footnote, the quantity of iron and aluminum oxides. They do not show the minimum limit of the iron, but they do show its maximum limit, for the iron can not be more than 0.7 times the oxides.

Few surface waters contain in solution as much as 1 part per million of iron. In most of them the quantity is nearer 0.1 part. Many ground waters contain several parts per million of iron, which must be removed in order to make the waters satisfactory for domestic and industrial use. Only a few of the large cities here considered are supplied from sources that furnish such water, but the use of such sources is not uncommon in the smaller cities. Water that contains much iron is objectionable on account of its appearance after exposure to the air and on account of the unsightly stains it makes on white porcelain or enameled ware or fixtures and on clothing or other fabrics washed in it. Smaller quantities of iron are said to cause trouble in the use of certain dyes. Excessive iron may interfere with the efficient operation of exchange-silicate water softeners.

Iron is almost completely removed by filtration as practiced at water-purification plants, but the treatment sometimes leaves the water in such condition that it can and does dissolve iron from pipes, particularly hot-water pipes. (See p. 21.) Some natural waters also have this property.

Aluminum is found only in negligible quantities in natural waters used for large public supplies. Under certain conditions of operation aluminum may pass through filters but in quantities too small to affect seriously the industrial use of the water.

Calcium and magnesium.—Though calcium and magnesium have somewhat different properties their effects upon the industrial uses of water are so much alike that they can not well be treated separately. They cause hardness in water (see p. 9) and together with the acid radicles in equilibrium with them make up from 60 to 90 per cent of the mineral matter of hard waters. Calcium and magnesium are also the predominating basic radicles in most soft waters.

The general industrial value of waters used for public supplies is more affected by calcium and magnesium than by any other constituents. Their main effects are discussed under "Hardness" (p. 9) and under "Industrial treatment of water" (p. 25).

The results of determinations of calcium and magnesium in the waters of some public supplies are not available, but it is safe to assume that the quantities of these constituents in nearly all of them are about the same as in water that contains similar total dissolved solids or that is of similar hardness. The differences in the total dissolved solids of the waters here considered correspond closely to the differences in calcium and magnesium and the bicarbonate that holds them in solution.

Sodium and potassium.—The sodium and potassium in the water of most public supplies have little effect on the industrial use of the water. Natural waters that contain only 3 or 4 parts per million of the two together are likely to contain about equal quantities of sodium and potassium. As the total quantity of these constituents increases, the proportion of potassium becomes less: waters carrying from 30 to 50 parts per million of the two may contain from 4 to 10 times as much sodium as potassium; waters carrying more sodium may contain smaller proportions of potassium.

In most of the analyses given in this report the sodium and potassium were not separated. The potassium was determined in nearly all the analyses that were made especially for the report and in a few that were obtained from other laboratories. Generally the mixed chlorides of sodium and potassium were weighed together, and the sodium equivalent to the weight of mixed chloride was reported as sodium and potassium. This procedure introduces a slight error, due to the difference between the atomic weights of sodium and potassium, but the error is not much greater than the other possible errors in the analysis.

A calculated quantity of sodium and potassium is given in some analyses—the quantity of sodium that is needed, in addition to the calcium and magnesium, to balance the acid radicles bicarbonate, sulphate, chloride, and nitrate. The quantity thus obtained is affected by any errors in the determination of the individual constituents. The calculation sometimes leads to a negative quantity for sodium, especially if no nitrate is given. In a few such analyses the sodium and potassium have been reported as "less than 10."

Bicarbonate.—The usual methods of analysis lead to the conclusion that the carbon dioxide in most natural waters is present as bicarbonate (HCO_3) and free carbon dioxide (CO_2). A few natural waters contain little carbon dioxide and therefore show carbonate radicle (CO_3), which may be found also in water raised by an air lift that tends to sweep the carbon dioxide out of it. Many waters that have been treated with lime contain carbonate or even hydroxide. Some analyses show the composition of the residue on evaporation and therefore give carbonate instead of bicarbonate. In some partial analyses alkalinity is reported in terms of calcium carbonate ($CaCO_3$).

For uniformity and simplicity all results of determinations of alkalinity, whether expressed in terms of bicarbonate (HCO_3), carbonate (CO_3), or as equivalent calcium carbonate ($CaCO_3$), are given in this report as bicarbonate (HCO_3). If the carbonate in a treated water was over 10 parts per million, the quantity is indicated in a footnote. The small quantities of carbonate found in some samples may be due to the action of the sample on the bottles.[1]

Bicarbonate is the chief acid radicle in nearly all the waters used for public supplies. Its relation to the hardness and softening of waters is discussed on pages 25 and 26.

Sulphate.—Sulphate is not a very important constituent of the water of most public supplies. The quantity present affects the softening of the water (see pp. 25–27) and is affected by treatment with coagulants. An analysis of a river water before filtration will therefore show a smaller quantity of sulphate than that in the filtered water. A part of the sulphate in the water of some sources of supply is contributed to it by human activities. Many supplies in Pennsylvania receive sulphuric acid from the drainage of mines,

[1] Collins, W. D., and Riffenburg, H. B., Contamination of water samples with material dissolved from glass containers: Ind. and Eng. Chemistry, vol. 15, pp. 48–49, 1923.

even enough to make the waters acid, and some waters that are used for public supplies are contaminated by sulphuric acid or sulphates discharged from industrial establishments.

Chloride.—The water of only a few public supplies contains enough chloride to have any effect on its use for most industrial processes. The addition of chlorine or hypochlorite has no practical effect on the quantity of chloride radicle in a water. The chloride contributed by most rocks to a natural water rarely amounts to as much as 10 parts per million. Larger quantities are usually the result of contamination with water from deep wells or from deposits of common salt. Some industrial plants discharge chlorides, and a considerable quantity is added to many rivers by sewage from large cities.

Nitrate.—The effect of nitrate on the industrial use of water obtained from public supplies is so nearly negligible that results of determinations of nitrate could be omitted from the tables without great loss. A few waters contain enough nitrate to affect the calculated quantity of sodium or to increase the apparent error in an analysis in which sodium is determined and nitrate is not reported.

HARDNESS.

Hardness in water is produced by calcium and magnesium. Other elements, such as iron, aluminum, strontium, or barium, would cause hardness, but these are not found in the water of public supplies in quantities large enough to have any appreciable effect.

Hardness may be recognized by the increased quantity of soap required to produce lather and by the deposits of insoluble salts formed when a hard water is heated or evaporated. Hardness may be determined by the use of a standard solution of soap. Practically all the "determined" results for hardness given in this report were so obtained. Although this method is not wholly reliable for some kinds of water, it should give accurate results with waters like most of those for which analyses are given.

Hardness can in general be determined more reliably by calculation than by the use of a soap solution. Most of the "calculated" results given in this report were obtained by calculations from the calcium and magnesium. The hardness as equivalent calcium carbonate ($CaCO_3$) is 2.5 times the calcium plus 4.1 times the magnesium.

Hardness is by far the most important property of a water with reference to its general industrial utility. The effects of the different forms of hardness are discussed in connection with the subject of water softening (p. 25).

DISTRIBUTION OF HARD WATER.

The distribution of hard water in the large public supplies in the United States is shown in Tables 3 and 4 and in Plate I and Figure 1.

TABLE 3.—*Number of persons, in thousands, using water of different degrees of hardness from large public supplies in the United States.*

Hardness in parts per million.	Surface water.	Ground water.	Total.	Hardness in parts per million.	Surface water.	Ground water.	Total.
1-10	2,454	31	2,485	251-300	862	397	1,259
11-20	4,339	131	4,470	301-350	71	645	716
21-30	1,214	159	1,373	351-400	....	314	314
31-40	1,632	68	1,700	401-450	....	209	209
41-50	6,242	374	6,616	451-500	....	....	....
51-60	1,073	....	1,073	501-550	92	72	164
61-80	2,009	66	2,075	551-600	....	40	40
81-100	2,974	260	3,234	601-650	....	28	28
101-120	2,773	88	2,861	651-700	....	....	....
121-140	5,453	208	5,661	701-750	....	....	....
141-160	606	28	634	751-800	....	15	15
161-180	1,136	127	1,263	801-850	....	29	29
181-200	743	242	985				
201-250	1,221	332	1,553		34,894	3,863	38,757

Table 3 shows the population in thousands using water of different degrees of hardness in steps of 10, 20, and 50 parts per million. The population of a large city that is supplied from two sources with waters that differ appreciably in hardness has been divided according to the quantities of water supplied from the two sources. Figures are given separately for surface waters and for ground waters. If the supplies of smaller cities were included the proportion of users of ground water would be larger. Nearly all private supplies are obtained from wells, so that the relative use of surface and ground water by the whole population of the country is in no way represented by the data for the larger cities.

TABLE 4.—*Average hardness of water from large public supplies in each State.*

State.	Surface supplies.			Ground supplies.			All supplies.		
	Average hardness as $CaCO_3$ in parts per million.	Population served.		Average hardness as $CaCO_3$ in parts per million.	Population served.		Average hardness as $CaCO_3$ in parts per million.	Population served.	
		Thousands.	Percentage of total population of State.		Thousands.	Percentage of total population of State.		Thousands.	Percentage of total population of State.
Alabama	59	240	10	20	43	2	53	283	12
Arizona	......	......	......	221	49	15	221	49	15
Arkansas	149	94	5	......	......	......	149	94	5
California	156	1,659	49	243	141	4	172	1,800	52
Colorado	144	330	35	......	......	......	144	330	35
Connecticut	25	826	60	......	......	......	25	826	60
Delaware	49	110	49	115	4	2	51	114	51
District of Columbia	80	438	100	......	......	......	80	438	100
Florida	......	......	......	296	204	21	296	204	21
Georgia	14	338	12	82	83	3	27	421	15
Idaho	......	......	......	91	36	8	91	36	8
Illinois:									
Supplied from Lake Michigan	131	2,824	44	......	......	......	131	2,824	44
Not supplied from Lake Michigan	184	279	4	350	332	5	274	611	9
Whole State	136	3,103	48	350	332	5	156	3,435	53
Indiana	244	659	23	330	214	7	264	873	30
Iowa	181	139	6	357	273	11	298	412	17
Kansas	255	151	9	543	72	4	316	223	13

TABLE 4.—*Average hardness of water from large public supplies in each State*—Continued.

State.	Surface supplies.			Ground supplies.			All supplies.		
	Average hardness as $CaCO_3$ in parts per million.	Population served.		Average hardness as $CaCO_3$ in parts per million.	Population served.		Average hardness as $CaCO_3$ in parts per million.	Population served.	
		Thousands.	Percentage of total population of State.		Thousands.	Percentage of total population of State.		Thousands.	Percentage of total population of State.
Kentucky	90	387	16				90	387	16
Louisiana	54	431	24				54	431	24
Maine	18	127	17				18	127	17
Maryland	53	792	55				53	792	55
Massachusetts	13	2,440	63	29	228	6	14	2,668	69
Michigan	114	1,497	41	267	225	6	134	1,722	47
Minnesota	158	714	30				158	714	30
Mississippi	14	46	3				14	46	3
Missouri	147	1,205	36	195	40	1	148	1,245	37
Montana	91	66	12				91	66	12
Nebraska	244	192	15	221	55	4	239	247	19
Nevada	36	12	16	185	4	5	74	16	21
New Hampshire	6	78	18	20	29	6	9.7	107	24
New Jersey	46	1,747	55	65	236	8	48	1,983	63
New Mexico	20	7	2	177	15	4	126	22	6
New York	46	7,448	72	120	128	1	47	7,576	73
North Carolina	22	157	6				22	157	6
North Dakota	141	36	6				141	36	6
Ohio	125	2,341	41	341	426	7	153	2,767	48
Oklahoma	400	194	10				400	194	10
Oregon	9	258	33	19	18	2	9.6	276	35
Pennsylvania	67	3,483	40	188	73	1	69	3,556	41
Rhode Island	12	475	79				12	475	79
South Carolina	31	105	6				31	105	6
South Dakota				503	40	6	503	40	6
Tennessee	64	254	11	46	162	7	57	416	18
Texas	100	385	8	166	456	10	136	841	18
Utah	172	118	26	109	33	8	158	151	34
Vermont	39	38	11				39	38	11
Virginia	45	489	21				45	489	21
Washington	22	466	34	125	104	8	41	570	42
West Virginia	76	174	12				76	174	12
Wisconsin	132	620	24	205	140	5	145	760	29
Wyoming	119	25	13				119	25	13
United States	85	34,894	33	225	3,863	4	99	38,757	37

Table 4 shows the average hardness of the water of the large supplies in each State—the surface, ground, and total supplies. To calculate an average for a State the hardness of each supply in the State is multiplied by the number of persons using it, and the sum of these products is divided by the sum of the numbers of persons.

The percentages of the total population of the States that use the supplies for which data are given range from 3 for Mississippi to 79 for Rhode Island. These percentages must be considered in attempting to estimate from the data in Table 4 the average hardness of the water used by the whole population of a State. In general, however, the results for the individual States are fairly representative.

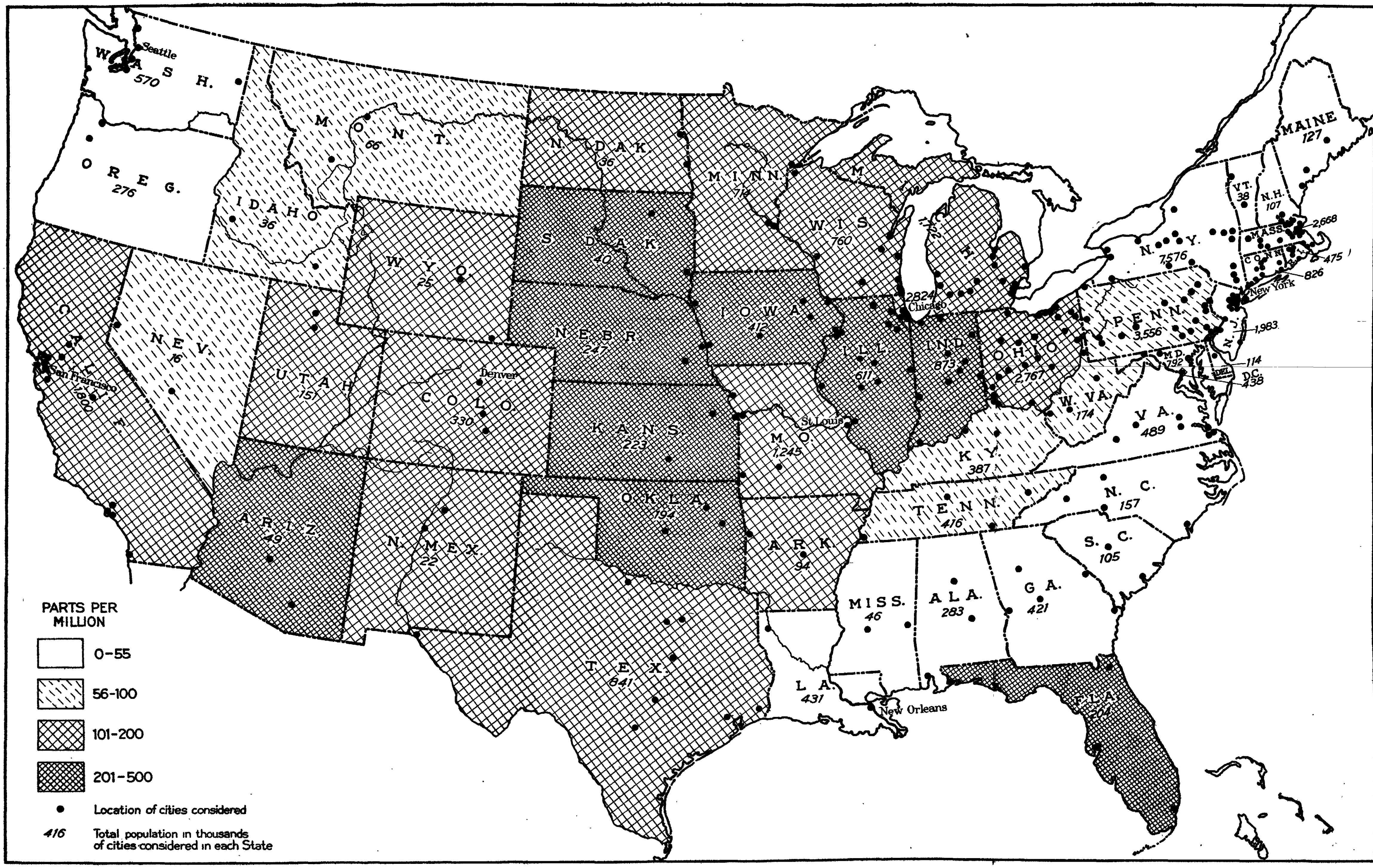
The figures in Table 4 are shown graphically in Plate I. Each city considered in the report is represented on the map by a dot. The number shown in each State is the total population, in thousands, of the cities in the State for which data were obtained. The shading indicates the average hardness of the water used by the population shown on the map—the population of the cities considered. The States are divided into four groups, representing four degrees of hardness.

The public water supplies of the large cities in the States in the first group—those that are unshaded on the map (hardness 0–55)—are generally considered soft. In ordinary household use the hardness of the waters of this group is rarely noticed. The removal of the hardness from the harder waters in the group is profitable only in laundries, in boiler plants operating at high capacity, and in a few other industrial plants.

The States in the second group, shown by the lightest shading on the map, include those for which the average hardness of the water of the municipal supplies is from 56 to 100 parts per million. Those who have really soft water will notice the slight hardness of these waters, but in ordinary use it causes no great difficulty. In softening the water of municipal supplies it is generally considered sufficient to reduce the hardness to 100 parts per million. The softening of the waters in this group is profitable for nearly all laundries, and softening or treatment within boilers is necessary to obtain the best results in steam plants. The waters in this group may be called "slightly hard."

The waters of the States of the third group, shown by the medium shading, include those for which the average hardness is from 101 to 200 parts per million. The hardness of these waters is noticed by anyone, and its reduction is frequently worth while to make them suitable for domestic use as well as for use in industrial plants. Softening is profitable or necessary for any industrial use in which hardness is detrimental. Some of the States in this group contain large cities that obtain supplies from lakes or streams bordering the States and therefore have softer water than that furnished by supplies obtained from streams or wells within the State. If they did not, they would be placed in the group of States whose waters have a hardness above 200 parts per million. Municipal softening in some large cities helps to bring some States into the third group. The waters in this group would be called "moderately hard" to "hard."

The States in the fourth group, shown by the darkest shading, include those in which the average hardness of the water of the large public supplies is from 200 to 500 parts per million. Such waters are truly hard, and some of them are excessively hard. Their hardness can not be ignored in any use of the water that is affected by hardness. In areas where domestic supplies have hardness of more than 200 parts per million many who live outside of the large cities have built cisterns to store rain water for laundry use. Municipal softening is worth considering wherever the hardness is much over this limit.



AVERAGE HARDNESS, BY STATES, OF WATER FURNISHED BY PUBLIC SUPPLY SYSTEMS IN OVER 300 CITIES IN THE UNITED STATES AND POPULATION, BY STATES, OF THE CITIES CONSIDERED.

In some cities in the States of this group the water of the municipal supplies is not excessively hard; in some areas individual supplies of soft water can be obtained; but in general throughout these States the water is hard.

Of course geologic divisions do not lie along State lines, so that Plate I gives only a rough indication of the character of the private water supplies in the United States. Furthermore, the averages calculated as explained on page 11 do not invariably give a fair picture of the conditions throughout a State. This fact is so conspicuously evident in Illinois that a small area close to Lake Michigan has been cut off from the rest of the State and treated as a separate division. Table 4 shows that the inclusion of the cities supplied by Lake Michigan makes the average hardness for Illinois 156 parts per million, whereas the hardness for 611,000 inhabitants of 12 cities in the State that do not use the water of Lake Michigan is 274 parts per million.

From the locations of the cities plotted on Plate I and the numbers showing the population in each State using the waters for which data are given it can be seen that most of the large municipal supply systems furnish soft or slightly hard waters. This fact is not obvious from a glance at the map, because the population is more concentrated in some small States where the supplies are soft.

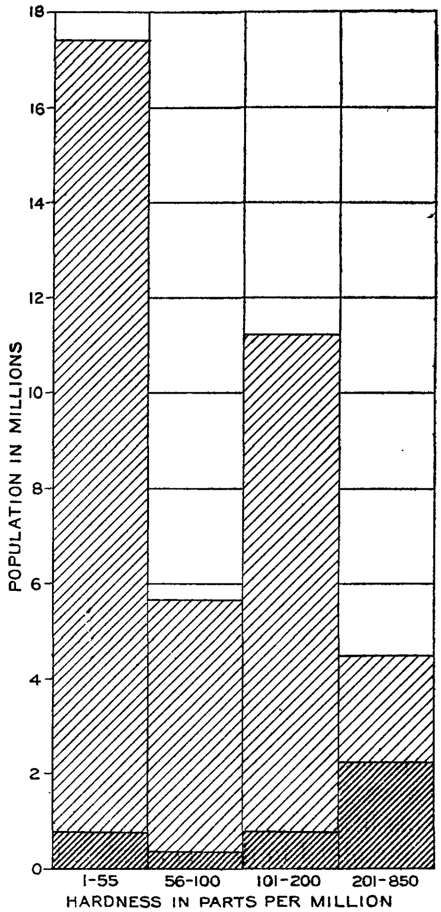


FIGURE 1.—Number of persons using water of certain degrees of hardness from large public supply systems in over 300 cities in the United States. Heavy shading indicates ground water; light shading, surface water.

Range of hardness (parts per million).	Population (thousands).		
	Surface.	Ground.	Total.
1-55	16,643	764	17,407
56-100	5,294	326	5,620
101-200	10,711	692	11,403
200+	2,246	2,081	4,327
	34,894	3,863	38,757

Figure 1 shows the number of persons using water of hardness within each set of the limits indicated on Plate I. It is made from the data presented in Table 3, but it gives a division at a hardness of 55 parts per million instead of at 60; the other divisions are made at hardnesses of 100 and 200 parts per million.

Figure 1 and Table 3 would seem to indicate that a large number of those who use the water of public supplies are not troubled by its hardness, but the figures in Table 4, giving the percentage of the population served by the supplies on which the statistics given in this report are based, show that a larger part of the population is represented for States where the average hardness as here computed is low than for States where it is high. The total number of persons in the United States that use hard water is therefore greater than that indicated by Figure 1 and Table 3.

SOURCES OF PUBLIC SUPPLIES.

SOLUTION OF ROCK MATERIALS.

Water is constantly passing through a cycle of evaporation and precipitation. Water that is precipitated as dew is nearly all soon evaporated again. A certain amount of the water that falls as rain or snow evaporates almost at once, but most of it runs quickly into streams or lakes or soaks into the ground. In passing over or through the soil the water dissolves the rock materials. Obviously water that runs quickly over the surface into a stream or lake will dissolve less material than water that seeps slowly through the ground. Thus the surface water in a given area usually contains less dissolved mineral matter than the ground water. The quantity of mineral matter dissolved depends also on the character of the rock materials in the soil. Granite is comparatively insoluble, and the water in areas where granitic rocks predominate therefore contains little dissolved mineral matter. Part of the rock material can be dissolved in distilled water, but the quantities of most rocks that could be dissolved by the action of water alone would be comparatively small.

In its passage through the air rain water takes up a certain amount of carbon dioxide gas, and in its passage through the ground it takes up much more. The gas it thus absorbs, which is formed in the decomposition of organic matter, enables the water to dissolve much larger quantities of the carbonates of calcium and magnesium that make up the greater part of the sedimentary rocks in large areas in the valleys of Mississippi and Ohio rivers.

Soluble salts were deposited with some of the sedimentary rocks, particularly sandstones, and water passing through such rocks will dissolve rather large quantities of these salts.

SOFT, HARD, AND ALKALI WATERS.

The waters used for public supplies in the United States may be divided roughly into three classes—soft waters, hard waters, and alkali waters—which merge into one another.

The soft waters come from igneous rocks and are nearly all surface waters. They contain so little dissolved mineral matter that for practically all uses they are equal to rain water or distilled water. The small quantities of dissolved mineral matter they contain are about equally divided between silica, alkaline earth salts, and alkali salts, with the quantity of silica frequently the largest. The predominating acid is bicarbonate, and there are nearly equal quantities of sulphate and chloride.

The hard waters have dissolved most of their mineral matter from limestone. Typical waters of this class contain from 200 to 400 parts per million of dissolved solids, of which practically all is calcium or magnesium and bicarbonate. The quantity of silica and of the alkalies may be no greater than in the soft waters. The quantity of chloride is not large, and that of sulphate is rather small unless the water contains dissolved gypsum or drainage from mines.

Comparatively few waters of the alkali type are used for public supplies. These waters contain large quantities of alkali salts, generally sodium sulphate or chloride. The quantity of silica may be insignificant. Some alkali waters contain large quantities of calcium and magnesium; others contain practically none. In some parts of the United States, as along the south Atlantic and east Gulf coasts, well waters contain little dissolved mineral matter except sodium bicarbonate. The quantities are not usually so large as the quantities of sodium sulphate and chloride in the alkali waters of the arid and semiarid regions. The waters in a few places contain considerable quantities of sodium bicarbonate, together with calcium and magnesium bicarbonates.

It is obvious that soft waters make the best supplies and that strong alkali waters make the worst. For drinking and for some other uses hardness is no disadvantage, but for general industrial use the value of a water depends largely on its hardness.

NATURAL SURFACE WATER.

The first large public water supplies were nearly all obtained from surface sources, and at the present time 50 per cent of the population of the larger cities use unfiltered surface waters. The number of consumers using each of several types of supply is shown in Table 5.

TABLE 5.—*Source and treatment of the public water supplies of the larger cities in the United States.*

Source and treatment.	Cities.	Population (thousands).
Surface water used without treatment other than chlorination	107	19,705
Surface water treated with a coagulant and not filtered	5	414
Surface water filtered without coagulation	9	3,620
Surface water treated with a coagulant and filtered	113	11,155
Total surface supplies	234	34,894
Infiltration galleries and wells less than 100 feet deep	28	1,466
Wells 100 feet or more deep	45	2,397
Total ground supplies	73	3,863
Total supplies	307	38,757

Some of the waters of the untreated surface supplies are almost ideal for industrial use. They are impounded in lakes or reservoirs that receive waters which have passed over comparatively insoluble rocks and which therefore contain very little dissolved mineral matter. Some of these waters are quite free from color and turbidity.

Not all the untreated surface waters are wholly satisfactory for industrial use. Some have too much color, which is extracted from decaying leaves and other organic matter. Others are so free from mineral matter and contain so much free carbon dioxide and possibly organic acids that they corrode iron pipes. The solution of lead pipes by some very soft waters, though it does not affect industrial use, has required the attention of waterworks officials.

The greater number of the waters supplied from lakes and reservoirs are not so free from color and turbidity as the waters supplied from well-operated filter plants, and as the standards for the appearance of the water supplied are gradually raised the tendency is toward the more general adoption of filtration for better appearance as well as for greater safety. Very few large supplies from rivers are unfiltered.

TREATED SURFACE WATER.

In 1922 about 39 per cent of the inhabitants of large cities in the United States used treated water, and the percentage will increase even if supplies for a few more cities are taken from distant mountain streams that require no purification. Filtration is contemplated for several large supplies, and the population of the cities that now use filtered surface water is increasing rapidly.

GROUND WATER.

Ground water probably furnishes the domestic supply for more than half the population of the United States. Well water is used by most of the 48.6 per cent of the population that live in rural districts and by a large proportion of the 15.6 per cent that live in cities of 2,500 to 25,000 inhabitants.

Only 10 per cent of the total population of cities having a population of more than 25,000 are supplied with ground water—4 per cent from infiltration galleries or wells less than 100 feet deep, and 6 per cent from wells 100 to 2,000 feet deep.

The largest city supplied from wells is Memphis, Tenn., which has a population of 162,351. Only seven other cities that have a population of more than 100,000 have ground-water supplies.

The limited quantity of ground water available at most places prevents the more general use of wells for public supplies. Heavy pumping increases the depth from which the water must be raised. This lowering of the water in wells adds to the cost of pumping and increases the chance of pollution. Along the seacoast heavy pumping has in some places caused contamination with sea water. Examples of such contamination are given in a report on the ground water of Long Island.[2] A report by Brown[3] gives a review of the literature on the subject and adds new data, particularly for wells in Connecticut.

Water obtained from deep wells is generally free from pollution and is in that respect superior to the water of most surface supplies. Reports of State boards of health and other organizations that have investigated private shallow wells with reference to their sanitary condition state that the greater number of them show evidence of pollution. Public supplies from shallow wells or infiltration galleries are usually properly protected.

Ground waters are generally clearer and cooler than surface waters and are therefore decidedly preferable for some industrial uses. Ground water generally contains more iron than surface water, sometimes so much as to make it necessary to install a plant for the removal of iron.

The average hardness of the ground water used for the supplies of large cities is given in Table 4 as 225 parts per million, against an average hardness of 85 parts per million for the surface water. The comparison thus made, however, is not wholly accurate. The ground waters in regions where large supplies of soft surface water are found are soft, and the surface waters in regions where supplies of hard ground water are found are hard. It is nevertheless true that in nearly every region where all the water is hard the ground water is much harder than the surface water.

The waters of many of the public supplies for which analyses are given in Table 6 are obtained from streams whose waters contain

---

[2] Veatch, A. C., Slichter, C. S., Bowman, Isaiah, Crosby, W. O., and Horton, R. E., Underground water resources of Long Island, N. Y.: U. S. Geol. Survey Prof. Paper 44, 1906.

[3] Brown, J. S., A study of coastal ground waters, with special reference to Connecticut: U. S. Geol. Survey Water-Supply Paper — (in preparation).

much less dissolved mineral matter than the best well waters in or near the cities. The water of some of these public supplies is so much better than the ground water that no industrial plant can afford to use a private supply from wells for any use for which hard water is unsuitable.

TREATMENT OF WATER FOR PUBLIC SUPPLIES.

SANITARY CONSIDERATIONS.

Although sanitary considerations may seem to have no direct bearing on the industrial utility of public water supplies, they usually govern the selection of the source of a supply and the treatment of the water. In a discussion of public water supplies, therefore, it is not possible to omit all consideration of sanitary questions, but their discussion in this paper is confined to points that affect the industrial use of the waters.

It is generally agreed that the water of a public supply should at all times be safe to drink. Practically the only thing that makes the water of any public supply unsafe is pollution with organisms that may cause disease, mainly intestinal diseases and especially typhoid fever. Well waters may be kept free from possible pollution, but water flowing in underground channels is subject to pollution and surface water is obviously open to pollution by men and animals.

The range of probability of pollution of the water of surface supplies is great. Some reservoirs impound mountain streams and springs that are almost inaccessible and that are thus safe from contamination. Practically the whole drainage area of some supplies is owned by the company or municipality that operates the waterworks. Other drainage areas are carefully patrolled and are protected by strict regulations to prevent accidental contamination of the water. From these extremes the probability of pollution increases by stages until sources of supply are encountered that are so polluted that it becomes a question whether the pollution is not approaching a limit beyond which no reasonable method of purification can be relied upon to produce a safe water.[4]

Over against these possibilities of pollution must be set a certain amount of natural purification. The number of bacteria is reduced by the long storage permissible for some supplies, and this storage also may improve the water for industrial use by reducing its color and turbidity.

[4] Streeter, H. W., The loading of filter plants: Am. Waterworks Assoc. Jour., vol. 9, pp. 157-171, 1922.

CHLORINATION.

The treatment of water with sterilizing agents[5] is of comparatively recent development. The use of chloride of lime by Johnson at the filter plant of the Chicago stockyards in the fall of 1908 and the equally successful treatment of the Boonton supply of Jersey City, N. J., in 1909 led to the adoption of this treatment at a large number of other plants. Although chloride of lime is still used at some plants and chloramine and ultra-violet rays have been used to a certain extent, the total use of other sterilizing agents is almost negligible compared with the use of liquid chlorine.

The uncombined chlorine in a chlorinated water probably has no harmful effect in the industrial use of the water. If, however, the water to which the chlorine is added is contaminated with phenolic compounds from the waste liquors of coke ovens or gas works, compounds may be formed that have decidedly objectionable taste or odor, although the water before chlorination may have had no noticeable taste or odor. Contamination of this kind may make a water unfit for the preparation of food products.

The use of chlorine is so common that no mention is made of it in the descriptions of water supplies given in Table 6. A small quantity of chlorine is added to the water at nearly every filtration plant and to all but a very few of the supplies that are not filtered.

SEDIMENTATION.

As already noted, sedimentation improves the quality of waters for industrial use. Waters that are suitable for use with no other treatment than sedimentation generally would not be very bad without it. For most waters sedimentation is merely preliminary to filtration and serves to decrease the work required of the filters.

COAGULATION AND SEDIMENTATION.

A few turbid waters carry suspended material that is coarse enough to settle to the bottom as sediment in a short time, leaving the waters fairly clear. Other waters, and these include a large proportion of the river waters used as sources of public supplies, carry considerable quantities of suspended material so fine that it will not settle in weeks. Such waters may be treated with chemicals to coagulate the finely divided material. At a few plants the water is distributed after coagulation and sedimentation, but at most of them these steps are merely preliminary to filtration.

The chemical generally used for coagulation is aluminum sulphate, which in most natural waters forms a flocculent gelatinous precipitate that carries down a considerable proportion of the bacteria in

[5] Race, Joseph, Chlorination of water, John Wiley & Sons, 1918.

the water together with much of the finely divided clay and other suspended material.

The quantity of aluminum sulphate used to treat turbid waters was at first determined largely by the degree of their turbidity, and frequently excessive quantities were used. The quantity now generally used is 1 to 2 grains per gallon, or 17 to 34 parts per million. The addition of 20 parts per million of aluminum sulphate of the grade commonly used will decrease the bicarbonate of the water by 12 parts per million and increase the sulphate by 8 parts. Such a change is of little importance in waters that contain several hundred parts per million of dissolved solids but is not negligible in waters that contain less than 100 parts per million.

If the alkalinity of a water is low, only a limited quantity of aluminum can be precipitated as hydroxide. More aluminum added as sulphate will not be precipitated, although it may assist the coagulation of the suspended clay in the water. In order to prevent the occurrence of residual aluminum in the filtered water the additions of aluminum sulphate at many filtration plants were regulated according to the alkalinity of the water as determined by titration with acid. When the alkalinity was not high enough to cause precipitation of all the aluminum that was needed for clarification lime was also added.

It has long been known that good coagulation is not assured by adjustment of the addition of aluminum sulphate and lime according to titrations of total alkalinity, although the results are better than those obtained by the addition of aluminum sulphate according to turbidity. It is now rather generally recognized that flocculation depends in large measure on the intensity of the acidity of the water, which is generally expressed as the hydrogen-ion concentration. During the last few years [6] the relations of hydrogen-ion concentration to coagulation and sedimentation have received considerable attention, and they are now being investigated at a number of plants. It appears that the best results from the use of aluminum sulphate will be obtained by regulating the quantities of aluminum sulphate and lime according to the alkalinity and turbidity of the water so as to keep the resulting hydrogen-ion concentration within fairly narrow limits. These limits may vary with the quantity of mineral matter dissolved in the water and the turbidity and temperature of the water.

---

[6] Wolman, Abel, and Hannan, Frank, Residual aluminum compounds in filter effluents: Chem. and Met. Eng., vol. 24, No. 17, pp. 728–735, 1921. Wolman, Abel, and Hannan, Frank, Further observations on pH in natural waters: Chem. and Met. Eng., vol. 25, No. 11, pp. 502–506, 1921. Massink, A., and Heymann, J. A., Significance of hydrogen-ion concentration in drinking water and particularly for the business of water supply: Am. Waterworks Assoc. Jour., vol. 8, No. 3, pp. 239–269, 1921. Hannan, Frank, Hydrogen-ion concentration and water-supply problems: Am. Waterworks Assoc. Jour., vol. 9, No. 1, pp. 39–44, 1922. Wagner, A., and Enslow, L. H., Applied hydrogen-ion concentration—a study of its merits in practical filter-plant operation: Am. Waterworks Assoc. Jour., vol. 9, No. 3, pp. 373–391, 1922.

Treatment with aluminum sulphate does not affect the total hardness of a water unless a large excess is added. It does change a certain amount of the carbonate hardness to noncarbonate hardness, but this is not often of any consequence. If lime is added with the aluminum sulphate the hardness may be decreased or increased according to the quantity of lime used.

The most serious effect of aluminum sulphate on the industrial value of a water is a change in the alkalinity or the acidity of the water. The reaction between aluminum sulphate and the carbonate or bicarbonate of a natural water sets free a quantity of carbon dioxide corresponding to the quantity of aluminum hydroxide precipitated. This action may make the intensity of acidity or hydrogen-ion concentration great enough to cause serious trouble from corrosion of iron pipes. Excessive carbon dioxide has caused what is known as "red water" in a number of public supplies. The red appearance is due to iron dissolved from the pipes and then precipitated. It is unsightly and it interferes with the use of the water in some industries, and the corrosion may be so great as to damage the pipes. The steps taken to overcome these difficulties are outlined on pages 23 and 25.

FILTRATION WITHOUT COAGULATION (SLOW SAND FILTERS).

The consideration of the treatment of water supplies in this report is limited as far as possible to features that affect the industrial utility of the water, so that little will be said about filtration without the use of chemicals. A few of the best plants use slow sand filters, which are regularly operated without the use of any chemicals except for the final chlorination, although a little coagulant may occasionally be added to the water at some. The period of sedimentation before filtration at these plants is usually longer than at those where a coagulant is used regularly. Water treated by slow sand filters is clear and may contain slightly less iron than before filtration, but it is not otherwise improved for industrial use. On the other hand, it has not the undesirable properties that are sometimes produced by the use of chemicals in connection with filtration.

FILTRATION AFTER COAGULATION.

The tendency in waterworks practice in the United States is toward the general use of coagulation, filtration, and chlorination. In the descriptions of waterworks systems in Table 6 the term "filtered" is used to indicate this type of treatment. Methods of water purification are described in detail in a number of recent publications.[7]

---

[7] Ellms, J. W., Water purification, McGraw-Hill Book Co., 1917. Mason, W. P. Water supply, John Wiley & Sons, 1916. Stein, M. F., Water purification plants and their operation, John Wiley & Sons 1920.

The so-called "mechanical filter" or "rapid sand filter," when skillfully operated, furnishes water that is as safe as that furnished by a slow sand filter and that is as pleasing in appearance. By the use of chemicals with a rapid sand filter it is possible not only to clarify water but at the same time to improve its quality for industrial use. The rapid filter accomplishes these results with waters that without the use of chemicals could not be made fit to use.

The complete treatment of a water involves chemical reactions on a very large scale and with exceedingly low concentrations of the reacting substances. Successful operation of the process requires practically constant attention and regulation. A small plant may require just as expert attention as a large one, although the income will not justify the employment of an operator who has had wide experience. By employing an expert to visit them at stated intervals and supervise their operation, including the chemical and bacteriological tests, many small plants obtain better advice and supervision than they could afford singly. Several plants are controlled by holding or operating companies that have acquired a large fund of experience on which to draw for the solution of problems that may arise at even the smallest plants they control. Some State boards of health furnish valuable assistance in the operation of filtration plants. Practically all this advice and supervision is given primarily to insure the sanitary purity of the water, though it can not entirely neglect questions that affect the industrial use of the waters. In general everything that tends to improve the sanitary condition of the water and to prevent complaints from domestic users is advantageous to industrial users.

Iron sulphate is sometimes used instead of aluminum sulphate as a coagulant, but it requires the addition of lime and thereby introduces another complication. If lime is added to most natural waters it reacts with the carbon dioxide in the water, and some of the calcium present as bicarbonate is precipitated as carbonate and the added lime is also precipitated. This reaction is not instantaneous: it extends over several hours. The reaction between the iron sulphate and lime is also somewhat slow and proceeds best if a moderate excess of lime is used. This excess of lime over the amount required by the iron sulphate reacts slowly with the calcium bicarbonate in the water to form a fine precipitate of calcium carbonate. This precipitate forms on the grains of sand in the filters and if not removed will in time clog the filters. It is not practicable to allow sufficient time for the complete separation of this calcium carbonate before filtration. At some plants the water goes through the filters before the reaction is completed, and the calcium carbonate is later deposited in the mains.

At Cleveland, Ohio,[8] two difficulties arising from chemical treatment of the water have been made to neutralize each other. Iron sulphate

[8] Ellms, J. W., Operation and tuning up of the Cleveland filters: Eng. News Record, vol. 88, pp. 776–779, 1922.

and lime are used until the sand grains have become incrusted with a layer of precipitated calcium carbonate. Then aluminum sulphate is used without lime. Its addition sets free an excessive amount of carbon dioxide, which, if left in the water, would cause corrosion of pipes. In the filters, however, it causes solution of the precipitated calcium carbonate. Thus the treatment cleans the filter bed and at the same time makes the water noncorrosive.

At Baltimore, Md.,[9] it has been found that the best coagulation is obtained when the hydrogen-ion concentration is so high that the filtered water would cause marked corrosion if delivered directly to the mains. Corrosion is prevented, however, by the addition of lime water to the filtered water.

It is desirable to have a moderate quantity of free carbon dioxide in water for domestic use, for if the quantity is very small the taste of the water is not pleasant. For this reason, as well as to prevent delayed precipitation of calcium carbonate, it is sometimes necessary to add carbon dioxide to filtered water.

MUNICIPAL SOFTENING.

The methods of treatment already described are used primarily to improve the sanitary condition of water and secondarily to improve its appearance. Any improvement for industrial use is incidental, though the removal of color and suspended matter is decidedly advantageous for industrial as well as for domestic use.

Softening is entirely for industrial improvement, in the sense of the word industrial as it is used in this report, where industrial use includes home laundry work and the other domestic uses that are affected by the dissolved mineral matter.

As noted above, water may be somewhat softened by the use of lime with iron sulphate for coagulation. This treatment, with an adjusted excess of lime, may be used at times when the raw water is hardest, and treatment with aluminum sulphate alone may be used when the raw water is not so hard. At some plants about all the softening that is profitable can be obtained by the use of lime. At best, lime removes only the carbonate hardness down to a point corresponding to the solubility of calcium and magnesium carbonates in the presence of the other constituents of the water. This part of the hardness is the least troublesome in steam boilers. To reduce the more troublesome noncarbonate hardness, sodium carbonate (soda ash) is sometimes added.

By properly proportioning the chemicals used it is possible to obtain good coagulation and also to reduce the hardness to a low point. If the raw water changes rapidly in composition, constant

[9] Baylis, J. R., The solution of corrosion and coagulation problems at Montebello Filters, Baltimore: Am. Waterworks Assoc. Jour., vol. 9, pp. 408–417, 1922.

watchfulness is required, with frequent analyses, to control the addition of the chemicals.

Water softened in a municipal purification plant may have a residual hardness of about 100 parts per million, which is not generally objectionable for domestic use. The expense of further softening of a public supply is hardly justified in view of the large proportion of the water that is used for watering streets and lawns, for flushing sewers, and for other uses that are not affected by the hardness of the water used. Water from a softened public supply usually must be softened still more for use in large steam boiler plants or in laundries.

Difficulties arising from the slow precipitation of calcium carbonate are common in municipal filtration plants where the water is softened. It is also necessary at all times to watch for caustic alkalinity.

QUANTITIES OF CHEMICALS USED IN TREATMENT OF THE WATER OF PUBLIC SUPPLIES.

The quantities of chemicals used in the treatment of water for public supplies are really comparatively very small. Natural waters are very dilute solutions of the rock constituents. They are so dilute that the quantities of the substances in solution are generally expressed in parts per million. Sea water, which is a moderately strong solution, contains about 35,000 parts per million of dissolved salts. Some natural brines from deep wells contain more than 200,000 parts per million. In comparison with these figures the 100 or 200 parts per million of dissolved solids in ordinary public water supplies seem almost negligible. Few people can detect the taste of salt in water that contains less than 600 or 800 parts per million.

Aluminum sulphate is added to water at filtration plants in quantities of 20 to 40 parts per million, and the aluminum is usually precipitated so completely that it is difficult to detect a trace of it in the filtered water. Iron sulphate, lime, and soda ash are used in quantities well below 100 parts per million, generally considerably below 50 parts. At nearly every filtration plant the total dissolved mineral matter in the filtered water is less than that in the raw water or is not greater by more than 10 or 15 parts per million. The regular dosage of chlorine is well below 1 part per million, and most of this is used up by oxidizable material in the water. The small amount of free chlorine regularly left in the water could not be tasted. The taste noted in chlorinated water is generally due to compounds that can be tasted when present to the extent of 1 part in 500,000,000 parts of water.

It thus appears that the quantities of chemicals used in the treatment of public water supplies are insignificant as compared with the quantities of water treated and are much less than the quantities of mineral matter already dissolved in the water.

REMOVAL OF IRON AND MANGANESE.

The foregoing consideration of the treatment of the water of public supplies relates to surface waters. Few ground waters require purification on account of contamination with bacteria or treatment for the removal of suspended clay or organic matter. Many well waters that are clear when drawn from the ground become turbid after standing a short time on account of the precipitation of iron. Manganese is similarly precipitated from a few waters.

Iron or manganese is usually removed by aeration and filtration.[10] This treatment rarely has any effect on the industrial use of the water aside from the improvement due to the removal of the iron.

INDUSTRIAL TREATMENT OF WATER FROM PUBLIC SUPPLIES.

CLARIFICATION.

Water for some industrial uses must be clearer and less colored than that furnished by some unfiltered public supplies which are entirely satisfactory to domestic consumers. Simple filtration through charcoal and sand usually removes the last traces of turbidity. Removal of color generally requires the use of aluminum sulphate and filtration.

PREVENTION OF CORROSION.

The untreated surface water of certain public supplies is corrosive on account of its high content of carbon dioxide or possibly of organic compounds that attack metals. The water of a few supplies is contaminated by drainage water from mines, which contains free sulphuric acid. Some well waters contain a little free acid. Other waters are not corrosive when cold but contain compounds that decompose on heating, especially under pressure, and liberate a free acid that is corrosive.

Corrosion by free mineral acids must be prevented by neutralizing the acid, usually with soda ash. Corrosion due to other causes has been prevented[11] by permitting the water to attack sheets of iron in a suitable container until the oxygen necessary for corrosion is exhausted.

SOFTENING WITH LIME AND SODA.

The lime-soda process for softening water has been used so long that it need not be described in detail. Theoretically lime equivalent to the free carbon dioxide, the carbonate hardness, and the magnesium is added to the water, and soda ash or sodium carbonate is added equivalent to the noncarbonate hardness. In practice the addition of chemicals is often determined by tests of the softened water. If the softening is conducted at a high temperature there is a

[10] Weston, R. S., The physical chemistry of deferrization: Am. Waterworks Assoc. Jour., vol. 9, pp. 491-495, 1922.

[11] West, Percy, Prevention of corrosion of metals by water in a closed system: Jour. Ind. Eng. Chemistry, vol. 14, pp. 601-607, 1922.

saving of chemicals and the softening is more nearly complete than when it is conducted at ordinary temperatures.

The lime-soda process works best with water of constant composition. Changes in the mineral content of the water make it necessary to alter the rate of addition of the chemicals and sometimes their relative proportions. Well waters and surface waters obtained from large lakes or other sources of constant composition are more easily treated than waters from smaller rivers, which at times may have from 50 to 150 per cent of their average content of dissolved mineral matter. Municipal softening is a help to the operation of a lime-soda softener in that it tends to keep the hardness of the water more uniform.

Lime-soda softening properly conducted always decreases the total quantity of dissolved material in the water. The carbonate hardness is nearly all removed, and the dissolved solids are correspondingly decreased. The calcium and magnesium of the non-carbonate hardness are replaced by sodium, making little difference in the quantity of dissolved solids. Some waters have so much non-carbonate hardness that after treatment they are likely to cause foaming in steam boilers.

SOFTENING WITH EXCHANGE SILICATES.

A newer process for softening water depends on the property of some silicates of exchanging sodium for calcium or magnesium. When used in treating ordinary hard water these insoluble silicates take from it practically all its calcium and magnesium and give in exchange sodium. Water thus treated is for all practical purposes free from hardness, although analyses may show that it contains very small quantities of calcium and magnesium.

When the silicate in a softener begins to lose its exchange capacity it is regenerated by passing a strong solution of common salt through the layer of silicate, which now takes sodium from the solution in exchange for the calcium and magnesium it had removed from the hard water. The salt solution must be completely washed out before water is again taken from the softener for use in steam boilers.

Whatever may be the composition of a water it can not be overtreated in an exchange-silicate softener, and unless the capacity of the apparatus is overtaxed the water will not be undertreated. The size of softener required for a given capacity depends, however, on the hardness of the water. The exchange-silicate softener makes practically no change in the total quantity of dissolved solids in a water. This is a disadvantage that is sometimes overcome by first treating the water with lime to remove most of the carbonate hardness and passing it through the bed of silicate after the precipitated calcium carbonate is filtered out.

TREATMENT WITH HEAT AND WITHIN THE BOILER.

Systems are in use for removing scale-forming substances by heating feed water to boiler temperature before it enters the boiler. These systems serve for boiler feed water but have not the universal applicability of the lime-soda or exchange-silicate systems, which are used to furnish soft water for all purposes.

The treatment of water within boilers is often the best method of preventing scale and is the only method of preventing foaming. At small plants waters of moderate hardness can generally be treated more satisfactorily in the boiler than in outside softening apparatus.

SUMMARY.

The public water supplies of 307 cities in the United States—the supplies described in this report—furnish water for nearly 39,000,000 persons, about 37 per cent of the population of the country. These 307 cities include 287 that have a population of more than 25,000 each and 20 others so selected as to give among the 307 two cities for each State.

Surface water is supplied to 234 of these cities that together have a population of about 35,000,000, and ground water to 73 of these cities that have a population of about 4,000,000. The surface supplies used in 112 cities that have a population of about 20,000,000 are not filtered. The surface supplies used in 113 cities that have a population of about 11,000,000 are treated with a coagulant and filtered. The supplies for 9 cities that have a population of about 3,500,000 are filtered without previous addition of chemicals.

In practically all the waters for which analyses are given in this report the only constituents of much industrial consequence are calcium and magnesium, which cause hardness.

More than 17,000,000 consumers are served with water of less than 55 parts per million of hardness, nearly 6,000,000 with water of 55 to 100 parts per million of hardness, more than 11,000,000 with water of 100 to 200 parts per million of hardness, and about 4,500,000 with water of more than 200 parts per million of hardness.

Municipal treatment of the water of a public supply generally improves it for industrial use. At some places the improvement consists merely of removal of suspended material. At other places color is reduced, and at some the water is softened. Further softening of municipally softened water is profitable for most industrial plants.

DESCRIPTIONS AND ANALYSES OF PUBLIC SUPPLIES.

In the following table are given the data in detail upon which the report is based. The population of each city is given in parentheses after the name; the other data are self-explanatory.

TABLE 6.—*Public water supplies of the*

No.	Description.
	ALABAMA.
1	Birmingham (178,806); Birmingham Waterworks Co. (controlled by American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.). Cahaba River and Fivemile Creek, both filtered. Cahaba River furnishes about two-thirds of the total supply. A, Average of analyses of 30 composites of 10 daily samples each from Cahaba River; analyzed by U. S. Geological Survey, 1906-7 (Water-Supply Paper 236, p. 51). B, Composite sample of filtered water from Fivemile Creek, May 15-25, 1922; analyzed by Norbert M. Berberich, Birmingham Waterworks Co.
2	Mobile (60,777); municipal; creeks impounded. Analyzed by Margaret D. Foster, U. S. Geological Survey, Feb. 21, 1922. A, Spring Hill Creek; B, Bienville Creek.
3	Montgomery (43,464); municipal; wells 200-700 feet deep. Analyzed by C. L. Hare, Auburn, Ala., August, 1921.
	ARIZONA.
4	Phoenix (29,053); municipal; infiltration galleries near Verde River, near Fort McDowell. Analyzed by John C. Sparks, New York, N. Y., 1918.
5	Tucson (20,292); municipal; wells. Analyzed by C. S. Howard, U. S. Geological Survey

Source.	Depth (feet).	Per cent of total supply.	Date of collection.
A, Santa Cruz drainage basin, seven wells at Eighteenth and Osborn streets.	75-471	60	June 14, 1922.
B, Rillito drainage basin, Eighth Street well	500	13	Do.
C, Rillito drainage basin, Second Street well	500	6	June 19, 1922.
D, Rillito drainage basin, Speedway Heights, two wells.	500	21	No sample; see analyses B and C.

No.	Description.
	ARKANSAS.
6	Fort Smith (28,870); municipal; Poteau River; filtered. Analyzed by E. F. Voigt, Fort Smith District Board of Health, 1921.
7	Little Rock (65,142); Arkansaw Water Co. (controlled by American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.); Arkansas River; filtered. Analyzed by U. S. Geological Survey, 1906-7 (Water-Supply Paper 236, p. 49).
	CALIFORNIA.
8	Alameda (28,806); East Bay Water Co., Oakland. (See Oakland)
9	Berkeley (56,036); East Bay Water Co., Oakland. (See Oakland)
10	Fresno (45,086); Fresno Water Co., wells 110 to 215 feet deep at 23 pumping stations in different parts of the city. Analyses of water from other wells in the county indicate that the supply may be rather hard and possibly high in sulphate. A, Average of determinations on 6 samples from different pumping stations. B, Griffith McKenzie Building. C, Station No. 20 (2 wells). Analyzed by State Board of Health, Sept. 29, 1921.
11	Long Beach (55,593); municipal; drilled wells, 12 inches in diameter; water is mixed by pumping into a single main. Analyzed by Margaret D. Foster, U. S. Geological Survey, Oct. 19, 1921.

Source.	Depth (feet).	Yield (gallons per minute).
A, Alamitos No. 2	273	1,100
B, Development No. 1	1,017	1,700
C, Citizen No. 1	420	1,100
D, Citizen No. 4	1,155	2,700

larger cities of the United States.

Analyses (parts per million).													
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
A......	76	......	16	0.44	13	2.5	9.1	52	8.8	2.2	0.6	43	1
B......	183	......	7.0	[b].4	35	14	9.4	169	27	3.5	.6	145	
A......	22	1.8	6.0	.16	1.6	.4	Na 1.9; K .3	2.4	1.1	4.5	.16	6	2
B......	20	2.6	5.8	.11	.9	.4	Na 1.9; K .3	2.4	1.4	3.2	.14	4	
....	173	28	......	[b]2.6	5.5	3.5	Na 36; K 5.8	75	26	18	....	20	3
....	[a] 299	......	5.3	.6	53	21	32	266	27	29	....	219	4
A......	498	14	45	.10	78	15	62	285	132	16	3.6	256	5
B......	280	7.2	39	.13	42	5.4	42	[c] 164	59	13	....	127	
C......	272	8.8	15	.21	38	4.5	42	155	62	6.6	....	113	
....	131	45	......	......	......	......	......	66	....	13	....	[d] 53	6
Avg....	630	......	28	.82	55	13	144	148	93	203	2.0	191	7
Max....	1,500	......	54	2.4	96	23	415	230	212	610	6.3	332	
Min....	271	......	13	.06	25	2.7	31	76	32	34	Tr.	89	
....	......	......	......	......	......	......	......	......	....	....	....	....	8
....	......	......	......	......	......	......	......	......	....	....	....	....	9
A......	......	......	......	......	......	......	......	170	....	16	....	....	10
B......	......	......	......	......	......	......	......	300	....	16	....	....	
C......	......	......	......	......	......	......	......	93	....	7	....	....	
A......	214	2.4	20	.07	13	1.7	Na 58; K 3.5	158	22	12	.61	39	11
B......	203	8.3	21	.07	12	1.8	Na 55; K 4.4	151	5.5	17	Tr.	37	
C......	209	2.6	26	.06	22	2.7	Na 43; K 3.6	164	13	12	.62	66	
D......	246	5.0	19	.04	6.0	1.7	Na 78; K 3.9	[e]207	2.1	17	Tr.	22	

[a] Calculated.
[b] Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
[c] Includes equivalent of 13 parts CO_3.
[d] Determined.
[e] Includes equivalent of 12 parts CO_3.

22937—23—WSP 496——3

TABLE 6.—*Public water supplies of the*

No.	Description.
	CALIFORNIA—continued.
12	Los Angeles (576,673); municipal; Owens River and tunnels beneath Los Angeles River. Analyzed in laboratory of Los Angeles Dept. Public Service, 1921. A, Owens River (44 per cent of supply); B, Los Angeles River (56 per cent of supply).
13	Oakland (216,261); East Bay Water Co.; wells and surface waters, filtered. The East Bay Water Co. also supplies Alameda, Berkeley, Richmond, and a number of small towns and unincorporated territory in between; total population supplied about 350,000. A, Sample from tap at Twenty-fourth Avenue pumping station. This supply is one-half ground and one-half surface water and constitutes about two-thirds of the daily supply of the district served. B, Sample from pure-water basin, San Pablo filters. This supply is all surface water and is about one-third of the total supply. Analyzed by Western Laboratories, Oakland, Aug. 4, 1921.
14	Pasadena (45,354); municipal; Arroyo Seco Canyon and filter galleries and wells in the valley. Analyzed by Pasadena city chemist, Oct. 4, 1920.
15	Sacramento (65,908); municipal; Sacramento River; filtered. Average of analyses made by U. S. Geological Survey, 1907-8 (Water-Supply Paper 237, p. 32).
16	San Diego (74,683); municipal; reservoirs. Analyzed by Smith-Emery Co., Los Angeles, Calif., July 23, 1921. A, Morena reservoir (chlorinated water), 40 miles east of city; Morena, Barrett, and Otay reservoirs via Otay supply 91 per cent of water. B, Hodges reservoir (raw water), 30 miles north of city; supplies 9 per cent of total.
17	San Francisco (506,676); Spring Valley Water Co.; reservoirs and wells. Water from the different sources is mixed in varying proportions at different times of the year. The maximum and minimum results given possibly do not represent the extremes but probably cover the usual range in composition of the water. Analyzed by Albert S. Corwithen, Geo. W. Lord Co., Philadelphia, Pa., Apr. 10, 1910.
18	San Jose (39,642); San Jose Waterworks (private company); impounding reservoirs and wells. About 70 per cent of the water supplied is collected in reservoirs from the Santa Cruz Mountains. The rest is pumped from deep wells. Analyzed by Frank Bachman, California State Board of Health, Apr. 4, 1919. A, Raw water from Tisdale flume, Santa Cruz Mountains. B, Water from well M.
19	Stockton (40,296); Pacific Gas & Electric Co.; wells from 200 to 1,100 feet deep. Analyzed by California State Board of Health, Jan. 26, 1920.
	COLORADO.
20	Colorado Springs (30,105); municipal; reservoirs. Analyzed by city department of public health and sanitation, December, 1915.
21	Denver (256,491); municipal; South Fork of Platte River (93 per cent), Bear Creek (5 per cent), and Cherry Creek (2 per cent); part filtered. Analyzed by Ray R. LaCroix, Denver, Oct. 24, 1921.
22	Pueblo (43,050); municipal; Arkansas River; iron sulphate and lime; sedimentation. Analysis furnished by Pueblo Waterworks, Nov. 7, 1921.
	CONNECTICUT.
23	Bridgeport (143,555); Bridgeport Hydraulic Co.; impounding reservoirs. Supplies Stratford, Shelton, Trumbull, Fairfield, and Westport; total population served about 185,000. Analyzed by F. C. Barrows, Bridgeport Hydraulic Co., 1921.
24	Hartford (138,036); municipal; impounding reservoirs filtered without coagulation. Analyzed by Newlands Sanitary Laboratory, Hartford; A, Aug. 4, 1922; B and C, September, 1917. A, Nepaug reservoir (principal supply). B, Reservoir No. 2. C, Reservoir No. 6.
25	Meriden (34,764); municipal; impounding reservoirs fed by surface streams. The composition of the water is similar to that of the New Haven supply. Analyzed by Connecticut State Board of Health. A, Average of 12 samples from Kenmere reservoir, 1899. B, Average of 23 samples at gate house, 1889-90. C, Average of 12 samples from Merimere reservoir, 1889. D, Average of 2 samples, 1920.
26	New Britain (59,316); municipal; impounding reservoir. The composition of the water is similar to that of the New Haven supply. Average of monthly samples April, 1920, to March, 1921. Analyzed by Davenport & Keeler, New Britain.
27	New Haven (162,537); New Haven Water Co.; impounding reservoirs. Supplies East Haven, Hamden, Woodbridge, West Haven, North Haven, and Cheshire. Total population supplied about 194,000. Analyzed by Margaret D. Foster, U. S. Geological Survey.

Source.	Million gallons per day.	Date of collection.
A, Mill River at Whitneyville pumping station	10	Nov. 29, 1921
B, Saltonstall reservoir	7	Feb. 7, 1922
C, Maltby Lakes	3	.....do........
D, West River	10	Nov. 29, 1921

larger cities of the United States—Continued.

Analyses (parts per million).													
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
A......	[a] 279	......	22	0	39	16	34	165	59	28	Tr.	163	12
B......	[a] 378	......	22	0	66	21	33	214	103	28	Tr.	251	
A......	341	......	16	[b] 2.3	51	13	[a] 61	207	60	57	....	181	13
B......	360	......	2.9	[b] 2.4	49	15	[a] 45	174	94	30	....	183	
....	218	......	36	[b] .18	38	10	6.4	142	24	12	2.3	139	14
....	113	......	28	.43	13	6.7	13	74	17	5.4	.64	60	15
A......	365	36	9.9	[b] 3.9	38	18	62	238	25	57	....	169	16
B......	350	54	7.2	[b] 2.7	22	19	64	172	14	82	....	133	
Max....	369	30	......	......	38	18	70	276	36	76	....	166	17
Min....	218	7.5	......	......	21	7.6	37	91	10	23	....	83	
A......	200	......	......	.1	34	14	16	183	13	10	....	142	18
B......	300	......	......	.0	44	16	39	262	20	16	....	176	
....	970	312	......	.2	139	52	71	157	30	352	....	560	19
....	38	9.5	7.5	[b] .69	6.7	1.7	3.2	5.6	7.1	7.3	Tr.	24	20
....	250	......	7.0	.20	41	10	26	104	80	22	.13	143	21
....	447	42	11	[b] 1.5	56	23	44	105	209	15	Tr.	234	22
....	[a] 47	9.6	14	.30	4.5	.7	Na 3.4; K 3.1	[a] 16	7.1	3.5	....	14	23
A......	......	......	3.2	[b] .6	2.6	.4	5.7	12	8.0	1.4	....	8	24
B......	67	21	9.0	[b] 2.9	9.3	2.8	([f])	25	9.3	2.6	....	35	
C......	60	16	5.9	[b] 2.5	6.0	2.2	[a] 3.5	25	7.8	2.2	....	24	
A......	70	......	......	......	......	......	......	......	......	......	....	[d] 29	25
B......	41	......	......	......	......	......	......	......	......	......	....	[d] 17	
C......	41	......	......	......	......	......	......	......	......	......	....	[d] 13	
D......	54	......	......	......	......	......	......	......	......	......	....	[d] 38	
Avg....	46	18	......	......	......	......	......	......	......	2.2	....	....	26
A......	94	2.0	6.7	.06	22	3.3	Na 4.0; K 1.8	62	13	7.6	1.6	69	27
B......	76	......	......	......	21	......	......	50	12	4.2	....	[d] 53	
C......	60	......	......	......	15	......	......	17	10	5.0	....	[d] 27	
D......	39	1.8	5.9	.16	4.9	1.7	Na 2.0; K 1.1	15	7.6	3.4	.22	19	

[a] Calculated.
[b] Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
[d] Determined.
[f] Less than 10 parts.

TABLE 6.—*Public water supplies of the*

No.	Description.
	CONNECTICUT—continued.
28	New London (25,688); municipal; reservoirs impounding water from Lake Konomoc and from surface streams. The composition of the water is similar to that of the West River supply at New Haven. Average of 5 analyses made by Connecticut State Board of Health in 1920.
29	Norwalk (27,743); municipal; reservoir fed by streams. The composition of the water is similar to that of the New Haven supply. Average of 10 analyses made by Connecticut State Board of Health in 1921.
30	Norwich (29,685); municipal; reservoir fed by streams. The composition of the water is similar to that of the West River supply at New Haven. Average of 31 analyses made by Connecticut State Board of Health in 1921.
31	Stamford (40,067); municipal; reservoirs fed by Mill River and other streams. The composition of the water is similar to that of the Mill River supply at New Haven. Average of 7 analyses made by Connecticut State Board of Health in 1921.
32	Waterbury (91,715); municipal; stream impounded. Analysis by Connecticut State Board of Health, July 26, 1921.
	DELAWARE.
33	Dover (4,042); municipal; artesian wells about 200 feet deep; auxiliary supply from wells 22 and 24 feet deep. Analyzed by Margaret D. Foster, U. S. Geological Survey, Feb. 28, 1922.
34	Wilmington (110,168); municipal; Brandywine Creek; filtered. Average of concordant analyses of samples collected Aug. 11, 1913, Aug. 10, 1914, and May 19, 1915. Analyzed by James M. Caird, Troy, N. Y.
	DISTRICT OF COLUMBIA.
35	Washington (437,571); municipal; Potomac River; filtered. Average of analyses of composite samples made by Margaret D. Foster, U. S. Geological Survey, 1921. For individual analyses see page 3.
	FLORIDA.
36	Jacksonville (91,558); municipal; wells 650 to 1,175 feet deep. Analyzed by Margaret D. Foster, U. S. Geological Survey, Aug. 7, 1922.
37	Miami (29,571); Miami Water Co.; wells 40 to 45 feet deep. Analyzed by Margaret D. Foster and Clara M. Forman, U. S. Geological Survey, Jan. 21, 1920.
38	Pensacola (31,035); municipal; wells 150 to 250 feet deep. Analyzed by U. S. Geological Survey, Dec. 16, 1907.
39	Tampa (51,608); Tampa Waterworks Co. About four-fifths of the supply is from wells and one-fifth from Magbee Spring. Analyzed by Margaret D. Foster, U. S. Geological Survey, Aug. 21, 1922. A, Composite of 7 samples proportional to the quantities of water supplied by each source represented. B, Most concentrated sample, 16-inch conduit. C, Least concentrated sample, Magbee Spring.
	GEORGIA.
40	Atlanta (200,616); municipal; Chattahoochee River; filtered. The composition of the river water is variable, but the total quantity of dissolved material is at all times so small that a single analysis of the filtered water is probably as useful as a series of results. Analyzed by Margaret D. Foster, U. S. Geological Survey, Aug. 31, 1921.
41	Augusta (52,548); municipal; Savannah River; filtered. The analyses made by the U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 99) may be taken to represent the character of the city water at the present time except for silica, which is probably less than 10 parts per million in the water served to consumers.
42	Columbus (31,125); municipal; Chattahoochee River; filtered. The analysis of Chattahoochee River at West Point made by the U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 54) may be taken as representative of the city water at Columbus except for silica, which is probably less than 10 parts per million.
43	Macon (52,995); municipal; Ocmulgee River; filtered. The treatment slightly decreases the quantity of silica and of bicarbonate and increases the sulphate. Analyzed by U. S. Geological Survey, 1906-7 (Water-Supply Paper 236, p. 86).
44	Savannah (83,252); municipal; wells about 400 feet deep. Earlier and later analyses of samples from other wells indicate that the analysis of the composite sample from 4 wells represents the water now used. Analyzed by R. B. Dole, U. S. Geological Survey, Aug. 3, 1915.
	IDAHO.
45	Boise (21,393); Boise Artesian Water Co.; artesian wells about 600 feet deep and a dug well 30 feet deep and 22 feet in diameter. A, Artesian wells. B, Dug well. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 27, 1922.
46	Pocatello (15,001); municipal; reservoirs fed by springs. Analyzed by E. O. Leonard, Pocatello, June 2, 1921.

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
....	37	......	......	......	......	......		......	......	......	......	[d] 14	28
....	53	......	......	......	......	......		......	......	......	......	[d] 30	29
....	38	......	......	......	......	......		......	......	......	......	[d] 17	30
....	75	......	......	......	......	......		......	......	......	......	[d] 40	31
....	34	6	......	......	......	......	......	18	......	2.8	......	[d] 24	32
....	201	3.5	55	0.09	36	6.1	Na 11 K 1.6	160	7.2	3.0	0.12	115	33
Avg....	94	44	6.7	.13	17	1.7	5.4	48	9.7	8.4	......	49	34
Avg....	103	3.8	6.6	.07	23	5.4	Na 3.0 K 1.4	70	20	3.3	2.8	80	35
....	420	8.4	24	.15	76	28	Na 12 K 2.1	163	165	15	.42	305	36
....	772	1.6	12	.64	116	18	141	282	56	269	Tr.	364	37
....	22	......	8.8	Tr.	.7	.4	3.1	3.7	2.0	4.8	.2	3	38
A......	1,273	80	22	.48	113	33	[a] 275	176	92	548	2.8	418	39
B......	......	......	......	......	......	......	......	144	[g] 220	1,414	......	[d] 487	
C......	......	......	......	......	......	......	......	203	[g] 28	136	......	[d] 286	
....	32	1.5	10	.08	2.4	1.1	Na 2.3 K .6	6.6	7.8	1.8	.33	11	40
Avg....	60	......	23	.44	5.7	.8	12	30	6.0	2.1	.6	18	41
Max....	90	......	37	1.8	8.4	4.8	13	40	7.4	3.5	3.0	35	
Min....	42	......	12	Tr.	3.9	Tr.	9.2	9.8	4.7	Tr.	.0	10	
Avg....	52	......	20	.47	4.8	.8	7.7	23	4.5	2.1	.7	15	42
Avg....	69	......	26	.9	6.3	1.2	8.3	28	4.9	2.8	.7	21	43
....	183	......	53	.03	24	7.4	18	129	15	6.4	.1	82	44
A......	81	3.5	20	.16	12	2.3	Na 7.7 K 1.0	50	8.5	1.4	2.0	39	45
B......	187	4.1	33	.32	34	3.9	Na 15 K 1.8	107	38	3.2	6.7	101	
....	164	7	......	......	......	......	......	85	......	8.0	......	[h] 122	46

[a] Calculated.
[d] Determined.
[g] Determined by turbidity.
[h] Determined. Noncarbonate hardness, 52 parts.

TABLE 6.—*Public water supplies of the*

No.	Description.
	ILLINOIS.
47	Aurora (36,397); municipal; wells. Analyzed by Illinois State Water Survey, Oct. 28, 1902 (Illinois Univ. Bull., vol. 5, No. 7, p. 14).
48	Bloomington (28,725); municipal; wells 60 to 80 feet deep. Analyzed by Illinois State Water Survey, Feb. 8, 1916.
49	Chicago (2,701,705); municipal; Lake Michigan. Analyzed by G. A. Weinhold, Illinois State Water Survey, Dec. 5, 1921.
50	Cicero (44,995); municipal; Chicago supply. (See Chicago.)..
51	Danville (33,776); municipal; North Fork of Vermilion River; filtered. Analyzed by G. A. Weinhold, Illinois State Water Survey, May 9, 1921.
52	Decatur (43,818); municipal; Sangamon River; filtered. Silica is probably less than 10 parts per million in the filtered water, but in other respects the analyses made by U. S. Geological Survey in 1906-7 (Water-Supply Paper 239, p. 72) probably represent the city water at the present time.
53	East St. Louis (66,767); East St. Louis & Interurban Water Co. (controlled by American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.); Mississippi River; filtered. Supplies Lovejoy, Fairmount, Granite City, Madison, Venice, Belleville, Swansea, and National City; total population served about 100,000. Filtration reduces the silica to less than 10 parts per million and slightly increases the sulphate and decreases the bicarbonate. The average of analyses of samples for a year at Chester, Ill., may be taken to represent the average character of the water. Analyzed by U. S. Geological Survey, 1906-7 (Water-Supply Paper 239, p. 83).
54	Elgin (27,454); municipal; wells. Analyzed by Illinois State Water Survey, January, 1906 (Illinois Univ. Bull., vol. 5, No. 7, p. 43).
55	Evanston (37,234); municipal; Lake Michigan; filtered. The chemical treatment decreases the silica and bicarbonate and increases the sulphate, but the filtered water is not very different in chemical composition from the unfiltered water used at Chicago. (See Chicago.)
56	Joliet (38,442); municipal; wells about 40 feet deep in drift, and drilled wells 1,200 to 1,700 feet deep. Analyzed by Illinois State Water Survey. A, Mixture of deep and shallow well water, June 27, 1918. B, Deep-well water, Apr. 24, 1918.
57	Moline (30,734); municipal; Mississippi River; filtered. Filtration reduces the silica to less than 10 parts per million and slightly increases the sulphate and decreases the bicarbonate. Analysis of river water by U. S. Geological Survey, 1906-7 (Water-Supply Paper 239, p. 81).
58	Oak Park (39,858); municipal; obtains its supply from Chicago. (See Chicago)...................
59	Peoria (76,121); Peoria Waterworks Co.; wells 60 to 90 feet deep. Analysis furnished by Peoria Waterworks Co. as an average mineral analysis, 1921.
60	Quincy (35,978); municipal; Mississippi River; filtered. The treatment with aluminum sulphate and lime decreases the alkalinity and silica and increases the sulphate, but the changes are not great. Analyzed by U. S. Geological Survey, 1906-7 (Water-Supply Paper 239, p. 82).
61	Rock Island (35,177); municipal; Mississippi River; filtered. The analyses of Mississippi River at Moline made by the U. S. Geological Survey in 1906-7 may be taken as representative of the city supply at Rock Island. (See Moline.)
62	Rockford (65,651); municipal; wells 1,300 to 2,000 feet deep. Analyzed by Illinois State Water Survey, June 25, 1917.
63	Springfield (59,183); municipal; wells and infiltration galleries along Sangamon River. Analyzed by Illinois State Water Survey, Feb. 26, 1917.
	INDIANA.
64	Anderson (29,767); municipal; White River; filtered. The composition of the water is fairly uniform throughout the year. Analyzed by Margaret D. Foster, U. S. Geological Survey, Feb. 27, 1922.
65	East Chicago (35,967); East Chicago & Indiana Harbor Water Co., controlled by Indianapolis Water Co.; Lake Michigan; filtered. Average of monthly analyses for two years made by Indianapolis Water Co.
66	Evansville (85,264); municipal; Ohio River; filtered. Analyses from laboratory of filtration plant; monthly averages; published in annual report of city of Evansville for 1920.
67	Fort Wayne (86,549); muncipal; wells 150 to 270 feet deep. Analyzed by C. H. Hurd, Indianapolis, Ind., for Fort Wayne Waterworks, Jan. 8, 1919. A, Sample from pumping station No. 1. B, Sample from pumping station No. 2.
68	Gary (55,378); Gary Heat, Light & Water Co.; Lake Michigan. The water is practically the same as the supply for East Chicago. (See East Chicago.)
69	Hammond (36,004); municipal; Lake Michigan; filtered. The water is practically the same as the supply for East Chicago. (See East Chicago.)
70	Indianapolis (314,194); Indianapolis Water Co.; White River, filtered without coagulation (85 to 88 per cent of supply); wells (12 to 15 per cent of supply). Analyzed by Indianapolis Water Co. A, Average of analyses of composites of daily samples of filtered water over a period of 7 years. B, Average of analyses of composites of daily samples from Fall Creek station wells over a period of 2 years.
71	Kokomo (30,067); Kokomo Waterworks Co. (controlled by American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.); wells 130 and 150 feet deep. Analyzed by Dearborn Chemical Co., Chicago, Ill., Aug. 19, 1921.

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.*a*	No.
....	*a* 455	......	6.2	0.8	66	15	Na 74 K 15	*a* 253	31	122	0.6	228	47
....	*a* 969	......	16	.14	203	74	Na 14 K 2.7	*a* 504	404	8.0	.0	811	48
....	183	......	18	.4	36	10	Na 4.6 K 1.6	144	10	6.0	1.8	131	49
....	....	......	......	......	......	......	....	....	....	....	....	....	50
....	326	......	4.3	.1	58	27	Na 7.6 K 2.0	206	80	6.0	18	256	51
Avg....	293	......	19	.27	55	26	14	268	35	5.4	8.5	244	52
Avg....	269	......	22	.39	44	16	21	174	56	9.8	2.7	176	53
....	*a* 344	......	12	.6	54	29	Na 31 K 8.1	*a* 415	2.8	2.0	.9	254	54
....	....	......	......	......	......	......	....	....	....	....	....	....	55
A......	685	......	7.4	.07	120	45	Na 26 K 4.6	269	293	19	9.2	484	56
B......	475	......	11	.0	58	21	82	322	97	36	.9	231	
Avg....	179	......	16	.39	33	13	10	152	24	3.7	1.8	136	57
Max....	241	......	29	.80	42	19	18	205	35	8.3	4.0	176	
Min....	124	......	8.0	.20	20	8.2	5.9	91	15	1.8	.3	124	
....	....	......	......	......	......	......	....	....	....	....	....	....	58
Avg....	430	6.0	7.4	......	72	36	36	426	30	18	....	328	59
Avg....	203	......	18	.46	36	16	11	175	25	4.4	2.2	156	60
Max....	244	......	31	2.2	45	24	18	225	39	9.0	5.0	191	
Min....	144	......	8.4	.02	24	10	7.0	121	14	2.3	.3	101	
....	....	......	......	......	......	......	....	....	....	....	....	....	61
....	*a* 339	......	9.9	.07	68	36	Na 8.9 K 3.5	*a* 378	18	6	3.5	316	62
....	*a* 371	......	10	1.0	73	30	Na 20 K 1.7	*a* 318	59	18	1.8	305	63
....	348	12	7.0	.17	72	29	Na 5.1 K 2.0	262	72	20	11	299	64
....	*a*188	......	......	......	44	14	5	*a* 189	15	5.3	.50	167	65
Avg....	......	......	......	......	......	8.5	....	71	....	19	....	*d* 110	66
Max....	......	......	......	......	......	16	....	101	....	30	....	*d* 169	
Min....	......	......	......	......	......	3.7	....	48	....	14	....	*d* 82	
A......	528	......	......	.2	83	43	*a*35	399	118	8	....	384	67
B......	536	......	......	.01	67	63	*a*31	380	167	6	....	426	
....	....	......	......	......	......	......	....	....	....	....	....	....	68
....	....	......	......	......	......	......	....	....	....	....	....	....	69
A......	342	......	7.3	.31	72	27	13	275	58	20	5.8	291	70
B......	361	......	14	1.2	74	32	16	380	29	6.5	.3	316	
....	*a*465	6.5	11	5.9	59	25	68	133	130	28	....	250	71

a Calculated.
d Determined.

TABLE 6.—*Public water supplies of the*

No.	Description.
	INDIANA—continued.
72	Muncie (36,524); Muncie Waterworks Co. (controlled by American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.); White River; filtered. Records over a period of several years show variations in alkalinity of 150 to 300 parts per million. The average analysis given for filtered water at Indianapolis may be taken as fairly representative of the average composition of the water at Muncie. (See analysis A, Indianapolis.)
73	Richmond (26,765); Richmond City Waterworks (private company). Infiltration galleries. Analysis furnished by Richmond City Waterworks, Jan. 9, 1922.
74	South Bend (70,983); municipal; wells about 100 feet deep. Analyses by U. S. Geological Survey, October, 1907 (Water Supply Paper 254, p. 214). A, Sample from central station. B, Sample from north station.
75	Terre Haute (66,083); Terre Haute Waterworks Co.; Wabash River; filtered. Analyses furnished by Terre Haute Waterworks Co., 1920; based on monthly composites of daily samples collected during 1920.
	IOWA.
76	Cedar Rapids (45,566); municipal; main supply from Cedar River; filtered; 5 to 30 per cent of supply from wells 1,450 feet deep. A, Analyses of water from Cedar River at Cedar Rapids made by U. S. Geological Survey in 1906–7 (Water-Supply Paper 236, p. 53). B, Analysis of water from West Side well made by Kansas City Testing Laboratory, 1921.
77	Council Bluffs (36,162); municipal; Missouri River; filtered. Analyses by Joseph B. Thornell indicate that the composition of the water is practically the same as at Omaha, Nebr. Analyses of Missouri River near Omaha made by U. S. Geological Survey in 1906–7 (Water-Supply Paper 236, p. 78).
78	Davenport (56,727); Davenport Water Co.; Mississippi River; filtered. The treatment undoubtedly removes more silica and slightly more iron than the laboratory filtration of the samples analyzed in 1907. The sulphate may be slightly increased. With these relatively unimportant exceptions the published analyses probably represent very closely the composition of the water delivered to consumers. The analyses of Mississippi River at Moline, Ill., made by the U. S. Geological Survey in 1906–7 (Water-Supply Paper 239, p. 81) may be taken as representative of the city supply at Davenport.
79	Des Moines (126,468); municipal; infiltration galleries. Analyzed by Dale L. Maffitt, Des Moines Water Department, May 23, 1921.
80	Dubuque (39,141); municipal. Analyzed by Margaret D. Foster, U. S. Geological Survey, May 16, 1922.

Source.	Approximate average depth (feet).	Per cent of total supply.
A, Shallow wells	100	55
B, Artesian wells	1,400	32
C, Level tunnel	....	13

No.	Description.
81	Sioux City (71,227); municipal; wells. Analyzed by Margaret D. Foster, U. S. Geological Survey, Mar. 17, 1922.

Source.	Diameter (inches).	Depth (feet).
A, Leeds Station	8	280
B, Lowell station	26	327
C, North Riverside	12	347

No.	Description.
82	Waterloo (36,230); municipal; deep wells. Analysis by W. S. Hendrixson published in U. S. Geol. Survey Water-Supply Paper 293, p. 143.

larger cities of the United States—Continued.

Analyses (parts per million).													
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
....	......	......	......	......	......	......	......	......	......	......	......	......	72
....	368	......	1.7	0.3	88	27	7.6	320	54	3.0	29	331	73
A......	405	......	13	.4	88	29	16	294	78	18	3.2	339	74
B......	242	......	14	3.8	45	22	7.7	222	25	3.2	.0	203	
Avg....	383	......	11	[b].29	70	26	6.9	221	85	12	....	280	75
Max...	440	......	18	[b]2.0	87	38	9.1	290	99	15	....	341	
Min....	284	......	4	[b]Tr.	44	18	4.4	141	71	8	....	184	
A Avg.	228	......	14	.09	48	16	12	209	30	3.4	3.1	186	76
A Max.	311	......	27	.48	64	26	20	309	46	8.8	8.0	267	
A Min.	119	......	3.0	Tr.	24	6.6	6.4	87	21	1.9	.0	87	
B......	454	......	17	.7	75	30	22	329	71	10	....	310	
Avg....	454	......	31	.44	65	20	49	203	168	8.9	1.8	244	77
Max...	663	......	76	2.0	102	38	72	337	237	15	5.5	411	
Min...	300	......	10	Tr.	45	7.9	34	146	81	5.0	Tr.	155	
Av.....	179	......	16	.39	33	13	10	152	24	3.7	1.8	136	78
Max...	241	......	29	.80	42	19	18	205	35	8.3	4.0	176	
Min....	124	......	8.0	.20	20	8.2	5.9	91	15	1.8	.3	91	
....	483	172	13	.31	88	29	4.9	222	157	7.5	1.5	339	79
A......	279	11	19	.08	58	25	Na 5.0, K 1.1	272	24	4.4	2.7	248	80
B......	297	5.8	13	.13	57	35	Na 3.9, K 1.3	327	19	1.8	Tr.	286	
C.......	453	18	15	.07	86	41	Na 13, K 2.9	376	96	4.8	1.2	383	
A......	419	11	17	.48	95	27	Na 16, K 3.7	344	86	11	.15	348	81
B......	589	16	16	.44	119	34	Na 27, K 5.9	371	174	11	.16	437	
C.......	775	23	14	1.8	155	46	Na 26, K 5.6	415	276	12	Tr.	576	
....	[a]468	......	7	......	78	38	Na 41, K 5	368	106	8	....	351	82

[a] Calculated.
[b] Iron and aluminum oxides (Fe_2O_3+Al_2O_3.)

TABLE 6.—*Public water supplies of the*

No.	Description.
	KANSAS.
83	Kansas City (101,177); municipal; Missouri River; filtered. As the water is not softened the analyses of filtered river water made by the U. S. Geological Survey in 1906–7 (Water-Supply Paper 236, p. 79) may be taken to represent the water delivered to consumers. The city water probably contains less iron and much less silica than the quantities given in the table.
84	Topeka (50,022); municipal; Kansas River; filtered. Composite of daily samples of filtered water for month of January, 1923. Analyzed by waterworks laboratory.
85	Wichita (72,217); Wichita Water Co.; wells 35 feet deep. Analyzed by Kansas State Board of Health, Apr. 9, 1921.
	KENTUCKY.
86	Covington (57,121); municipal; Ohio River. Supplies Fort Thomas, city, and United States barracks, Ludlow, and a small part of Bellevue; total population supplied about 67,000. The analyses for a year of composite monthly samples of filtered water at Cincinnati, Ohio (annual report of Cincinnati Waterworks, 1917–18, p. 73), may be taken to represent the character of the water at Covington.
87	Lexington (41,534); Lexington Hydraulic & Manufacturing Co.; impounding reservoirs; filtered. Analyzed by J. M. Caird, Feb. 27, 1922.
88	Louisville (234,891); Louisville Water Co.; Ohio River; filtered. Analyzed by Louisville Water Co.
89	Newport (29,317); municipal; Ohio River. Supplies Bellevue and Dayton; total population supplied, about 44,000. The composition of the water is practically the same as at Covington and at Cincinnati, Ohio. (For analysis see Covington.)
	LOUISIANA.
90	New Orleans (387,219); municipal; Mississippi River; filtered; softened. Analyzed in laboratory of Purification Department, Sewerage and Water Board; approximate average composition for a number of years.
91	Shreveport (43,874); municipal; Cross Bayou and Red River; filtered. In 1920 the supply was obtained from Cross Bayou for about 8 months, from Red River about 3 months, and from both sources 1 month. The pumping in 1921 was in about the same proportions. A, Tap water from Cross Bayou, analyzed by H. H. Pier, Feb. 21, 1921. B, Tap water from Red River, analyzed by H. H. Pier, Dec. 5, 1918. C, Average of analyses of composite samples from Red River made by U. S. Geological Survey in 1907–8 (Water-Supply Paper 236, p. 95).
	MAINE.
92	Bangor (25,978); municipal; Penobscot River; filtered. Analyzed by James M. Caird, Troy, N. Y. Single samples of tap water collected each month, March, 1918, to February, 1919.
93	Lewiston (31,791); municipal; Lake Auburn. Analysis furnished by State Department of Health, 1921.
94	Portland (69,272); municipal; Lake Sebago. Analyzed by James M. Caird, Troy, N. Y. (14th Annual Report of Portland Water District, p. 49, 1920).
	MARYLAND.
95	Baltimore (733,826); municipal; Gunpowder River; filtered. Analyses of composite samples for each month of 1921 made in laboratory of filtration plant.
96	Cumberland (29,837); municipal; impounding reservoir; filtered. Analysis of raw water by Maryland State Board of Health, Dec. 31, 1920.
97	Hagerstown (28,064): municipal. Supply for about 9 months from mountain springs and reservoirs; the rest of the time from Antietam Creek, filtered. Analyzed by Maryland State Board of Health, determinations on 6 samples, May, 1919, to October, 1921.
	MASSACHUSETTS.
98	Boston (748,060); Metropolitan Water District; supplies also Arlington, Belmont, Chelsea, Everett, Lexington, Malden, Medford, Melrose, Milton, Nahant, Quincy, Revere, Somerville, Stoneham, Swampscott, Watertown, Winthrop; total population supplied about 1,207,000. Nashua River impounded in Wachusett reservoir; other smaller streams and reservoirs. The Wachusett reservoir furnishes about 90 per cent of the water used, and the drainage basins from which the other water is obtained are not sufficiently different in character from that of Nashua River to make the water delivered to consumers much different from the water in the Wachusett reservoir under present methods of operation. The reservoir is so large and the mineral content of the water so low that the one analysis given may safely be taken to represent the mineral content of the Metropolitan water supply at any time. Analyzed by Margaret D. Foster, U. S. Geological Survey, May 12, 1921.

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
Avg....	426	......	37	0.73	62	18	44	202	135	13	2.2	229	83
Max....	590	......	89	3.2	91	30	68	334	179	24	5.3	348	
Min....	291	......	15	Tr.	44	9.8	29	136	87	5.5	Tr.	159	
....	391	103	14	.07	40	16	[a]97	133	93	92	51	166	84
....	[a]1772	......	24	[b]3.0	158	36	426	234	400	610	....	543	85
Avg....	[a]161	......	......	.03	33	3.7	[a]13	42	62	19	....	97	86
Max....	......	......	......	.08	44	7.0	[a]26	52	95	31	....	130	
Min....	......	......	......	.00	24	.5	[a]1.4	32	45	7	....	72	
....	170	80	3.5	.1	37	1.2	2.6	85	28	2.5	2.8	97	87
Avg....	150	......	4	[b]1.5	35	7	15	30	45	10	....	[d]85	88
Max....	230	......	6	[b]3.0	50	12	30	45	75	35	....	[d]125	
Min....	110	......	1.5	[b].5	25	1	6	18	31	8	....	[d]40	
....	......	......	......	......	......	......	....	....	....	....	....	....	89
Avg....	100	......	10	.03	15	3	13	50	25	9.6	.9	50	90
A......	[a]190	18	8.2	[b]1.7	9.9	2.4	52	28	52	50	....	35	91
B......	328	17	3.1	[b]2.0	84	.3	30	137	93	48	....	211	
C......	561	......	30	1.1	74	17	90	144	140	121	.4	255	
Avg....	78	44	1.4	.20	7.8	.8	[a]4.4	8.2	21	2.8	.04	36	92
Max....	99	64	1.8	.25	11	1.3	[a]7.7	11	24	3.5	.09	39	
Min....	57	26	1.0	.15	6.6	.6	[a]1.9	6.1	17	1.5	Tr.	30	
....	32	......	......	......	......	......	....	13	....	....	....	[d]17	93
....	22	10	2.0	.05	2.8	1.3	1.2	3.3	6.8	1.5	.66	12	94
Avg....	74	......	6.5	.07	14	4.1	3.1	47	14	5.1	1.0	52	95
Max....	88	......	16	.1	21	5.2	4.7	56	24	6.5	1.4	71	
Min....	64	......	1.7	.0	11	2.5	1.8	34	9.5	4.0	.5	41	
....	122	36	......	.0	34	1.5	[a]36	79	10	1.1	.40	91	96
Max....	78	......	......	.8	......	......	....	40	....	3.2	....	[d]120	97
Min....	26	......	......	.0	......	......	....	7	....	1.6	....	[d]8	
....	28	2.3	3.7	.02	3.0	.7	Na 2.2; K 1.0	7.0	6.0	2.1	.22	10	98

[a] Calculated. [b] Iron and aluminum oxides (Fe_2O_3+Al_2O_3). [d] Determined.

TABLE 6.—*Public water supplies of the*

No.	Description.
	MASSACHUSETTS—continued.
99	Brockton (66,254); municipal; Silver Lake and impounding reservoir. Analyzed by laboratory of Health and Water Department, 1921.
100	Brookline (37,748); municipal; tubular wells and filter gallery; filtered. Analyzed by State Board of Health, 1919.
101	Cambridge (109,694); municipal; impounding reservoirs; filtered. The quantity of dissolved mineral matter is so small that its actual composition is of little importance. The proportions of the different constituents are probably the same as in other surface waters in New England. Analyzed by Melville C. Whipple, Laboratory of Hygiene and Sanitation, Harvard University, Cambridge, July 12, 1921.
102	Chelsea (43,184); supplied by Metropolitan Water District. (See Boston)
103	Chicopee (36,214); municipal; Cooley Brook. Analyzed by State Board of Health, 1919
104	Everett (40,120); supplied by Metropolitan Water District. (See Boston)
105	Fall River (120,485); municipal; North Watuppa Lake. The composition of the small amount of dissolved mineral matter is probably very similar to that of other surface supplies in the State. Average of 32 analyses made by State Board of Health in 1918-19.
106	Fitchburg (41,029); municipal; lakes and ponds. Maximum and minimum of average analyses for year 1919 from 5 sources; analyzed by State Board of Health.
107	Haverhill (53,884); municipal; lakes and reservoirs. Maximum and minimum of analyses of samples collected from 6 sources, Apr. 20 and 21, 1921; analyzed by State Board of Health.
108	Holyoke (60,203); municipal; reservoirs. Maximum and minimum of averages for year 1919 of samples from 5 sources; analyzed by State Board of Health.
109	Lawrence (94,270); municipal; Merrimack River; filtered without coagulation. Average of analyses by State Board of Health, 1919.
110	Lowell (112,759); municipal; wells; treated for removal of iron and manganese. Average of analyses by State Board of Health, 1919.
111	Lynn (99,148); municipal; reservoirs and Saugus River. Maximum and minimum of analyses of samples from 4 reservoirs; analyzed by State Board of Health, 1919.
112	Malden (49,103); supplied by Metropolitan Water District. (See Boston)
113	Medford (39,038); supplied by Metropolitan Water District. (See Boston)
114	New Bedford (121,217); municipal; Little Quittacas Pond and Great Qnittacas Pond. The water contains so little dissolved mineral matter that the variations are of no practical importance. The composition of the mineral matter is undoubtedly similar to that of the supply for Boston. Maximum and minimum of analyses made by State Board of Health, 1920. A, Little Quittacas Pond. B, Great Quittacas Pond.
115	Newton (46,054); municipal; wells and filter gallery. Average of analyses by State Board of Health, 1919.
116	Pittsfield (41,763); municipal; brooks and reservoirs. The different sources differ in chemical character, but the water from all is mixed. Average of analyses of samples from individual sources, weighted approximately according to the quantities supplied. Analyzed by State Board of Health, 1919.
117	Quincy (47,876); supplied by Metropolitan Water District. (See Boston)
118	Revere (28,823); supplied by Metropolitan Water District. (See Boston)
119	Salem (42,529); municipal; Wenham Lake and Longham reservoir. Averages of analyses by State Board of Health, 1919. A, Wenham Lake. B. Longham reservoir.
120	Somerville (93,091); supplied by Metropolitan Water District. (See Boston)
121	Springfield (129,614); municipal; Westfield Little River; filtered without coagulation. Analyzed by H. F. Salmonde, municipal waterworks. Average from March, 1920, to February, 1921.
122	Taunton (37,137); municipal; Assawompsett Pond and Elder's Pond. Average of analyses by State Board of Health, 1919.
123	Waltham (30,915); municipal; wells. Average of analyses by State Board of Health, 1919
124	Worcester (179,754); municipal; impounding reservoirs. The composition of the dissolved mineral matter is probably very similar to that of the water in Wachusett reservoir, an analysis of which is given for the Boston supply. Average of analyses of samples from 6 reservoirs of Worcester supply; analyzed by State Board of Health, 1919.
	MICHIGAN.
125	Battle Creek (36,164); municipal; 15 wells 110 to 131 feet deep. Analysis of sample from Verona station of Battle Creek waterworks, by Margaret D. Foster, U. S. Geological Survey, Mar. 3, 1922.
126	Bay City (47,554); municipal; Saginaw Bay; filtered. Analysis of unfiltered water from Saginaw Bay by C. S. Howard, U. S. Geological Survey, June 20, 1922.
127	Detroit (993,678); municipal; Detroit River. Supplies Hamtramck and a number of smaller communities. Total population supplied about 1,050,000. Analyzed by W. M. Wallace, chemist, Detroit waterworks, July, 1921.

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
....	a 31	2.0	3.9	b 2.4	2.2	1.1	4.3	8.1	6.1	4.6	....	10	99
....	89	......	......	.10	......	......	....	....	....	7.7	....	d 40	100
....	73	23	......	.15	......	......	....	20	....	7.0	1.2	d 28	101
....	......	......	......	......	......	......	....	....	....	....	....	....	102
Avg....	37	......	......	......	......	......	....	....	....	2.1	....	d 14	103
....	......	......	......	......	......	......	....	....	....	....	....	....	104
Avg....	41	16	......	.14	......	......	....	....	....	6.2	....	d 14	105
Max....	35	......	......	......	......	......	....	....	....	2.3	....	d 11	106
Min....	30	......	......	......	......	......	....	....	....	1.9	....	d 7	
Max....	69	19	......	.85	......	......	....	....	....	6.1	....	d 29	107
Min....	31	11	......	.05	......	......	....	....	....	3.4	....	d 10	
Max....	55	......	......	......	......	......	....	....	....	2.2	....	d 29	108
Min....	41	......	......	......	......	......	....	....	....	1.7	....	d 17	
Avg....	61	......	......	......	......	......	....	....	....	4.8	....	d 11	109
Avg....	64	......	......	.22	......	......	....	....	....	4.9	....	d 24	110
Max....	62	......	......	......	......	......	....	....	....	7.5	....	d 23	111
Min....	54	......	......	......	......	......	....	....	....	6.4	....	d 20	
....	......	......	......	......	......	......	....	....	....	....	....	....	112
....	......	......	......	......	......	......	....	....	....	....	....	....	113
A {Max.	44	26	......	.55	......	......	....	....	....	5.6	....	d 11	114
A {Min.	32	12	......	.15	......	......	....	....	....	4.0	....	d 3	
B {Max.	52	25	......	.50	......	......	....	....	....	5.8	....	d 16	
B {Min.	32	15	......	.12	......	......	....	....	....	4.0	....	d 2	
Avg....	61	......	......	.05	......	......	....	....	....	4.9	....	d 26	115
Avg....	50	......	......	......	......	......	....	....	....	1.5	....	d 35	116
....	......	......	......	......	......	......	....	....	....	....	....	....	117
....	......	......	......	......	......	......	....	....	....	....	....	....	118
A......	75	......	......	......	......	......	....	....	....	9.0	....	d 24	119
B......	72	......	......	......	......	......	....	....	....	9.0	....	d 20	
....	......	......	......	......	......	......	....	....	....	....	....	....	120
Avg....	33	......	4.4	b 2.1	3.3	1.1	....	5.9	....	i 1.6	....	13	121
Av.....	41	......	......	......	......	......	....	....	....	5.0	....	d 8	122
Avg....	83	......	......	.38	......	......	....	....	....	7.2	....	d 38	123
Avg....	41	......	......	......	......	......	....	....	....	2.6	....	d 14	124
....	288	6.0	14	.08	71	23	{Na 2.0 {K 1.3	278	43	3.0	.36	272	125
....	267	25	21	.30	53	13	13	165	41	18	3.1	186	126
....	a 99	......	1	.2	27	7.0	2	102	7.4	4.5	.08	96	127

a Calculated.
b Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
d Determined.
i Average for year 1919 reported by Massachusetts State Board of Health.

TABLE 6.—*Public water supplies of the*

No.	Description.
	MICHIGAN—continued.
128	Flint (91,599); municipal; Flint River; Filtered; Softened since Jan. 23, 1923. Analyzed by R. S. Buzzell, filtration-plant laboratory. A, Filtered water in 1921. B, Softened water in January, 1923.
129	Grand Rapids (137,634); municipal; Grand River; filtered. Analyses of composite monthly samples by W. A. Sperry, waterworks laboratory, November, 1920, to June, 1921.
130	Hamtramck (48,615); supplied by Detroit. (See Detroit)..
131	Highland Park (46,499); municipal; Lake St. Clair; filtered. Typical analysis by waterworks laboratory, 1922.
132	Jackson (48,374); municipal; wells 350 feet deep. Analysis furnished by State Board of Health, 1922
133	Kalamazoo (48,487); municipal; wells 30 feet and 70 to 125 feet; all the water is probably from the same geologic formation. Analyzed by State Board of Health, 1922.
134	Lansing (57,327); municipal; wells 350 feet deep. Analyzed by State Board of Health, Aug. 12, 1919, from group of wells at Pennsylvania Avenue substation, which furnishes most of supply.
135	Muskegon (36,570): municipal; Lake Michigan. Analyses of Lake Michigan at St. Ignace made by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 73) are fairly representative of the quality of the lake water at Muskegon.
136	Pontiac (34,273); municipal; wells about 200 feet deep; Dawson's Pond; filtered. A, Wells. B, Dawson's Pond. Analyzed by C. S. Howard, U. S. Geological Survey, June 13, 1922.
137	Port Huron (25,944); municipal; Lake Huron. Analyzed by U. S. Geological Survey, 1906-7 (Water-Supply Paper 236, p. 65).
138	Saginaw (61,903); Saginaw River. Analyzed by Margaret D. Foster, U. S. Geological Survey, Aug. 16, 1922.
	MINNESOTA.
139	Duluth (98,917); municipal; Lake Superior. Partial analyses of samples taken in July and August, 1921, indicate that the composition of the water is practically the same as found at Sault Ste. Marie by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 101).
140	Minneapolis (380,582); municipal; Mississippi River; filtered. Analyses of monthly composite samples of combined filter effluent, Minneapolis Waterworks Department, 1921.
141	St. Paul (234,698); municipal. The main supply is from lakes and is supplemented part of the time by water from wells. A, Lake water from screen chamber at McCarron pumping station, Apr. 19, 1921. B, Wells at McCarron station, Sept. 6, 1921. C, Average of 7 analyses of tap water between Jan. 1 and Mar. 3, 1922. Analyzed by R. A. Thuma, laboratory, Division of Water Purification.
	MISSISSIPPI.
142	Jackson (22,817); municipal; Pearl River; filtered. The coagulation and filtration of the water probably reduce the silica to about 5 or 6 parts per million, slightly increase the sulphate, and decrease the bicarbonate, but the general character of the water is not greatly changed by the treatment. Analyzed by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 89).
143	Meridian (23,399); municipal; reservoirs; filtered. The coagulation and filtration reduce the silica to about 5 parts per million and the iron to less than 1 part. The other changes in composition are not of much importance. Analysis of unfiltered water by Margaret D. Foster, U. S. Geological Survey, Aug. 27, 1919.
	MISSOURI.
144	Joplin (29,902); Joplin Waterworks Co. (controlled by the American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.); Shoal Creek; filtered. Analyzed by Margaret D. Foster, U. S. Geological Survey, Mar. 10, 1922.
145	Kansas City (324,410); municipal; Missouri River; filtered. The analyses of the river water at Kansas City, Kans., show the probable composition of the water supplied in Kansas City, Mo., except for the reduction in silica caused by the coagulation. The silica is probably less than 10 parts per million. Average, maximum, and minimum analyses of Missouri River at Kansas City, Kans., by U. S. Geological Survey, in 1906-7. (Water-Supply Paper 236, p. 79).
146	St. Joseph (77,939); St. Joseph Water Co. (controlled by American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.); Missouri River; filtered. The chemical character of the water is represented fairly well by the analyses of Missouri River water given for Kansas City. (See Kansas City.)

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
A Avg.	[a] 380	......	6	[b] 7	80	28	Na 15, K 6	[a] 342	64	5.5	0.27	315	128
A Max.	......	......	10	[b] 13	120	35	Na 20, K 10	......	125	9.0	.33	......	
A Min.	......	......	2	[b] 3.0	60	20	Na 3.0, K 2.0	......	10	3.0	.23	......	
B	265	......	6	......	32	24	Na 10, K 3	140	60	5.5	......	178	
Avg....	203	......	6.5	[b] 3.0	31	14	9.4	84	62	9	......	136	129
Max....	234	......	......	......	39	20	15	110	81	11	......	168	
Min....	185	......	......	......	24	8.6	1.6	60	38	7	......	118	
......	......	......	......	......	......	......	......	......	......	......	......	......	130
......	150	......	1	.02	27	7.0	2.1	102	7.4	4.5	.08	96	131
......	495	......	15	[b] .7	77	24	[a] 77	355	41	88	......	290	132
......	330	......	14	......	75	26	[a] 3.8	319	29	7.6	......	298	133
......	416	......	12	[b] 1.4	95	30	[a] 5.6	364	62	6.0	......	360	134
Avg....	118	......	10	.04	26	8.2	4.7	118	7.2	2.7	.3	99	135
A	355	8.4	18	.87	61	13	42	320	10	27	Tr....	206	136
B	195	9.4	4.4	.12	38	8.9	16	183	16	2.9	Tr....	131	
Avg....	108	......	12	.04	24	7.0	4.4	104	6.2	2.6	.4	89	137
......	394	1.2	10	.12	68	21	Na 36, K 2.7	215	57	66	.78	256	138
Avg....	60	......	7.4	.06	13	3.1	3.2	56	2.1	1.1	.5	45	139
Avg....	[a] 191	......	9.1	.05	42	16	7.8	172	28	2.1	.25	171	140
Max....	......	......	16	.10	53	19	12	232	54	2.8	.57	......	
Min....	......	......	6.0	.03	35	13	3.2	92	15	1.8	.12	......	
A	180	79	......	.2	37	12	([j])	118	12	3.2	.2	142	141
B	270	64	......	.2	62	26	[a] 19	336	24	1.9	.0	262	
C	211	91	......	.16	42	19	[a] 5.0	213	16	1.9	......	183	
Avg....	59	......	18	.37	7.1	1.1	8.9	32	6.4	3.4	.7	22	142
Max....	79	......	32	2.8	12	2.1	14	56	11	6.0	2.2	35	
Min....	36	......	8.9	Tr.	4.0	Tr.	4.7	12	4.7	1.8	Tr.	11	
......	56	3.9	29	6.4	1.6	.4	6.8	15	3.1	3.4	Tr.	6	143
......	175	3.8	8.6	.12	49	5.6	Na 4.1, K 1.3	149	20	3.0	6.4	145	144
Avg....	426	......	37	.73	62	18	44	202	135	13	2.2	229	145
Max....	590	......	89	3.2	91	30	68	334	179	24	5.3	348	
Min....	291	......	15	Tr.	44	9.8	29	136	87	5.5	Tr.	159	
......	......	......	......	......	......	......	......	......	......	......	......	......	146

[a] Calculated.
[b] Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
[j] Less than 10 parts.

TABLE 6.—*Public water supplies of the*

No.	Description.
	MISSOURI—continued.
147	St. Louis (772,897); municipal; Mississippi River; filtered. Analyses of semimonthly composite samples July 1, 1920, to June 30, 1921, made by St. Louis Waterworks laboratory.
148	Springfield (39,631); Springfield City Water Co.; springs and wells. Analyzed by R. Neal, Drury College, Springfield, Nov. 25, 1921.
	MONTANA.
149	Butte (41,611); Butte Water Co.; reservoirs. Average of analyses of samples collected Oct. 16, 1912, from Basin Creek, from Moulton supply, and from Bighole River. Analyzed for U. S. Geological Survey by S. C. Dinsmore.
150	Great Falls (24,121); municipal; Missouri River; filtered. Analyzed by W. M. Cobleigh, Montana State College, Bozeman, Mont., Aug. 28, 1920.
	NEBRASKA.
151	Lincoln (54,948); municipal; wells 190 to 200 feet deep. Analyzed by Margaret D. Foster, U. S. Geological Survey, Oct. 17, 1921.
152	Omaha (191,601); municipal; Missouri River at Florence; filtered. The changes in composition of the dissolved mineral matter due to the chemicals used in treatment are insignificant compared to those that take place with the changes in stage of the river. The analyses of filtered composite samples made by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 78) may safely be taken to represent the general chemical character of water used in Omaha.
	NEVADA.
153	Reno (12,016); Truckee River; Truckee River General Electric Co., under management of Stone & Webster (Inc.). Analyzed by Wayne B. Adams, University of Nevada, Aug. 21, 1922.
154	Tonopah (4,144); Water Co. of Tonopah; wells. Analyzed by S. C. Dinsmore, Nevada State Board of Health (Report of Department of Food and Drugs Control, Weights and Measures, and Soils and Water Laboratory for period ending Dec. 31, 1918, p. 23).
	NEW HAMPSHIRE.
155	Manchester (78,384); municipal; Lake Massabesic. Average of analyses by State Board of Health, 1902-1909.
156	Nashua (28,379); Pennichuck Waterworks Co.; flowing wells. Average of analyses by State Board of Health, 1902-1910.
	NEW JERSEY.
157	Atlantic City (50,707); municipal; wells and impounding reservoirs. Analyzed by Dearborn Drug & Chemical Co., 1908.
158	Bayonne (76,754); East Jersey Water Co.; Passaic River at Little Falls; filtered. The East Jersey Water Co. also supplies Bloomfield, East Newark, Harrison, Kearny, Little Falls, and Nutley; total population supplied about 157,000. The filtration plant is operated by the Montclair Water Co. and furnishes water also to Acquackanonk Water Co., Montclair Water Co., and Passaic Water Co. Total population supplied by the 4 companies about 421,000. The East Jersey Water Co. distributes only filtered water. Analyzed in laboratory of Montclair Water Co., Little Falls, N. J., 1920. A, Filtered water. B, Unfiltered water furnished for industrial use.
159	Camden (116,309); municipal; wells, 100 to 150 feet deep. Analyzed by Margaret D. Foster, U. S. Geological Survey, Mar. 24, 1922.
160	Clifton (26,470); Acquackanonk Water Co.; Passaic River at Little Falls; filtered. Also supplies Passaic. Total population supplied about 90,000. (See Bayonne, analyses A.)
161	East Orange (50,710); municipal; wells 125 to 225 feet deep. Analysis of sample of tap water by Margaret D. Foster, U. S. Geological Survey, Feb. 23, 1922.
162	Elizabeth (95,783); Elizabethtown Water Co.; also supplies Irvington (25,480); 12 different sources. Average of analyses of water from 6 sources used by Elizabethtown Water Co., by State Board of Health.

larger cities of the United States—Continued.

	Analyses (parts per million).												No.
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	
Avg....	201	......	8.3	[b]2.7	22	12	26	[k] 65	77	10	3.8	[d] 104	147
Max....	255	......	12	[b]4.0	32	19	32	[l] 116	107	16	5.8	[d] 145	
Min....	165	......	5.2	[b].6	18	4.2	14	[m] 41	55	6.5	2.3	[d] 80	
....	[a] 270	......	8	[b]1.5	71	4.3	[a] 20	208	59	4.8	....	195	148
....	93	......	24	.4	16	3.8	Tr.	48	10	2.8	....	56	149
....	193	......	......	Tr.	37	14	[a] 2.7	137	33	6.3	....	150	150
....	347	5.2	36	.17	62	16	Na 28, K 6.4	259	53	11	3.1	221	151
Avg....	454	......	31	.44	65	20	49	203	168	8.9	1.8	244	152
Max....	663	......	76	2.0	102	38	72	337	237	15	5.5	411	
Min....	300	......	10	Tr.	45	7.9	34	146	81	5.0	Tr.	155	
....	84	......	15	[b].8	13	.8	Na 11, K 1.6	68	5.6	8.0	....	36	153
....	273	......	60	.2	51	14	8	141	38	16	11	185	154
Avg....	45	20	......	......	......	......	......	......	......	2.0	....	[d] 6	155
Avg....	45	15	......	......	......	......	......	......	......	2.0	....	[d] 20	156
....	[a] 38	......	6.4	[b]1.0	1.2	1.8	8.2	5.5	5.6	11	....	10	157
A Avg.	88	......	......	.2	([n])	......	......	24	19	4.7	1.7	[d] 40	158
A Max.	133	......	......	.3	......	......	......	40	29	6.0	11	[d] 56	
A Min.	53	......	......	.0	......	......	......	10	11	3.3	.0	[d] 26	
B Avg.	91	......	......	.4	([o])	......	......	35	12	4.6	2.2	[d] 40	
B Max.	136	......	......	.6	......	......	......	50	19	6.0	13	[d] 56	
B Min.	55	......	......	.2	......	......	......	16	3	3.0	.0	[d] 26	
....	66	6.0	6.2	.06	8.3	5.2	Na 4.6, K .7	25	13	5.4	9.1	42	159
....	......	......	......	......	......	......	......	......	......	......	....	....	160
....	153	3.2	24	.06	29	9.6	Na 5.0, K 1.2	112	20	4.7	3.6	112	161
Avg....	267	67	......	.2	......	......	......	100	......	8.8	....	[d] 100	162

[a] Calculated.
[b] Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
[d] Determined.
[k] Calculated from HCO_3, 44.9, and CO_3, 9.7 parts.
[l] Calculated from HCO_3, 98.8, and CO_3, 8.4 parts; maximum CO_3 16.
[m] Calculated from HCO_3, 12.2, and CO_3, 14.4 parts; minimum CO_3 1.2.
[n] Single determination, Apr. 13, 1921, 9.2 parts per million.
[o] Single determination, Apr. 13, 1921, 9.0 parts per million.

TABLE 6.—*Public water supplies of the*

No	Description.
	NEW JERSEY—continued.
163	Hoboken (68,166); Hackensack Water Co.; Hackensack River; filtered. Supplies Guttenberg, Secaucus, Union, West Hoboken, West New York, North Bergen, and Weehawken (in Bergen County); Bergenfields, Bogota, Carlstadt, Cliffside, Closter, Cresskill, Delford, Demarest, Dumont, East Rutherford, Edgewater, Englewood, Englewood Cliffs, Fairview, Hackensack, Hasbrouck Heights, Leonia, Little Ferry, Lodi, Maywood, Overpeck, Palisades Park, Palisades Township, Ridgefield, Riverside, Rutherford, Teaneck, Tenafly, Wallington, Westwood, and Woodridge; total population supplied about 256,000. On account of the large reservoir capacity and the comparatively small quantity of dissolved mineral matter, a single representative analysis is sufficient. Analyzed by G. R. Spalding, Hackensack Water Co., New Milford, N. J., Apr. 19, 1921.
164	Irvington (25,480); supplied by Elizabethtown Water Co., Elizabeth, N. J. (See Elizabeth)......
165	Jersey City (298,103); municipal; impounding reservoir, Boonton, N. J. A, Analysis of water at Summit Avenue gate house by Margaret D. Foster, U. S. Geological Survey, Feb. 7, 1922. B, Average, maximum, and minimum analyses made in laboratory of City Bureau of Water on weekly samples for year 1921.
166	Kearney (26,724); supplied by East Jersey Water Co. (See Bayonne)............................
167	Montclair (28,810); Montclair Water Co.; Passaic River at Little Falls; filtered. Also supplies Essex County institutions; total population supplied about 32,000. (See Bayonne, analyses A.)
168	New Brunswick (32,779); municipal; Lawrence Brook; filtered. Analyzed by Margaret D. Foster, U. S. Geological Survey, Feb. 8, 1922.
169	Newark (414,524); municipal; impounding reservoir. Analyses of monthly samples by Justus Goslau, Bureau of Water, Newark, 1920.
170	Orange (33,268); municipal; Orange reservoir; Campbells Pond. Analyzed by State Board of Health.
171	Passaic (63,841); Acquackanonk Water Co.; Passaic River at Little Falls; filtered. (See Bayonne, analyses A.)
172	Paterson (135,875); Passaic Water Co.; Passaic River at Little Falls; filtered; unfiltered water is also supplied for industrial use. Prospect Park and Totowa are furnished with filtered water, making the total population supplied about 142,000. (For analyses see Bayonne.)
173	Perth Amboy (41,707); municipal; wells 80 feet deep at Runyon, N. J. Analyzed by Margaret D. Foster, U. S. Geological Survey, Feb. 25, 1922.
174	Plainfield (27,700); Union Water Co.; deep wells. Analyzed by State Board of Health............
175	Trenton (119,289); municipal; Delaware River; filtered. Analyses of Delaware River at Lambertville made by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 60).
176	West Hoboken (40,074); supplied by Hackensack Water Co., New Milford, N. J. (See Hoboken).....
177	West New York (29,926); supplied by Hackensack Water Co., New Milford, N. J. (See Hoboken)..
	NEW MEXICO.
178	Albuquerque (15,157); municipal; wells 60 to 700 feet deep. Most of the water is from the 75 to 80-foot level. Analyzed by John D. Clark, Jan. 28, 1922.
179	Santa Fe (7,236); Santa Fe Water & Light Co.; impounding reservoir on Santa Fe Creek. Analyzed by C. C. Young, University of Kansas, about 1917.
	NEW YORK.
180	Albany (113,344); municipal; Hudson River; slow sand filtration. Analyses of water from Hudson River at Hudson by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 64).
181	Amsterdam (33,524); municipal; Hawes Creek; impounded. Average analysis by State Board of Health.
182	Auburn (36,192); municipal; Owasco Lake. The composition of the water is probably not very different from that supplied at Rochester and Syracuse from similar lakes. Analysis by State Board of Health.
183	Binghamton (66,800); municipal; Susquehanna River (filtered), and small amounts of well water, up to 10 per cent of total supply. The well waters are harder and contain more chloride than the river water. Partial analyses at Binghamton indicate that the river water has practically the same composition as at West Pittston, Pa. Average of analyses of water from Susquehanna River at West Pittston by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 102).
184	Buffalo (506,775); municipal; Lake Erie. Average of analyses of water from Lake Erie by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 62).
185	Elmira (45,393); municipal; storage reservoir furnishes 35 to 40 per cent of supply; remainder from Chemung River, filtered. Average analysis from storage reservoir by State Board of Health.
186	Jamestown (38,917); municipal; wells 100 to 130 feet deep. Analysis furnished by Department of Water and Lighting, Sept. 20, 1921.

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
....	112	37	1.9	[b]1.5	17	5.4	[a]2.4	37	30	6.2	....	65	163
....	....	....	....	....	....	....	....	....	....	....	....	....	164
A......	81	3.5	6.5	.08	13	5.6	Na 3.6 K 1.0	40	22	5.1	1.1	55	165
B Avg.	78	31	....	....	....	....	....	29	....	5.1	....	[d]41	
B Max.	106	50	....	....	....	....	....	50	....	7.4	....	[d]57	
B Min.	54	13	....	....	....	....	....	18	....	3.6	....	[d]26	
....	....	....	....	....	....	....	....	....	....	....	....	....	166
....	....	....	....	....	....	....	....	....	....	....	....	....	167
....	42	4.0	4.7	.39	3.8	2.0	Na 2.2 K .9	0	17	3.0	1.1	18	168
Avg....	56	17	1.7	[b]1.2	9.7	2.6	[a].8	22	12	2.0	.06	35	169
Max....	70	20	3.6	[b]2.0	15	3.1	....	28	19	2.2	.10	50	
Min....	49	15	1.0	[b]1.0	7.1	2.1	....	14	8.0	2.0	.04	27	
....	110	44	....	....	....	....	....	62	....	7.5	....	[d]66	170
....	....	....	....	....	....	....	....	....	....	....	....	....	171
....	....	....	....	....	....	....	....	....	....	....	....	....	172
....	38	2.9	5.2	.31	2.3	1.9	Na 2.2 K .5	0	[p]21	1.5	Tr.	14	173
....	275	70	....	.6	....	....	....	144	....	8.5	....	[d]150	174
Avg....	70	....	9.0	.07	12	3.3	5.4	46	12	2.9	1.1	44	175
Max....	109	....	22	.20	19	5.2	9.1	72	19	5.4	2.1	61	
Min....	46	....	3.0	Tr.	7.8	1.0	3.0	28	9.2	1.8	.5	24	
....	....	....	....	....	....	....	....	....	....	....	....	....	176
....	....	....	....	....	....	....	....	....	....	....	....	....	177
....	406	....	62	[b]1.5	38	20	53	240	83	30	.13	177	178
....	[a]33	....	9.6	....	5.6	1.3	2.2	24	....	2.0	....	20	179
Avg....	108	....	11	.15	21	3.8	7.9	73	16	4.0	.8	68	180
Max....	135	....	27	.42	26	5.8	12	95	23	6.2	2.1	89	
Min....	63	....	4.2	.05	15	1.0	4.6	48	9.7	1.2	.0	45	
Avg....	64	31	....	....	....	....	....	23	....	.8	....	[d]25	181
....	136	20	....	....	....	....	....	122	....	2.2	....	[d]103	182
Avg....	90	....	10	.12	18	3.4	6.3	63	14	4.2	1.5	59	183
Avg....	133	....	5.9	.07	31	7.6	6.5	120	13	8.7	.3	109	184
Avg....	151	37	....	....	....	....	....	89	....	3.6	....	[d][q]80	185
....	[a]122	....	....	.1	25	7.5	[a]9	116	4.8	9.0	....	94	186

a Calculated.
b Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
d Determined.
p Includes free sulphuric acid (H_2SO_4), 3.0 parts per million.
q Average hardness of river water, 150 parts per million.

TABLE 6.—*Public water supplies of the*

No.	Description.
	NEW YORK—continued.
187	Kingston (26,688); municipal; mountain stream and impounding reservoirs; filtered. Average analysis by State Board of Health.
188	Mount Vernon (42,726); New York Interurban Water Co.; Mamaroneck River at Mamaroneck, with additional supply from Hutchinson River. Also supplies town of Harrison, village of Mamaroneck, including Orienta and Rye Neck, town of Mamaroneck, outside of villages, village of Pelham, part of village of Rye; total population supplied about 55,500. Analyzed by State Board of Health, November, 1921.
189	New Rochelle (36,213); New Rochelle Water Co.; impounding reservoirs. Average of analyses, November, 1920, to September, 1921, by Pease Laboratories, New York.
190	New York (5,620,048); municipal. A, Croton reservoir, available supply 395,000,000 gallons a day. B, Catskill reservoir, available supply 395,000,000 gallons a day. C, Ridgewood supply, 50,000,000 gallons a day of surface water and 100,000,000 gallons a day from wells and infiltration galleries. In addition about 20,000,000 gallons a day from the Bronx mixes with the Catskill supply in Kensico reservoir, and about 50,000,000 gallons a day can be obtained from wells of private water companies and from well systems not connected with the Ridgewood supply. The supplies from wells generally contain more mineral matter and are harder than the supplies for which analyses are given. Analyses A and B made by Margaret D. Foster, U. S. Geological Survey, Mar. 8, 1921. C, Typical analysis made at Mount Prospect Laboratory, Brooklyn, before 1917.
191	Newburgh (30,366); municipal; reservoir. Analyzed by State Board of Health, June 3, 1921......
192	Niagara Falls (50,760); municipal; Niagara River. The chemical composition of the water is practically the same as that of Lake Erie at Buffalo. (See Buffalo.)
193	Poughkeepsie (35,000); municipal; Hudson River; filtered. The chemical composition of the water is practically the same as that of Hudson River at Hudson. (See Albany.)
194	Rochester (295,750); municipal; Hemlock Lake. Analyzed by Margaret D. Foster, U. S. Geological Survey, June 14, 1921.
195	Rome (26,341); municipal; Fish Creek. Analyzed by State Board of Health......................
196	Schenectady (88,723); municipal; infiltration galleries. Analyzed by State Board of Health.......
197	Syracuse (171,717); municipal; Skaneateles Lake. Analyzed by Margaret D. Foster, U. S. Geological Survey, June 14, 1921.
198	Troy (72,013); municipal; reservoirs. Tomhannock reservoir furnishes 11,500,000 gallons to "lower service" and 2,000,000 gallons to "middle service;" Grafton system of reservoirs furnishes 2,500,000 gallons to "upper service." The drainage basins are continuous and adjacent. The analysis of water from the "lower service" may be taken to represent the average composition of water supplied in the city. Analyzed by J. M. Caird, Troy, Sept. 4, 1919.
199	Utica (94,156); Consolidated Water Co. of Utica, N. Y.; West Canada Creek (about 80 per cent) and reservoirs in a southern drainage basin (about 20 per cent). A, West Canada Creek (Bacot reservoir, north supply). B, reservoir No. 4, southern basin. A and B analyzed by Margaret D. Foster, U. S. Geological Survey, May 8, 1922. C, West Canada Creek. D, Reservoir No. 4. C and D, averages of determinations of hardness for 1920-21, made at waterworks laboratory.
200	Watertown (31,285); municipal; Black River; filtered. Average analysis by State Board of Health.
201	Yonkers (100,176); municipal; Nepperhan River; filtered, with about 10 per cent of unfiltered water from a reservoir. Analyzed by Dearborn Chemical Co., Chicago, Ill., November, 1920.
	NORTH CAROLINA.
202	Asheville (28,504); municipal; impounding reservoir. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 18, 1922.
203	Charlotte (46,338); municipal; Catawba River; filtered. Analyzed by Margaret D. Foster, U. S. Geological Survey; Apr. 3, 1922.
204	Wilmington (33,372); municipal; Cape Fear River; filtered. At times of low water the river is contaminated with sea water, which has sometimes made the supply unsatisfactory. The average of analyses made in 1906-7 by the U. S. Geological Survey (Water-Supply Paper 236, p. 52) may be taken to represent the river water when not contaminated with sea water.
205	Winston-Salem (48,395); municipal; Salem Creek; impounded; filtered. Average determinations of bicarbonate and chloride indicate that the water is like the supply of Wilmington. (See Wilmington.)
	NORTH DAKOTA.
206	Fargo (21,961); municipal; Red River; filtered; softened. A, Analysis of unfiltered water by H. B. Riffenburg, U. S. Geological Survey, June 25, 1921. B, Analyses of filtered water, which represent about the average, maximum, and minimum contents of dissolved solids over a period of several years; analyzed by Roberts Hulbert, North Dakota Agricultural College.
207	Grand Forks (14,010); municipal; Red Lake River; filtered. Analyzed by A. E. McCoy, State Public Health Laboratories, Dec. 29, 1920.

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
Avg....	41	13	......	......	......	......	....	4	....	1.2	....	d 14	187
....	166	106	......	0.4	......	......	....	....	....	16	....	d 45	188
Avg....	65	......	......	.4	......	......	....		....	8.6	....	d 34	189
A......	69	3.1	9.6	.05	12	4.4	Na 1.7 K 1.2	41	11	2.6	0.88	48	190
B......	28	2.5	2.6	.04	4.5	1.2	Na 1.1 K .6	11	7.7	1.0	.49	16	
C......	131	17	13	.7	11	4.3	Na 11 K 2.7	10	12	13	4.3	45	
....	......	......	......	......	......	......	....	55	....	2.4	....	d 47	191
....	......	......	......	......	......	......	....	....	....	....	....	....	192
....	......	......	......	......	......	......	....	....	....	....	....	....	193
....	91	4.9	1.9	.20	20	5.2	Na 3.0 K 1.1	67	18	2.0	.38	71	194
....	80	20	......	.1	......	......	....	....	....	3.8	....	d 38	195
....	180	20	......	......	......	......	....	154	....	3.4	....	d 131	196
....	124	7.7	1.5	.24	33	6.1	Na 1.7 K .8	113	13	1.5	.96	108	197
....	75	30	3.8	.20	11	1.3	3.6	30	8.2	2.0	1.3	33	198
A......	50	4.5	5.2	.26	8.8	2.2	Na 1.3 K .2	23	11	.7	1.0	31	199
B......	78	5.5	3.6	.11	15	5.4	Na 1.7 K .6	46	23	1.2	1.1	60	
C......	......	......	......	......	......	......	....	....	....	....	....	d 44	
D......	......	......	......	......	......	......	....	....	....	....	....	d 76	
Avg....	88	12	......	r .2	......	......	....	21	....	2.0	....	d 46	200
....	a 182	......	6.4	r .3	22	12	25	130	26	14	7.7	104	201
....	19	2.7	7.8	.05	.8	.6	Na 1.8 K .5	7.3	1.7	.7	Tr.	4	202
....	57	1.9	8.4	.09	11	2.2	Na 2.0 K .8	16	23	1.5	.43	37	203
Avg....	57	......	9.9	.78	5.0	1.5	7.2	25	3.2	5.8	.2	19	204
....	......	......	......	......	......	......	....	r 24	....	r 3	....	....	205
A......	361	7.2	20	Tr.	50	34	a 21	261	83	6.0	1.6	264	206
B, Avg..	a 188	......	20	b 1.5	16	27	6.5	s 134	45	6	0	d 150	
B, Max..	a 294	......	30	b 2.5	18	40	23	t 219	60	12	0	d 210	
B, Min..	a 87	......	12	b .5	7.6	15	1	u 91	4	3	0	d 80	
....	226	58	......	Tr.	35	10	7.0	118	38	5.0	....	128	207

a Calculated.
b Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
d Determined.
r Average of determinations at waterworks.
s Includes equivalent of 24 parts per million of CO_2.
t Includes equivalent of 42 parts per million of CO_2.
u Includes equivalent of 12 parts per million of CO_2

TABLE 6.—*Public water supplies of the*

No.	Description.
	OHIO.
208	Akron (208,435); municipal; Cuyahoga River; filtered. Average of analyses of composite samples by Akron Waterworks laboratory, 1921.
209	Canton (87,091); municipal; 3 groups of wells. A, 62 wells, 80 to 100 feet deep, in gravel in the valley of Nimishillen Creek in the western part of the city; B, 2 drilled wells, 335 feet deep, in sandstone in the northeast section of the city; C, about 20 wells, 150 feet deep, in gravel outside the city limits northeast of the city. A, Average of 14 analyses from May 9, 1907, to March 21, 1918. B, Average of 3 analyses June 10 to June 15, 1916. C, Average of 3 analyses May 10, 1917. All analyses by the State Board of Health.
210	Cincinnati (401,247); municipal; Ohio River; filtered. Analyses for a year of composite monthly samples of filtered water (annual report of Cincinnati Waterworks, 1917-18, p. 73).
211	Cleveland (796,841); municipal; Lake Erie; filtered. Also supplies East Cleveland, Lakewood, and a number of other communities; total population supplied about 925,000. Average of analyses of monthly composites made in Cleveland Waterworks laboratory, 1921.
212	Columbus (237,031); Scioto River impounded; filtered and partly softened. A, Average, maximum, and minimum of determinations made in 1920. B, Analysis of softened water made in 1921. Analyzed by C. P. Hoover, Water Softening & Purification Works, Columbus.
213	Dayton (152,559); municipal; wells about 60 feet deep. Analyzed by Margaret D. Foster, U. S. Geological Survey, Aug. 21, 1922.
214	East Cleveland (27,292); supplied by Cleveland. (See Cleveland)
215	Hamilton (39,675); municipal; wells 100 feet deep. Analyzed by C. W. Foulk, Ohio State University, April, 1915.
216	Lakewood (41,732); municipal; obtains supply from Cleveland. (See Cleveland)
217	Lima (41,323); municipal; Ottawa River; impounded; filtered. Average, maximum, and minimum results of analyses of monthly composite samples of filtered water by Lima Waterworks laboratory, 1921.
218	Lorain (37,295); municipal; Lake Erie; filtered. Determinations of alkalinity made at the filtration plant from 1917 to 1921 indicate that the composition of the water is not very different from that at Cleveland. (For analyses see Cleveland.)
219	Mansfield (27,824); municipal; wells, 160 to 180 feet deep. Analyzed by C. W. Foulk, Ohio State University, 1915.
220	Marion (27,891); Marion Water Co.; wells about 135 feet deep. Analyzed by C. W. Foulk, Ohio State University, 1915.
221	Newark (26,718); municipal; Licking River; filtered. Analyzed by State Board of Health, Jan. 26, 1920.
222	Portsmouth (33,011); municipal; Ohio River; filtered. The composition of the filtered water is not very different from that of the water at Cincinnati. (See Cincinnati.)
223	Springfield (60,840); municipal; wells 30 feet in diameter and 22 feet deep. Analyzed by C. W. Foulk, Ohio State University, 1915.
224	Steubenville (28,508); municipal; Ohio River; filtered. Partial analyses made at the filtration plant indicate that the composition of the water is practically the same as at Cincinnati. (For analysis see Cincinnati.)
225	Toledo (243,164); municipal; Maumee River; filtered. Treated regularly with iron sulphate and lime, but part of the time with alum. Analyses from annual report of Water Department of Public Service, Toledo, 1921.
226	Warren (27,050); municipal; Mahoning River; filtered. Analyzed by P. J. O'Connor, Warren Waterworks, Oct. 4, 1921.
227	Youngstown (132,358); municipal; Mahoning River; filtered. Analysis of filtered water by William I. Van Arnum, 1921.
228	Zanesville (29,569); municipal; wells about 100 feet deep in gravel. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 25, 1922.
	OKLAHOMA.
229	Muskogee (30,277); municipal; Grand River; treated with iron sulphate and lime, not filtered. Single analysis by Orlin D. Horne, State Board of Health, Oct. 21, 1921.
230	Oklahoma City (91,295); municipal; North Canadian River; filtered. Analyzed by Orlin D. Horne, State Board of Health, Oct 22, 1921.
231	Tulsa (72,075); municipal; Arkansas River; filtered. Analyses of water from Arkansas River at Arkansas City, Kans., by University of Kansas.

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
....	133	......	......	0.04	23	5.8	[a] 11	66	44	4.3	....	81	208
A......	381	51	......	.4	......	......	....	300	....	13	....	[d] [v] 306	209
B......	307	76	......	.17	......	......	....	246	....	9.3	....	[d] [w] 263	
C......	331	84	......	.2	......	......	....	260	....	6.0	....	[d] [x] 226	
Avg....	[a] 161	......	......	.03	33	3.7	[a] 13	42	62	19	....	97	210
Max...	......	......	......	.08	44	7.0	[a] 26	52	95	31	....	130	
Min....	......	......	......	.00	24	.5	[a] 1.4	32	45	7	....	72	
....	159	......	......	.07	35	8.4	[a] 5.6	113	25	11	....	122	211
A Avg.	......	......	......	......	......	10	....	65	....	....	....	[d] 109	212
A Max.	......	......	......	......	......	27	....	212	....	....	....	[d] 210	
A Min.	......	......	......	......	......	3	....	37	....	....	....	[d] 61	
B......	220	88	......	Tr.	19	9	[a] 16	53	64	6	....	[d] 90	
....	434	17	10	.09	92	34	Na 8.2; K 1.4	339	84	9.6	13	369	213
....	......	......	......	......	......	......	....	....	....	....	....	....	214
....	[a] 386	......	14	[y] .6	85	29	23	348	54	8	1	331	215
....	......	......	......	......	......	......	....	....	....	....	....	....	216
Avg....	347	2.2	7	.19	72	20	[a] 3.9	134	115	29	....	[d] 244	217
Max....	426	2.6	15	1.2	82	24	....	145	142	53	....	[d] 271	
Min....	296	1.6	4	.06	58	16	....	127	87	18	....	[d] 226	
....	......	......	......	......	......	......	....	....	....	....	....	....	218
....	[a] 342	......	16	.4	70	23	16	293	57	10	6	269	219
....	[a] 811	......	84	1	168	47	43	384	270	8	.9	613	220
....	285	40	......	.2	......	......	....	213	....	6.0	2.1	[d] 205	221
....	......	......	......	......	......	......	....	....	....	....	....	....	222
....	[a] 362	......	20	.36	79	29	5.5	289	74	6	5.6	316	223
....	......	......	......	......	......	......	....	....	....	....	....	....	224
Avg....	332	......	......	.11	66	12	....	163	....	16	8.9	[d] [z] 218	225
Max....	404	......	......	.28	84	26	....	217	....	42	13	[d] [z] 278	
Min....	266	......	......	.05	41	1.5	....	77	....	4.0	.2	[d] [z] 141	
....	250	2.8	5	[b] .2	24	19	29	73	128	6.1	....	138	226
....	239	31	5.2	.07	49	4.1	....	[aa] 28	....	....	....	139	227
....	453	11	12	.37	89	18	Na 27; K 2.4	186	.28	50	.93	296	228
....	205	......	......	Tr.	48	5.8	[a] 29	140	32	42	....	144	229
....	786	......	20	[b] 7.2	135	48	[a] 58	330	138	175	....	534	230
Avg....	990	......	31	1.6	95	24	243	253	193	292	1.8	336	231
Max....	1,309	......	84	12	128	40	396	310	415	440	6.0	472	
Min....	662	....	14	.05	64	7.2	162	172	57	125	.5	238	

[a] Calculated.
[b] Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
[d] Determined.
[v] Incrustants as $CaCO_3$, 60 parts per million.
[w] Incrustants as $CaCO_3$, 61 parts per million.
[x] Incrustants as $CaCO_3$, 13 parts per million.
[y] Average of 17 determinations by State Board of Health, Oct. 28, 1910, to Jan. 19, 1921.
[z] Incrustants as $CaCO_3$; average 83, maximum 111, minimum 24 parts per million.
[aa] Includes equivalent of 6.6 parts per million of CO_3.

TABLE 6.—*Public water supplies of the*

No.	Description.
	OREGON.
232	Portland (258,288); municipal; Bull Run River and Lake. Analyses of water from Bull Run River near Bull Run, by Walton Van Winkle, U. S. Geological Survey, in 1911-12 (Water-Supply Paper 363, p. 86).
233	Salem (17,679); Salem Water, Light & Power Co.; infiltration galleries near Willamette River. Average of analyses of water from Willamette River at Salem, by Walton Van Winkle, U. S. Geological Survey, in 1911-12 (Water-Supply Paper 363, p. 90).
	PENNSYLVANIA.
234	Allentown (73,502); municipal; springs. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 27, 1922.
235	Altoona (60,331); municipal; impounding reservoirs (4 sources). Sample from a domestic tap. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 22, 1922.
236	Bethlehem (50,358); municipal; Lehigh River; filtered. Analyses of Lehigh River at South Bethlehem by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 70).
237	Chester (58,030); New Chester Water Co.; Delaware River; filtered. Also supplies Nether Providence, Aston, Upper Chichester, Lower Chichester, Edgemont, Marcus Hook, Parkside, Linwood, Trainer, and Upland; total population supplied about 77,000. The composition of the water is practically the same as that of the Delaware River supply of Philadelphia. (See Philadelphia, analyses A and B.)
238	Easton (33,813); Lehigh Water Co.; Delaware River above mouth of Lehigh River and of Bushkill Creek; filtered. Also supplies Phillipsburg, N. J.; total population supplied about 51,000. The water is like the Delaware River supply of Philadelphia but contains slightly less mineral matter. (See Philadelphia analysis A.)
239	Erie (93,372); municipal; Lake Erie; filtered. Analysis furnished by Erie Water Department, 1921.
240	Harrisburg (75,917); municipal; Susquehanna River; filtered. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 20, 1922.
241	Hazleton (32,277); Wyoming Valley Water Supply Co.; impounded streams and springs. The partial analyses of samples from the other sources indicate that the water is practically the same as from Dreck Creek.

Source.	Per cent of total supply.	Sample collected (1922).	Analyst.
A, Dreck Creek	55	May 9	Margaret D. Foster, U. S. Geological Survey.
B, Harleigh Springs	4	...do....	Do.
C, Barnes Run and Wolff's Run	25	June 14	C. S. Howard, U. S. Geological Survey.
D, Mount Pleasant supply	16	...do....	Do.

No.	Description.
242	Johnstown (67,327); Johnstown Water Co.; mountain streams impounded. The mineral content of the water from all the streams is so low that the exact composition is not important. The analyses show the general range of values for certain constituents. Analyzed by Johnstown Water Co., October, 1921.
243	Lancaster (53,150); municipal; creek and well; filtered. Analyzed by J. E. Goodell, Lancaster, Aug. 11, 1921.
244	McKeesport (46,781); municipal; Monongahela River; filtered. The variations in the river water are largely in sulphate and calcium. The river water is at times acid. The alkalinity of the filtered water is kept fairly uniform, and the hardness is more uniform than in the river water. A, Representative sample of city water supply, analyzed by E. C. Trax, filtration plant, McKeesport. B, Analyzed by E. C. Trax, 1921.
245	New Castle (44,938); New Castle Water Co. (controlled by American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.); Shenango River; filtered. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 28, 1922.
246	Norristown (32,319); Norristown Insurance & Water Co.; Schuylkill River; filtered. The composition of the water is practically the same as that of the Schuylkill River supply of Philadelphia. (See Philadelphia, analyses C and D.)

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
Avg....	30	......	9.0	0.03	2.7	0.53	3.5	12	3.1	1.3	0.31	9	232
Max....	45	......	16	.11	6.1	1.7	6.4	20	5.8	3.5	1.1	22	
Min....	21	......	4.1	Tr.	1.7	.04	1.8	8.1	1.1	.25	Tr.	6	
Avg....	51	......	15	.10	5.3	1.4	4.4	26	3.7	1.9	.36	19	233
....	236	12	9.4	.04	44	19	Na 11, K 2.6	193	14	18	17	188	234
....	87	13	5.1	.47	8.4	4.1	Na .7, K .6	0	bb 52	2.4	Tr.	38	235
Avg....	95	......	8.8	.10	14	5.7	7.5	40	30	4.9	2.2	58	236
Max...	147	......	17	.5	24	11	15	78	44	8.4	6.9	105	
Min....	48	......	3.0	.04	7.6	1.6	3.9	17	15	2.2	.0	26	
....	......	......	......	......	......	......	....	....	....	....	....	....	237
....	......	......	......	......	......	......	....	....	....	....	....	....	238
....	176	......	......	......	33	9.5	18	120	40	13	....	121	239
....	58	3.6	3.5	.05	10	3.5	Na 1.6, K .7	10	29	1.8	1.0	39	240
A......	18	2.0	1.7	.05	1.7	.8	Na .9, K .2	.7	6.3	.8	Tr.	8	241
B......	22	2.8	......	......	......	......	....	3.2	....	....	....	d 11	
C......	17	4.4	......	......	......	......	....	2.4	....	....	....	....	
D......	21	4.4	......	......	......	......	....	5.5	....	....	....		
Max....	94	......	......	Tr.	......	......	....	....	Tr.	10	....	d 11	242
Min....	70	......	......	Tr.	......	......	....	....	Tr.	4	....	d 9.2	
....	221	123	1.2	b 1.5	43	24	Na 8.4, K 3.8	a 264	3.6	6.0	....	206	243
A......	197	7.0	6.7	.1	35	5.2	a 21	28	104	9.0	....	110	244
B Avg.	......	......	......	......	......	......	....	29	....	....	....	d 77	
B Max.	......	......	......	......	......	......	....	40	....	....	....	d 109	
B Min.	......	......	......	......	......	......	....	15	....	....	....	d 42	
....	136	5.8	3.8	.17	27	6.1	Na 4.2, K 1.5	32	65	5.1	1.4	93	245
....	......	......	......	......	......	......	....	....	....	....	....	....	246

a Calculated.
b Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
d Determined.
bb Includes free sulphuric acid (H_2SO_4), 21 parts per million.

TABLE 6.—*Public water supplies of the*

No.	Description.
	PENNSYLVANIA—continued.
247	Philadelphia (1,823,779); municipal; Delaware River and Schuylkill River; filtered, generally without coagulation. The Torresdale plant, with a capacity of 200,000,000 gallons a day, filters Delaware River water. Four plants with capacities of 70, 60, 15, and 10 million gallons a day filter Schuylkill River water. A, Delaware River at Lambertville, N. J.; analyzed by U. S. Geological Survey in 1906–7 (Water-Supply Paper 236, p. 60). B, Delaware River, final filter effluent Torresdale filters; analyzed by city waterworks in 1920. C, Schuylkill River; analyzed by C. S. Howard, U. S. Geological Survey, July 19, 1920. D, Schuylkill River, effluent from filters; analyzed by city waterworks in 1920.
248	Pittsburgh (588,343); municipal; Allegheny River; filtered without coagulation. Analyses of weekly composite samples by Pittsburgh Waterworks laboratory, 1920.
249	Reading (107,784); municipal; creeks and springs. Analyses of samples from 5 sources, by I. Carroll Regan, Reading Waterworks, 1920.
250	Scranton (137,783); Scranton Gas & Water Co.; impounding reservoirs. About 10 per cent of the supply is filtered. Sample from Scranton Gas & Water Co. reservoir No. 7, which furnishes about 60 per cent of the total supply. Three other sources are lower in mineral matter, and a fourth is somewhat higher. Analyzed by C. S. Howard, U. S. Geological Survey, June 3, 1922.
251	Wilkes-Barre (73,833); Spring Brook Water Supply Co.; impounded streams. Part of the water is filtered. Sample from Spring Brook intake. Analyzed by Margaret D. Foster, U. S. Geological Survey, May 2, 1922.
252	Williamsport (36,198); Williamsport Water Co.; impounding reservoir on Mosquito Creek and Higgermans Run. An auxiliary supply from wells is occasionally drawn upon. Sample from Mosquito Creek. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 25, 1922.
253	York (47,512); York Water Co.; South Branch of Codorus Creek; impounded storage reservoir; filtered. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 25, 1922.
	RHODE ISLAND.
254	Cranston (29,407); supplied by Providence. (See Providence)..
255	Newport (30,255); Newport Water Co.; filtered; reservoirs impounding brooks; supplies part of Middletown. Average analysis by State Board of Health, 1920.
256	Pawtucket (64,248); municipal; Abbott Run and impounding reservoir; supplies Central Falls, Watchemoket fire district in town of East Providence, villages of Ashton, Berkeley, Lonsdale, and Valley Falls in the town of Cumberland, and a small part of the town of North Providence; total population supplied, about 100,000. Average analysis by State Board of Health, 1920.
257	Providence (237,595); municipal; Pawtuxet River; filtered without coagulation. Supplies Cranston, portions of the Lakewood, Lincoln Park, and Pawtuxet districts in the town of Warwick, Manton and Thorton districts in the town of Johnston, and Allendale, Centerdale, and Lymansville districts in the town of North Providence; total population supplied, about 295,000. Analyzed by J. W. Bugbee, city chemist, 1921.
258	Woonsocket (43,496); municipal; impounding reservoirs on Crook Fall Brook; supplies Union Village and Waterford in the town of North Smithfield, Manville in towns of Cumberland and Lincoln, and Blackstone and Bellingham in Massachusetts; total population supplied, about 50,000. Average analysis by State Board of Health, 1920.
	SOUTH CAROLINA.
259	Charleston (67,957); municipal; impounding reservoir on Goose Creek; filtered. Analyzed in Parker Laboratory, Charleston, S. C., Oct. 7, 1920.
260	Columbia (37,524); municipal; Congaree River at the junction of Broad and Saluda rivers; filtered. Except for silica, which is probably not much over 5 parts per million, the chemical character of the filtered water is indicated by the analyses of water from Saluda River near Columbia by U. S. Geological Survey in 1906–7 (Water-Supply Paper 236, p. 98).
	SOUTH DAKOTA.
261	Aberdeen (14,537); municipal; artesian wells, 1,200 to 1,400 feet deep. Analyzed by J. A. Montgomery, Borromite Co. of America, Chicago, Ill., June 6, 1921.
262	Sioux Falls (25,202); municipal; wells, 40 feet deep. Analysis furnished by Sioux Falls Water Department, May 11, 1919.
	TENNESSEE.
263	Chattanooga (57,895); City Water Co. (controlled by American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.); Tennessee River; filtered. Analyses of composites of daily samples from Tennessee River at Knoxville made in 1906–7 indicate that the composition of the water throughout the year is fairly constant. Analysis of filtered water at Chattanooga by Margaret D. Foster, U. S. Geological Survey, May 22, 1922.
264	Knoxville (77,818); municipal; Tennessee River; filtered. Analysis of filtered water by Earle G. McConnell, Knoxville Water Department, July 8, 1922.

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
A	70	...	9.0	0.07	12	3.3	5.4	46	12	2.9	1.1	44	247
B Avg.	76	...	...	.04	...	...	...	32	17	4.0	2.1	d 34	
B Max.	118	...	...	.18	...	...	...	48	29	5.5	3.8	d 48	
B Min.	47	...	...	.00	...	...	...	6	11	2.3	.4	d 23	
C	201	13	8.0	.33	24	12	19	56	87	11	.80	109	
D Avg.	168	...	...	...	...	...	...	53	68	6.6	...	d 99	
D Max.	248	...	...	...	...	...	...	85	124	11	...	d 144	
D Min.	105	...	...	...	...	...	...	20	29	2.8	...	d 49	
Avg.	148	...	8.2	.2	28	4.8	8.5	27	60	13	.8	d 66	248
Max.	243	...	13	.6	48	9.5	22	30	115	23	1.3	d 120	
Min.	70	...	3.1	.1	10	2.7	2.6	9.7	25	5.	.3	d 29	
Avg.	...	...	...	...	...	...	...	42	...	2.6	...	d 39	249
Max.	...	...	...	...	...	...	...	75	...	3.1	...	d 65	
Min.	...	...	...	...	...	...	...	9	...	2.0	...	d 12	
...	42	2.7	2.9	.13	6.8	1.0	5.0	18	13	1.8	.35	21	250
...	28	2.6	2.9	.06	4.3	1.3	Na 1.1, K .4	7.1	10	.7	Tr.	16	251
...	19	1.9	5.2	.03	2.3	1.1	Na 1.2, K .6	9.3	3.3	.7	.54	10	252
...	50	5.5	6.0	.18	6.8	3.2	Na 2.0, K 1.0	15	11	4.0	5.3	30	253
...	...	...	...	...	...	...	...	...	...	...	...	...	254
Avg.	88	29	...	...	...	...	...	22	...	15	...	d 28	255
Avg.	46	19	...	...	...	...	...	17	...	3.5	...	d 20	256
...	55	21	5.2	1.1	2.9	.3	...	...	16	6.0	...	8	257
...	38	17	...	...	...	...	...	12	...	3.0	...	d 10	258
...	72	20	4.0	.20	12	1.0	Na 1.0, K 1.0	22	20	9.0	.0	34	259
Avg.	62	...	21	.38	8.4	1.3	a 5.2	33	5.0	3.5	.43	26	260
Max.	80	...	32	1.0	12	2.8	10	44	10	5.0	.8	40	
Min.	48	...	15	.10	3.9	Tr.	1.0	24	Tr.	1.0	.1	10	
...	2,192	...	16	.6	216	57	405	163	1,310	96	...	770	261
...	346	...	...	...	...	...	...	310	...	5.0	...	d 349	262
...	76	2.7	7.3	Tr.	17	3.3	a 4.1	57	11	4.4	.56	56	263
...	109	43	10	1.1	13	3.6	8.4	29	21	14	...	47	264

a Calculated. d Determined.

TABLE 6.—*Public water supplies of the*

No.	Description.
	TENNESSEE—continued.
265	Memphis (162,351); municipal; wells, 400 to 475 feet deep. Analyzed by W. F. Monfort, St. Louis, Mo. A, Auction Avenue wells, Dec. 22, 1921. B, Central Avenue well No. 193, Dec. 22, 1921. C, Well No. 194, Dunlap site, Jan. 31, 1922.
266	Nashville (118,342); municipal; Cumberland River. Clarified with aluminum sulphate, not filtered. Analyses of water from Cumberland River near Nashville by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 57).
	TEXAS.
267	Austin (34,876); municipal; infiltration galleries near Colorado River. Analyzed by E. P. Schoch, University of Texas, Dec. 18, 1919.
268	Beaumont (40,422); municipal; Neches River 10 miles above the city; filtered. The quantities of sodium and chloride may vary 50 per cent either way from the quantities given in the analysis. The bicarbonate ranges from 4 to 30 parts per million. Analysis furnished by the city Department of Public Welfare.
269	Dallas (158,976); municipal; impounding reservoir; filtered. Analysis made at city water-purification plant under direction of Helman Rosenthal, 1922.
270	El Paso (77,560); municipal; wells. Analyses by F. C. Lamb, city chemist........................

Source.	Depth (feet).	Yield (million gallons per day).	Date of collection.
A, Mesa wells...	600-900	4.5	Aug. 25, 1920
B, Montana Street well..	860	2.1	Do.
C, Grama Street well..	950	1.5	Jan. 14, 1921

No.	Description.
271	Fort Worth (106,482); municipal; Lake Worth: filtered. Analyzed by Fort Worth Laboratories, May 21, 1919.
272	Galveston (44,255); municipal; wells about 800 feet deep. Analyzed by Felix Paquin, Water and Sewer departments, Galveston.
273	Houston (138,276); municipal; deep wells. Analyzed by P. S. Tilson, of Houston Laboratories, Nov. 17, 1920.
274	San Antonio (161,379); San Antonio Water Supply Co.; wells 880 feet deep. Analyzed by J. R. Bailey, University of Texas, Apr. 29, 1911.
275	Waco (38,500); municipal; artesian wells; Brazos River; filtered. A, Sample from 2,050-foot artesian well, analyzed by Margaret D. Foster, U. S. Geological Survey, Nov. 29, 1921. B, Analyses of water from Brazos River at Waco made by U. S. Geological Survey in 1906-7 (Water-Supply Paper 236, p. 50).
276	Wichita Falls (40,079); Wichita Falls Water Co.; Lake Wichita (artificial). Analyzed by W. M. Barr, U. S. Geological Survey, Oct. 1, 1906 (Water-Supply Paper 317, p. 54).
	UTAH.
277	Ogden (32,804); municipal; impounded surface waters and artesian wells. Analyzed by Margaret D. Foster, U. S. Geological Survey, Apr. 22, 1922. A, Sample from Cold Water Canyon. B, Sample from artesian wells.
278	Salt Lake City (118,110); municipal; creeks and springs. Analyses furnished by city waterworks, August, 1921. A, Big Cottonwood Canyon (furnishes 14 per cent of total supply). B, Parleys Canyon (furnishes 30 per cent). C, City Creek (furnishes 25 per cent). D, Emigration Springs (furnishes 1 per cent).
	VERMONT.
279	Burlington (22,779); municipal; Lake Champlain; filtered. Average of five concordant analyses of samples from the lake. Analyzed by W. M. Barr, U. S. Geological Survey, 1904 (Water-Supply Paper 121, p. 20).
280	Rutland (14,954); municipal; mountain streams impounded. Analyzed by C. S. Howard, U. S. Geological Survey, May 25, 1922.
	VIRGINIA.
281	Lynchburg (30,070); municipal; Pedlar River; filtered. Analysis furnished by city waterworks, Dec. 9, 1921.
282	Newport News (35,596); Newport News Light & Water Co.; reservoir; filtered. Analyzed by Margaret D. Foster, U. S. Geological Survey, Mar. 27, 1922.
283	Norfolk (115,777); municipal; reservoirs; filtered. Analyzed by Froehling & Robertson, Richmond, Va., July, 1919.
284	Petersburg (31,012); municipal; Appomattox River; filtered. A few individual determinations indicate that the filtered water is similar to the supply at Richmond. (See Richmond.)

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
A......	100	......	8.3	1.5	14	6.5	15	104	0	7.0	0.02	63	265
B......	84	......	9.0	.2	8.4	4.0	12	68	.9	6.0	.01	37	
C......	78	......	11	1.1	8.6	4.0	10	78	0	4.0	.01	38	
Avg....	119	......	20	.42	26	3.6	9.6	92	14	2.1	1.2	80	266
Max....	150	......	33	4.0	36	7.6	16	118	20	4.8	4.3	101	
Min....	87	......	5.2	Tr.	17	.9	2.9	73	9.7	1.0	.2	65	
....	432	32	6.4	.07	92	24	[a] 13	293	89	36	....	329	267
....	234	5.8	......	.5	14	3.3	53	8	31	89	....	48	268
....	248	......	15	[b] 6	31	1	57	61	100	20	....	82	269
A......	400	37	32	......	47	20	49	201	57	59	....	200	270
B......	557	35	29	......	37	14	134	156	43	189	....	150	
C......	378	30	32	......	20	8.6	63	140	39	46	....	85	
....	170	34	10	......	41	1.1	15	64	24	19	....	107	271
....	719	......	30	[b] 1.0	18	4.9	168	79	....	260	....	65	272
....	[a] 356	......	17	[b] .7	29	6.6	94	269	27	40	....	100	273
....	[a] 252	......	15	.07	61	15	Na 9.5, K 1.0	240	13	16	3.0	214	274
A......	694	4.2	20	.18	6.0	4.6	Na 237, K 12	[cc] 437	138	51	Tr.	34	275
B Avg.	1,136	......	22	.26	121	19	234	158	279	338	2.2	380	
B Max.	1,848	......	65	1.1	218	30	376	242	555	575	6.0	652	
B Min.	420	......	9.6	Tr.	60	6.3	69	98	84	119	Tr.	176	
....	[a] 139	......	......	......	18	15	14	60	20	22	.9	106	276
A......	143	3.7	8.3	.07	31	11	Na 7.8, K 1.3	145	11	4.7	Tr.	123	277
B......	161	4.5	17	.03	29	8.9	Na 16, K 1.8	127	9.1	17	4.0	109	
A......	180	23	7.5	[b] 1.9	26	14	7	[a] 98	43	10	....	122	278
B......	387	60	11	[b] 2.1	51	28	21	[a] 192	94	25	....	242	
C......	216	14	9.3	[b] 1.3	42	16	9	[a] 190	18	12	....	171	
D......	625	62	16	[b] 3.1	68	35	66	[a] 182	255	30	....	314	
Avg....	67	22	3.8	[b] 1.1	14	2.9	6.1	57	7.4	1.2	....	47	279
....	42	1.8	2.5	.06	8.4	2.4	2.8	34	7.0	1.5	.42	28	280
....	[a] 32	......	6.1	[b] 1.2	4.4	2.1	[a] 1.7	15	5.8	3.5	....	20	281
....	108	5.2	4.0	.12	27	2.8	Na 4.2, K .5	56	29	6.3	.20	79	282
....	[a] 122	......	12	[b] 3.0	9.3	4.1	Na 21, K 3.1	24	31	26	.6	40	283
....	......	......	......	......	......	......	......	......	......	......	....	....	284

[a] Calculated. [b] Iron and aluminum oxides ($Fe_2O_3 + Al_2O_3$).
[cc] Includes equivalent of 17 parts per million of CO_3.

TABLE 6.—*Public water supplies of the*

No.	Description.
	VIRGINIA—continued.
285	Portsmouth (54,387); municipal; lakes; filtered. Analyzed by Margaret D. Foster, U. S. Geological Survey, May 3, 1922.
286	Richmond (171,667); municipal; James River; coagulation and sedimentation. Analyses of water from James River at Richmond by U. S. Geological Survey in 1906–7 (Water-Supply Paper 236, p. 67).
287	Roanoke (50,842); Roanoke Waterworks Co.; Crystal Spring, 4,000,000 gallons a day; Muse Spring, 1,500,000 gallons a day; River Spring, 500,000 gallons a day; Vinton-Roanoke Water Co., Vinton Reservoir, Smith Spring. The analyses of samples from hydrants agree closely with analyses of samples from the individual sources. Analyzed by James H. Gibboney, Roanoke. A, Fire hydrant halfway between Albemarle and Walnut avenues on Third Street SE., Aug. 27, 1917; represents Roanoke Waterworks Co. supply. B, Fire hydrant at junction of Campbell and Norfolk avenues near Petty's coal yard, Aug. 27, 1917; represents Vinton-Roanoke Water Co. supply.
	WASHINGTON.
288	Bellingham (25,585); municipal; Lake Whatcom. The chemical character of the water is undoubtedly fairly represented by the analyses of water from Skagit River, which drains an area similar to that which is drained into Lake Whatcom. Average of analyses of water from Skagit River at Sedro Woolley by Walton Van Winkle, U. S. Geological Survey, in 1910–11 (Water-Supply Paper 339, p. 38).
289	Everett (27,644); municipal; Sultan River. Analyzed by Horace G. Byers, Washington State University, Feb. 19, 1915.
290	Seattle (315312) municipal; Cedar River and Cedar Lake. Analyses of water from Cedar River at Ravensdale, by Walton Van Winkle, U. S. Geological Survey, in 1910–11 (Water-Supply Paper 339, p. 44).
291	Spokane (104, 437); municipal; wells about 50 feet deep. Analyzed by Quintard Johnson, city chemist, 1920.
292	Tacoma (96,965); municipal; Green River. Average of analyses of water from Green River at Hot Springs by Walton Van Winkle, U. S. Geological Survey, in 1910–11 (Water-Supply Paper 339, p. 46).
	WEST VIRGINIA.
293	Charleston (39,608); West Virginia Water & Electric Co.; Elk River; filtered. Analyzed by R. I. Dodd, 1921.
294	Clarksburg (27,869); municipal; West Fork River; filtered. Monthly averages of analyses of filtered water in 1921, made by Ralph D. Bates, Clarksburg.
295	Huntington (50,177); Huntington Water Corporation (controlled by American Waterworks & Electric Co., 50 Broad Street, New York, N. Y.); Ohio River; settling and coagulating basins. The quantity of dissolved solids in the water changes with the stage of the river, but the average composition is similar to that of the water supplied at Cincinnati, Ohio. Average of analyses of samples of filtered water (annual report of Cincinnati Waterworks, 1917–18, p. 73).
296	Wheeling (56,208); municipal; Ohio River. (For analysis see Huntington.).....................
	WISCONSIN.
297	Green Bay, (31,017); municipal; artesian wells 930 feet deep. Analyzed by Margaret D. Foster, U. S. Geological Survey, Mar. 30, 1922.
298	Kenosha (40,472); municipal; Lake Michigan; filtered. The composition of the water is shown by the analysis of the water from Lake Michigan at Chicago made by G. A. Weinhold, Illinois State Water Survey, Dec. 5, 1921.
299	La Crosse (30,421); municipal; wells 120 feet deep. Analyzed by Dearborn Chemical Co., Chicago, Ill., February, 1922.
300	Madison (38,378); municipal; wells, 750 feet deep. Analyzed by Harry Klueter, State chemist, October, 1921.
301	Milwaukee (457,147); municipal; Lake Michigan. The chemical composition of the lake water is fairly constant and almost the same at Milwaukee as at Kenosha and at Chicago, Ill. (See Kenosha.) At Milwaukee iron is about 0.2 part per million and chloride about 4 parts.
302	Oshkosh (33,162); municipal; Lake Winnebago; filtered. Analyzed by R. A. Maddock, 1921.....
303	Racine (58,593); municipal; Lake Michigan. (For analysis see Kenosha.)........................
304	Sheboygan (30,955); municipal; Lake Michigan. (For analysis see Kenosha.).....................
305	Superior (39,671); Superior Water, Light & Power Co.; wells 14 to 40 feet deep in sand on shore of Lake Superior. Analysis furnished by Superior Water, Light & Power Co., September, 1921.
	WYOMING.
306	Casper (11,447); municipal; North Platte River; through natural sand filters. Analysis furnished by city engineer, Mar. 16, 1920.
307	Cheyenne (13,829); municipal; impounding reservoir. Analyzed by C. W. Killebrew, January, 1921.

larger cities of the United States—Continued.

	Analyses (parts per million).												
	Total dissolved solids.	Loss on ignition.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total hardness as $CaCO_3$.[a]	No.
....	43	4.2	3.2	0.22	3.6	1.2	Na 3.9 K .7	2.4	12	5.1	Tr.	14	285
Avg....	89	......	18	.5	14	3.0	6.7	60	7.1	2.3	.3	47	286
Max....	174	......	54	1.8	19	5.5	14	90	12	4.6	.9	70	
Min....	58	......	6.4	.04	9.6	.4	1.8	27	3.9	Tr.	.0	26	
A......	a 139	......	11	b 1.6	24	16	3.9	145	4.8	6.0	......	126	287
B......	a 41	......	16	b 2.4	2.8	2.3	2.6	17	2.4	4.0	......	16	
Avg....	48	......	9.4	.08	7.9	1.7	3.6	29	8.2	.9	.24	27	288
....	54	24	......	......	......	......	......	......	......	1.1	......	d 15	289
Avg....	49	......	13	.02	6.7	1.4	3.6	28	5.7	1.2	.20	23	290
Max....	84	......	31	.08	9.6	2.4	4.8	44	9.4	4.0	1.0	33	
Min....	34	......	7.1	Tr.	4.4	.5	2.5	17	3.4	.5	Tr.	14	
....	201	......	13	b .05	27	14	3.1	159	9.2	1.0	......	125	291
Avg....	55	......	17	.04	6.0	1.3	5.6	28	5.9	1.3	.13	20	292
....	a 75	......	4.8	b 1.6	9.3	1.9	12	30	26	7.1	......	31	293
Avg....	......	......	......	.15	......	......	......	23	......	18	......	d 58	294
Max....	......	......	......	dd .66	......	......	......	ee 32	......	dd 106	......	dd 103	
Min....	......	......	......	dd .03	......	......	......	ee 12	......	dd 3.0	......	dd 33	
Avg....	a 161	......	......	.03	33	3.7	a 13	42	62	19	......	97	295
....	......	......	......	......	......	......	......	......	......	......	......	......	296
....	287	8.6	14	.08	46	20	Na 31 K 4.0	218	55	16	Tr.	197	297
....	183	......	18	.4	36	10	Na 4.6 K 1.6	144	10	6.0	1.8	131	298
....	276	4	2.6	b .8	53	32	6.7	190	15	3.5	......	264	299
....	a 345	......	12	b 1.1	66	39	Na 6.2 K 3.2	385	23	4.0	.13	325	300
....	......	......	......	......	......	......	......	......	......	......	......	......	301
....	a 186	......	......	b 3.6	32	17	16	148	31	7.2	......	149	302
....	......	......	......	......	......	......	......	......	......	......	......	......	303
....	......	......	......	......	......	......	......	......	......	......	......	......	304
....	61	......	1.2	.14	14	3.7	2.9	62	2.8	1.1	.22	50	305
....	a 284	......	3.7	b 2.8	42	14	Na 29 K 8.1	124	111	12	......	162	306
....	a 116	......	16	.2	27	3.8	5.6	86	18	3.8	......	83	307

a Calculated.
b Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).
dd Single determinations.
ee Monthly averages.