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Water-Supply Paper 559

RELATIONS BETWEEN QUALITY OF WATER AND INDUSTRIAL DEVELOPMENT IN THE UNITED STATES

BY

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By W. D. COLLINS

INTRODUCTION

Every manufacturing establishment requires a water supply. The needs as to quantity vary greatly. A factory for the manufacture of clothing or of cigars may require little more water than that used for the individual needs of the workers and for cleaning workrooms. A textile mill in which dyeing is done may use several million gallons of water each day. The requirements as to quality also vary widely. Water used for cooling at steel works or in some types of condensers at a power plant may be of almost any quality if it is not acid. Feed water for steam boilers should be moderately free from suspended and dissolved mineral matter or easily made practically free from such constituents. A paper mill that makes brown wrapping paper can use water of much poorer quality than is needed for a mill that makes the highest grades of white paper. A plant that makes chemicals or drug products is forced to use distilled water almost exclusively in its manufacturing processes.

Water supply is always considered in locating a new plant. In some industries, like the manufacture of paper or textiles, it is probably the most important consideration. In the manufacture of steel a large quantity of water must be available, but its quality is not of prime importance. The preparation of food products, represented by the industries of slaughtering and meat packing, canning and preserving, and the making of bread and other bakery products, must be carried on where the raw materials can be obtained most easily, where the products can most quickly reach the consumer, or where the combined transportation is a minimum. The chemical character of the water available is a minor consideration, though its sanitary character is of the utmost importance.

A review of industrial development in the United States, as shown in the reports of manufactures prepared by the Bureau of the Census since 1850, brings out the fact that the early industrial activity

was confined almost wholly to areas in which natural waters of excellent quality abounded. With the growth of population and the movement of the center of population toward the west and south the total industrial activity spread in the same directions. Some individual industries, like the production of bread and other bakery products, have followed the movement of population; others, like the production of iron and steel, have remained centered in about the same regions. In the iron and steel industry there has been comparatively little growth in the New England States and large growth in the States of Illinois and Indiana, but about 60 per cent of the total activity in this industry has been located in Pennsylvania and Ohio since 1859. Still others, like the wool and silk industries, were in 1919 confined to nearly the same States as in 1849. Some industries in which the quality of water plays little part have also remained in the same localities throughout the period covered by reports of the census of manufactures, but the largest ones remaining in their original locations are the ones that require the best water.

Study of the chemical character of waters that have not yet been used industrially will show the most favorable regions for the future expansion of certain industries. The general improvements in the art of treating water, and particularly the development within the last 10 or 15 years of commercial water softening by exchange silicates, make available for certain manufacturing establishments some sites that would not have been considered 20 years ago. In discussions of purification of water stress is customarily and properly laid on the great savings that result from the use of softened water. A laundry may easily save enough in soap in a few years to pay for the installation of water-softening equipment, but if it had been located where softening was not necessary the money need not have been spent either for the excessive quantity of soap or for a water softener.

A survey of the chemical character of the waters used and available for industrial establishments has been published by the United States Geological Survey.[1] Although the report, as indicated by its title, deals only with public water supplies, the facts brought out in it as well as in the present report show that the largest quantities of water used industrially come from public supplies or from sources that yield water of the same quality as that of some of the large public supplies. Reports of manufactures prepared by the Bureau of the Census furnish the basis for the discussion here given of the development of industrial activity in the United States.

[1] Collins, W. D., The industrial utility of public water supplies in the United States: U. S. Geol. Survey Water-Supply Paper 496, iv, 59 pp., 1 pl., 1923.

Without any assumption that quality of water is a determining factor or a very significant factor in the location of some industries, the facts are presented as a recital of the general character of water available at the centers of different kinds of industrial activity. The movement of centers of industrial activity is considered in connection with the quality of water available at old and new locations.

The discussion of the movement of centers of industrial activity should not give the impression that plants are picked up from one place and set down in another. Almost invariably the movement of industries is accomplished by the establishment and growth of new plants in locations distant from the older plants at a rate faster than the development by the growth of old plants and the establishment of new ones in the original locations.

INDUSTRIAL ACTIVITY

METHOD OF MEASUREMENT

The figures given by the United States census in the reports of manufactures under the heading "Value added by manufacture" have been taken as an equitable basis for comparison of industrial activity in different places.

As the value of finished products given in the census reports includes the value of raw materials, the value of a product of one industry which is a raw material for another industry is counted twice. The value added by manufacture will be counted only to the extent to which the value is increased by the manufacturing process at each stage from the original natural state to the completed part of a finished article.

In order that fair comparison may be made between different years, the values added by manufacture considered in this discussion have all been reduced to the standard of 1913 by use of the index numbers of wholesale prices prepared by the United States Bureau of Labor Statistics, as given in Table 1. This correction is undoubtedly fair for the total industrial activity of a State or other unit, but it may be in error when applied to individual industries. However, the use of these index numbers probably never makes the results for a single industry less fairly comparable than they would be without modification.

TABLE 1.—*Index numbers of wholesale prices*

[Published by Bureau of Labor Statistics, U. S. Department of Labor. Computed by taking 1913 as 100]

Year	Index number	Year	Index number
1849	87	1889	83
1859	88	1899	75
1869	135	1909	97
1879	85	1919	206

UNIT AREAS

In order that the areas considered might be more uniform, two sets of States have been taken arbitrarily and treated throughout the discussion as single units. "Industrial New England" in this report designates a group that includes New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island. The area of this group of States, 33,384 square miles, is not much more than the area of the State of Maine, and is comparable with the average of about 46,600 square miles for the States east of Mississippi River other than New England, New Jersey, Maryland, and Delaware.

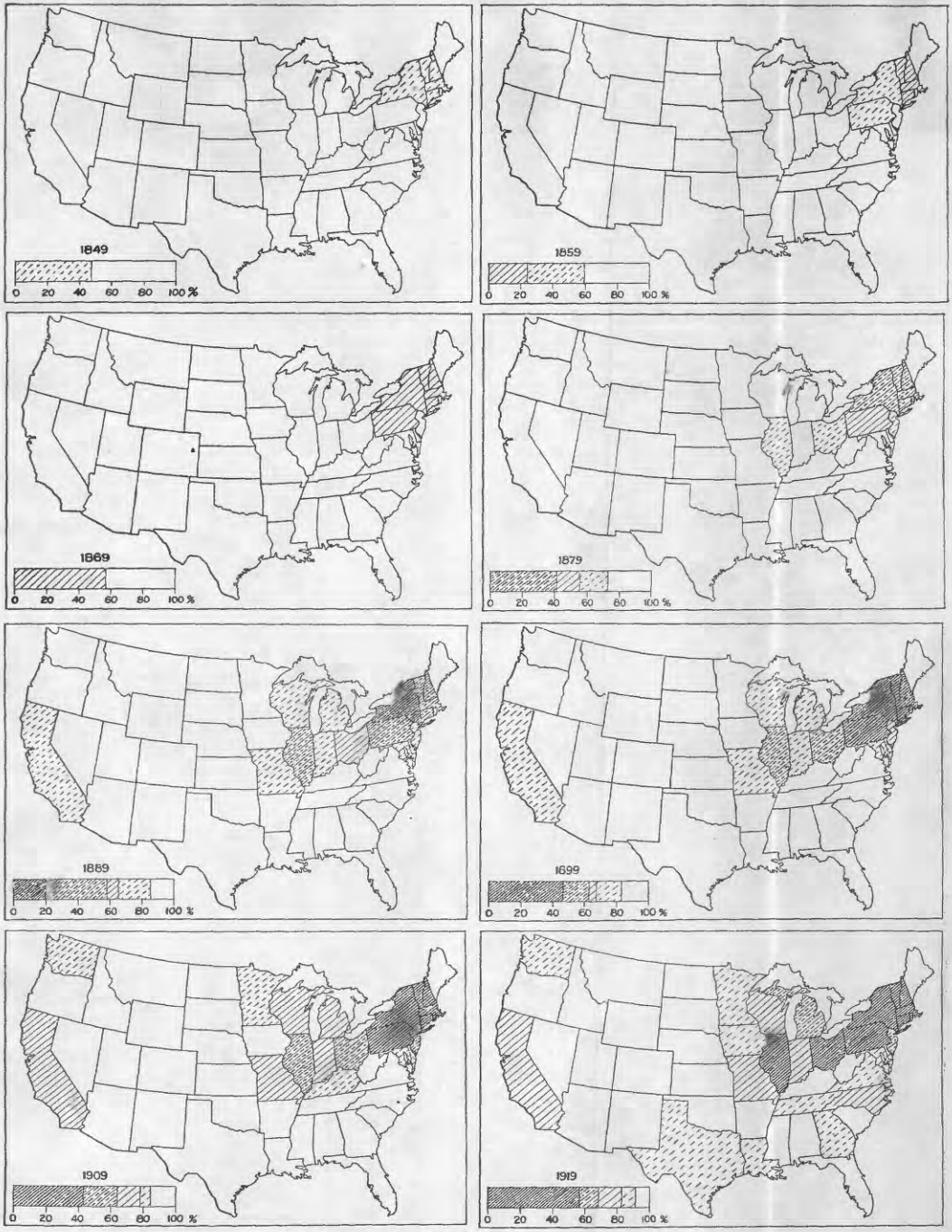
Maryland, Delaware, and the District of Columbia are considered together and are designated "Maryland" in the tables and discussion. The total area of this division (14,767 square miles) is much smaller than that of any other division taken as a unit except New Jersey (8,224 square miles), but it was not feasible to make any combination including either of these areas in order to make up a unit comparable in area with the average of 46,600 square miles.

INDUSTRIAL ACTIVITY, 1849–1919

The charts in Plate 1 show the development of industrial activity from 1849 to 1919. A State or group in which the value added by manufacture in the year indicated was $100,000,000 reduced to the standard of 1913 is shaded on the map. The darker shadings indicate values added of $200,000,000, $400,000,000, and $800,000,000. The percentages of total industrial activity for the areas with each degree of shading are indicated in the diagram at the lower left side of each map. The figures on which these charts are based are given in Table 2.

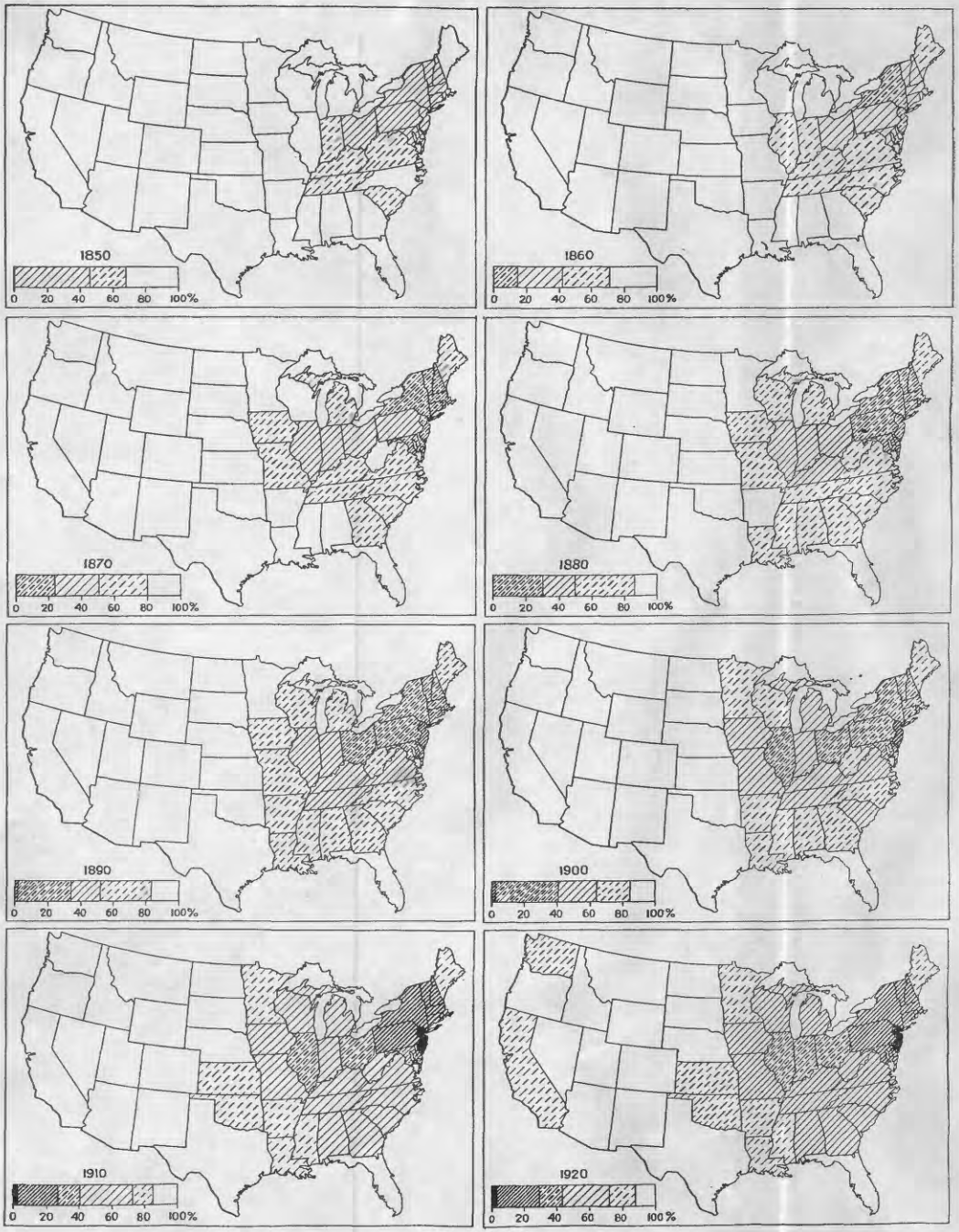
The table and charts show consistent growth in manufacturing for nearly all States and groups of States. The concentration of industrial activity is clearly indicated on the charts by comparison of the unshaded areas on the maps with the corresponding areas on the diagrams that show percentages.

The figures in Table 2 represent differences between the cost of raw material and the wholesale price of the finished product, adjusted to the standard of 1913 by the use of the index numbers furnished by the United States Bureau of Labor Statistics. The figures for 1889 and later years do not include neighborhood, hand, and building industries, which are included in earlier figures. The blanks indicate added values of less than $100,000,000, but these amounts are combined and given under "Other States."



TOTAL INDUSTRIAL ACTIVITY, BY STATES AND GROUPS OF STATES, 1849–1919

100574—26. (Face p. 4.) No. 1



DENSITY OF POPULATION, BY STATES AND GROUPS OF STATES, 1850–1920

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TABLE 2.—*Industrial activity in States and groups of States, 1849–1919, as indicated by value added to raw material by manufacture*

Millions of dollars

State or group	1849	1859	1869	1879	1889	1899	1909	1919
New York	118	186	247	472	1,012	1,137	1,560	1,905
Pennsylvania	-------	155	215	330	672	922	1,065	1,507
Industrial New England	137	234	277	490	798	939	1,150	1,470
Ohio	-------	-------	-------	157	362	452	633	1,062
Illinois	-------	-------	-------	147	457	586	782	940
Michigan	-------	-------	-------	-------	149	192	326	751
New Jersey	-------	-------	-------	105	199	291	438	681
California	-------	-------	-------	-------	112	123	211	370
Indiana	-------	-------	-------	-------	117	189	252	351
Wisconsin	-------	-------	-------	-------	124	188	251	350
Missouri	-------	-------	-------	-------	177	176	227	261
Maryland	-------	-------	-------	-------	143	143	158	215
North Carolina	-------	-------	-------	-------	-------	-------	-------	202
Washington	-------	-------	-------	-------	-------	-------	106	178
Minnesota	-------	-------	-------	-------	-------	-------	132	163
Texas	-------	-------	-------	-------	-------	-------	-------	145
Virginia	-------	-------	-------	-------	-------	-------	-------	132
Georgia	-------	-------	-------	-------	-------	-------	-------	123
Louisiana	-------	-------	-------	-------	-------	-------	-------	119
Iowa	-------	-------	-------	-------	-------	-------	-------	109
Tennessee	-------	-------	-------	-------	-------	-------	-------	103
Kentucky	-------	-------	-------	-------	-------	-------	115	-------
Other States	278	396	553	620	751	1,104	1,387	1,020
United States	533	971	1,292	2,321	5,073	6,442	8,793	12,157

Per cent of total

New York	22.1	19.2	19.1	20.4	20.0	17.7	17.7	15.6
Pennsylvania	25.7	15.9	16.6	14.2	13.3	14.3	12.1	12.4
Industrial New England	-------	24.1	21.5	21.1	15.8	14.6	13.1	12.1
Ohio	-------	-------	-------	6.8	7.1	7.0	7.2	8.7
Illinois	-------	-------	-------	6.3	9.0	9.1	8.9	7.7
Michigan	-------	-------	-------	-------	2.9	3.0	3.7	6.2
New Jersey	-------	-------	-------	4.5	3.9	4.5	5.0	5.6
California	-------	-------	-------	-------	2.2	1.9	2.4	3.0
Indiana	-------	-------	-------	-------	2.3	2.9	2.9	2.9
Wisconsin	-------	-------	-------	-------	2.4	2.9	2.8	2.9
Missouri	-------	-------	-------	-------	3.5	2.7	2.6	2.2
Maryland	-------	-------	-------	-------	2.8	2.2	1.8	1.8
North Carolina	-------	-------	-------	-------	-------	-------	-------	1.7
Washington	-------	-------	-------	-------	-------	-------	1.2	1.5
Minnesota	-------	-------	-------	-------	-------	-------	1.5	1.3
Texas	-------	-------	-------	-------	-------	-------	-------	1.2
Virginia	-------	-------	-------	-------	-------	-------	-------	1.1
Georgia	-------	-------	-------	-------	-------	-------	-------	1.0
Louisiana	-------	-------	-------	-------	-------	-------	-------	1.0
Iowa	-------	-------	-------	-------	-------	-------	-------	.9
Tennessee	-------	-------	-------	-------	-------	-------	-------	.8
Kentucky	-------	-------	-------	-------	-------	-------	1.3	-------
Other States	52.2	40.8	42.8	26.7	14.8	17.2	15.8	8.4
United States	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

POPULATION

DENSITY

The distribution of population in the States on the basis of the density in persons per square mile is shown in Plate 2.

The charts for population and for industrial activity are similar in showing concentration in New England and New York from early times, followed by a movement westward through Pennsylvania, Ohio, Indiana, and Illinois. They are, however, quite different as regards the South Atlantic States, where the population has been fairly large throughout the history of the United States, but where

manufacturing has been conducted on a rather small scale until recent years.

URBAN AND RURAL POPULATION IN 1920

The trend of population to the larger cities is too well known to require the repetition of statistics from the earlier census reports. The following table shows the number of persons living in groups of cities of different sizes in 1920.

TABLE 3.—*Distribution of population in groups of cities classified according to size and in rural territory, 1920* [a]

Class of places	Number of places	Population	Per cent of total population
Urban territory:			
Places of 100,000 or more	68	27,429,326	26.0
Places of 25,000 to 100,000	219	10,340,788	9.8
Places of 10,000 to 25,000	459	6,942,742	6.6
Places of 5,000 to 10,000	721	4,997,794	4.7
Places of 2,500 to 5,000	1,320	4,593,953	4.3
Rural territory		51,406,017	48.6
Total population of the United States		105,710,620	100.0

[a] Fourteenth Census of the United States, vol. 1, p. 50, Table 31, 1921.

Table 3 makes clear the concentration of urban population in the larger cities. Evidently any study in which the city is taken as a unit involves much more work for a given number of persons considered in the smaller cities than for the same number in the large ones. More persons reside in the 68 largest places than in the 2,719 other places included in the table. The 219 places that have a population between 25,000 and 100,000 have nearly as many inhabitants as the 1,180 places that have a population between 5,000 and 25,000, and over twice the number in the 1,320 places that have a population of 2,500 to 5,000. These considerations led to the selection of the population of 25,000 as the lower limit for cities to be included in the report on the industrial utility of public water supplies,[2] which furnishes most of the information in regard to quality of water for the discussions in the present report.

MANUFACTURING IN METROPOLITAN CENTERS IN 1919

Like the population, the industrial activity of the United States is notably concentrated at certain centers. The census reports for 1904, 1909, and 1914 present statistics for what are termed metropolitan districts. Most of these districts include places in more than one State. It is quite evident that industrially East St. Louis and Granite City, Ill., are closely related to St. Louis, Mo.; Camden, N. J., to Philadelphia, Pa.; the cities in northern New Jersey to

[2] U. S. Geol. Survey Water-Supply Paper 496, 1923.

New York City; and the lake cities of Indiana to Chicago. No report on metropolitan districts was prepared by the Bureau of the Census for 1919. The data in Table 4 are taken from the report of manufactures in 1919 for cities for which reports are given, and estimates are made for the total industrial activity of the districts on the assumption that in 1919 the value added by manufacture in the places for which separate reports were given bore the same relation to the total value added in each district as in 1914. The boundaries of the districts and other data are given in the census of manufactures for 1914.

The concentration of industrial activity in the metropolitan districts is shown in Figure 1. Each dot represents a value of $100,000,000 (standard of 1913) added by manufacture for the districts named.

TABLE 4.—*Industrial activity in metropolitan districts in 1919*

[Values adjusted to standard of 1913 by index numbers furnished by U. S. Bureau of Labor statistics]

District	Places for which separate reports are given	Value added by manufacture		
		Per cent of total for district in 1914 furnished by places for which separate reports are given	Estimated total value added in 1919—millions of dollars	Per cent of United States total
New York	New York, Bayonne, Bloomfield, East Orange, Elizabeth, Englewood, Hackensack, Harrison, Hoboken, Irvington, Jersey City, Kearny, Montclair, Mount Vernon, Newark, New Rochelle, Orange, Passaic, Paterson, Perth Amboy, Union, West Hoboken, West New York, Yonkers.	96.6	1,629	13.4
Chicago	Chicago, Chicago Heights, East Chicago, Evanston, Hammond, Oak Park.	90.5	716	5.9
Philadelphia	Philadelphia, Bristol, Camden, Chester, Gloucester, Norristown.	90.6	537	4.4
Detroit	Detroit	65.3	430	3.5
Boston	Boston, Arlington, Brookline, Cambridge, Chelsea, Dedham, Everett, Framingham, Lynn, Malden, Medford, Melrose, Natick, Newton, Peabody, Quincy, Revere, Salem, Somerville, Wakefield, Waltham, Watertown, Weymouth, Winchester, Winthrop, Woburn.	96.4	316	2.6
Cleveland	Cleveland, East Cleveland, Lakewood	97.7	239	2.0
Pittsburgh	Pittsburgh, Braddock, Carnegie, Homestead, McKeesport, McKees Rocks, Wilkinsburg.	52.5	220	1.8
St. Louis	St. Louis, East St. Louis, Granite City	89.7	199	1.6
Baltimore	Baltimore	83.4	146	1.2
San Francisco-Oakland.	San Francisco, Alameda, Berkeley, Oakland	79.5	146	1.2
Buffalo	Buffalo	83.8	135	1.1
Cincinnati	Cincinnati, Covington, Newport, Norwood	90.5	132	1.1
Minneapolis-St. Paul.	Minneapolis, St. Paul	93.3	100	.8
Los Angeles	Los Angeles, Long Beach, Pasadena	93.0	67	.6
Birmingham	Birmingham, Bessemer	81.0	27	.2

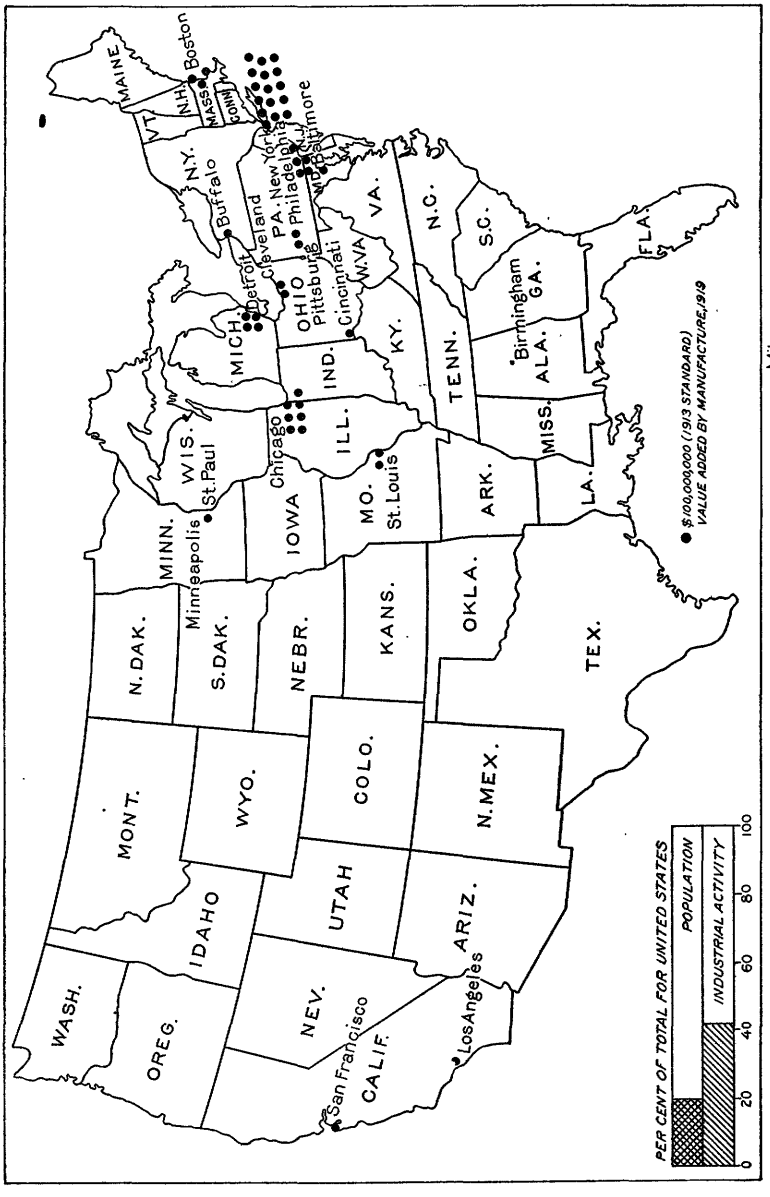


FIGURE 1.—Industrial activity in metropolitan districts

WATER FOR INDUSTRIAL USE

REQUIREMENTS

Many kinds of manufacturing have almost no requirements either for quantity or quality of water; other industries require large quantities of water without much regard for its quality; and some industries demand water of exceptional purity.

MINERAL CONSTITUENTS OF NATURAL WATERS

Nearly all the natural waters used industrially may be considered as modified solutions of the constituents of limestone, which consists essentially of calcium and magnesium carbonates. These carbonates are held in solution in natural waters by an excess of carbon dioxide, which forms bicarbonates of the calcium and magnesium. Sulphate is present in all waters. The quantity of sulphate is small in waters from granite or from certain limestones, but large quantities are found in waters that have had an opportunity to dissolve gypsum, and also in river waters that are contaminated with mine drainage or with some kinds of industrial wastes. Chloride, the acid radicle of common salt, is found in all waters, but the amount in waters used industrially is generally insignificant. Equally small quantities of nitrate are found in most waters. Sodium and potassium in waters used industrially are generally a little more than equivalent to the quantities of nitrate and chloride. They are rarely present in quantities equivalent to the combined chloride, nitrate, and sulphate. Silica is invariably present in small quantities. It makes up a much larger proportion of the total dissolved mineral matter in waters of low mineral content than it does in the waters of moderate or high mineral content. Iron is found in practically all waters, but the quantity is generally a wholly insignificant proportion of the total quantity of dissolved mineral. Small quantities of iron may, however, cause serious trouble in some industrial processes.

The dissolved mineral matter in the public water supplies of the industrial centers named in Table 4 ranges from 28 parts per million for Boston and the Catskill supply of New York to 378 parts per million for the Los Angeles River supply of Los Angeles. These quantities correspond respectively to 0.23 and 3.1 pounds per 1,000 gallons.

HARDNESS

The hardness of natural water is practically all caused by the compounds of calcium and magnesium. The most general industrial drawback to the use of hard water is either the scale that it forms in steam boilers, or the expense of installing and operating plants to treat the water so as to prevent the formation of scale.

Hardness must be completely removed for the best results in washing and dyeing textiles and in general laundry work. It may also be harmful in other industrial processes.

TURBIDITY

For some processes suspended material in turbid water may not be detrimental, but for certain other processes it must be removed completely. If water is forming scale in a boiler all the suspended matter contributes to the scale. The removal of suspended matter is obviously necessary in textile work or in the manufacture of white paper. Clear water must be used in the preparation of food products. The cost of clarifying water depends not only on the quantity of suspended material, but also on its fineness and chemical character.

CORROSION

Some natural or treated waters are corrosive. If the corrosive properties are due to free acid, as in water contaminated with large quantities of mine drainage, the waters may be wholly unfit for use in iron or steel pipes or boilers. Many waters are mildly corrosive on account of their content of carbon dioxide and oxygen. Some of these waters when cold will not seriously attack pipes, but when heated they cause extensive corrosion, the pipes being frequently nearly filled with products of corrosion before perforation occurs. The iron rust in these waters as they come from the pipes may cause serious trouble in some processes.

IRON

Natural surface waters rarely contain enough dissolved iron to affect their use in manufacturing. Ground waters, on the other hand, may contain large quantities of iron, which is held in solution in the clear water as it comes from the pump. In contact with the air the water quickly becomes turbid, and the oxidized iron separates out as a red sediment, which makes the water unfit for many industrial uses.

TREATMENT OF WATER

Natural waters can be successfully treated for the removal of turbidity, hardness, iron, corrosive properties, odors, and tastes, and can also be made safe to drink. Treatment, however, involves a constant expense, which is not required in localities where the water available can be used without treatment. A plant that uses a treated public water supply is dependent on the operator of the plant, whose first thought is necessarily to make the water safe. The treatment used to make the water safe to drink may not always be the best treatment to fit it for industrial use. Nevertheless, in many places

water from a treated municipal supply is much better for industrial use than any private supply that can be obtained in the neighborhood. Further treatment, however, is usually profitable for a manufacturing plant.

PUBLIC WATER SUPPLIES

The industrial utility of public water supplies is discussed in Water-Supply Paper 496, which gives analyses showing the composition of the water supplies of more than 300 cities of the United States, including all that have 25,000 inhabitants or more. The data in that paper have been used in preparing Figure 2, which shows the average hardness of water from public supplies in each State, and Figure 3, which shows the proportion of the population of each State in the cities considered in making Figure 2.

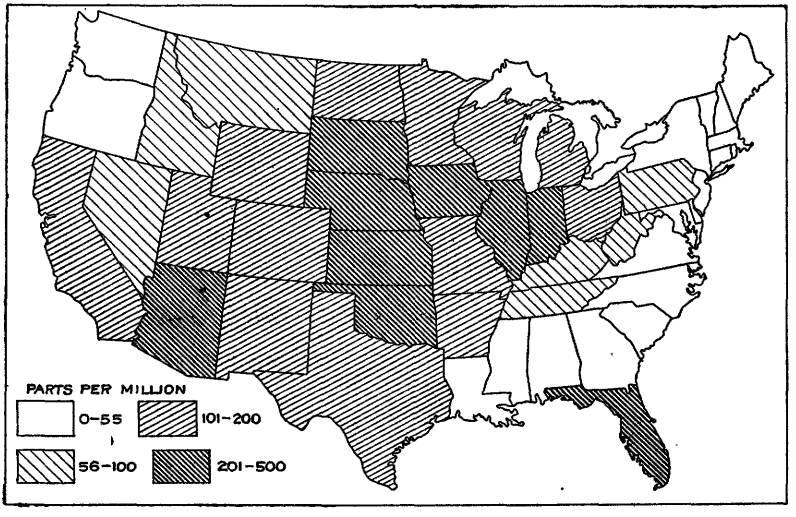


FIGURE 2.—Average hardness, by States, of water furnished by public supply systems in more than 300 cities in the United States

Inspection of Figure 3, together with the charts for 1919 in plates 1 and 2, shows that in general the States that have the denser population and the greater industrial activity are the ones that are better represented on the map that indicates the distribution of hardness. Table 4 (p. 7) shows that 41.4 per cent of the industrial activity of the country in 1919 was concentrated in 15 industrial centers, whose area is 0.21 per cent of the total area of the continental United States and whose population in 1914 was 21.5 per cent of the total.

The data relating to the water supplies of large cities which furnish the basis for Figure 2 evidently represent a much larger proportion of the manufacturing activity of the United States than of the population. Many industrial establishments have their own water

supplies, but in general the water of these private supplies does not differ greatly from the water of neighboring public supplies. Figure

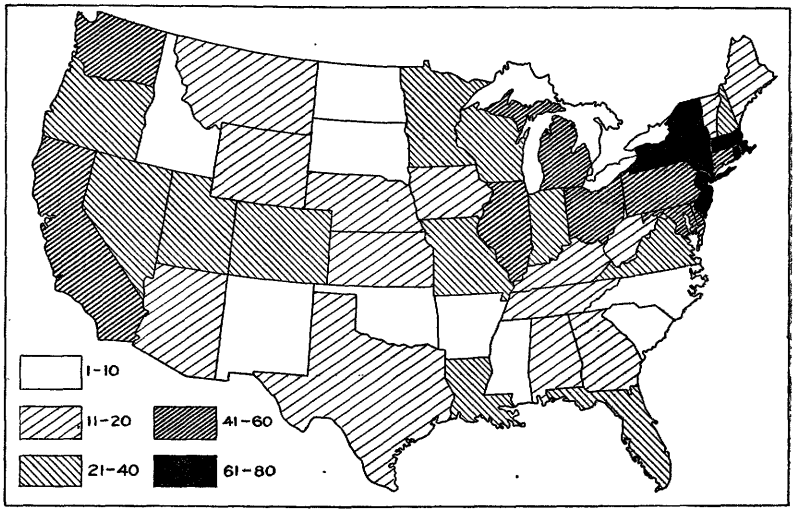


FIGURE 3.—Percentage of population of each State in the cities considered in preparing the map of average hardness

2 may therefore be assumed to show in a general way the hardness of water used by industrial plants in the several States.

TABLE 5.—*Analyses of waters used at industrial centers*

[Parts per million. Samples from public supplies except as otherwise indicated]

No.	Total dissolved solids	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 $CaCO_3$
1	28	2.6	0.04	4.5	1.2	1.1	0.6	11	7.7	1.0	0.49	16
2	69	9.6	.05	12	4.4	1.7	1.2	41	11	2.6	.88	48
3	183	18	.4	36	10	4.6	1.6	144	10	6.0	1.8	131
4	70	9.0	.07	12	3.3	5.4		46	12	2.9	1.1	44
5	201	8.0	.33	24	12	19		56	87	11	.80	109
6	[a] 99	1	.2	27	7.0	2		102	7.4	4.5	.08	96
7	28	3.7	.02	3.0	.7	2.2	1.0	7.0	6.0	2.1	.22	10
8	159	-------	.07	35	8.4	[a] 5.6		113	25	11	-------	122
9	148	8.2	.2	28	4.8	8.5		27	60	13	.8	90
10	201	8.3	[b] 2.7	22	12	26		65	77	10	3.8	104
11	269	22	.39	44	16	21		174	56	9.8	2.7	176
12	74	6.5	.07	14	4.1	3.1		47	14	5.1	1.0	52
13	218	-------	-------	21	7.6	37		91	10	23	-------	83
14	369	-------	-------	38	18	70		276	36	76	-------	166
15	133	5.9	.07	31	7.6	6.5		120	13	8.7	.3	109
16	[a] 162	-------	.03	33	3.7	[a] 13		42	62	19	-------	98
17	[a] 148	-------	.01	27	2.6	[a] 15		33	54	19	-------	78
18	[a] 191	9.1	.05	42	16	7.8		172	28	2.1	.25	171
19	[a] 279	22	0	39	16	34		165	59	28	Trace.	163
20	[a] 378	22	0	66	21	33		214	103	28	Trace.	251
21	76	16	.44	13	2.5	9.1		52	8.8	2.2	.6	43
22	183	7.0	[b] .4	35	14	9.4		169	27	3.5	.6	145
23	434	10	.09	92	34	8.2	1.4	339	84	9.6	13	369
24	289	17	.15	59	24	9.0		256	40	4.1	8.6	246

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

1. New York City; Catskill supply; Mar. 8, 1921. U. S. Geol. Survey Water-Supply Paper 496, p. 49 (No. 190-B), 1923.
2. New York City; Croton supply; Mar. 8, 1921, U. S. Geol. Survey Water-Supply Paper 496, p. 49 (No. 190-A), 1923.
3. Chicago; Lake Michigan; Dec. 5, 1921; analyzed by Illinois State Water Survey. U. S. Geol. Survey Water-Supply Paper 496, p. 35 (No. 49), 1923.
4. Philadelphia; Delaware River; filtered; average of analyses of 10-day composites of daily samples collected at Lambertville, N. J., 1906-7. U. S. Geol. Survey Water-Supply Paper 236, p. 60, 1909. Average suspended matter in raw water, 26 parts per million.
5. Philadelphia; Schuylkill River; filtered; July 19, 1920. U. S. Geol. Survey Water-Supply Paper 496, p. 55 (No. 247-C), 1923.
6. Detroit; Detroit River; filtered; July, 1921; analyzed by Detroit waterworks. U. S. Geol. Survey Water-Supply Paper 496, p. 41 (No. 127), 1923.
7. Boston; Wachusett Reservoir; May 12, 1921. U. S. Geol. Survey Water-Supply Paper 496, p. 39 (No. 98), 1923.
8. Cleveland; Lake Erie; filtered; average of analyses of monthly composites made in Cleveland waterworks laboratory, 1921. U. S. Geol. Survey Water-Supply Paper 496, p. 51 (No. 211), 1923.
9. Pittsburgh; Allegheny River; filtered without coagulation; average of analyses of weekly composite samples from Pittsburgh waterworks laboratory, 1920. U. S. Geol. Survey Water-Supply Paper 496, p. 55 (No. 248), 1923.
10. St. Louis; Mississippi River; filtered and softened; average of analyses of semimonthly composite samples July 1, 1920, to June 30, 1921, made by St. Louis waterworks laboratory. U. S. Geol. Survey Water-Supply Paper 496, p. 45 (No. 147), 1923.
11. St. Louis; Mississippi River; raw water; average of analyses of 10-day composites of daily samples collected near Chester, Ill., 1906-7. U. S. Geol. Survey Water-Supply Paper 239, p. 83, 1910. Average suspended matter, 634 parts per million.
12. Baltimore; Gunpowder River; filtered; average of analyses of composite samples for each month of 1921, made at filtration plant. U. S. Geol. Survey Water-Supply Paper 496, p. 39 (No. 95), 1923.
13. San Francisco; water from reservoir with comparatively low mineral content; analyzed by G. W. Lord Co., Philadelphia, Pa., Apr. 10, 1910. U. S. Geol. Survey Water-Supply Paper 496, p. 31 (No. 17), 1923.
14. San Francisco; water from reservoir with comparatively high mineral content; analyzed by G. W. Lord Co., Philadelphia, Pa., Apr. 10, 1910. U. S. Geol. Survey Water-Supply Paper 496, p. 31 (No. 17), 1923.
15. Buffalo; Lake Erie; average of analyses of monthly samples, 1906-7. U. S. Geol. Survey Water-Supply Paper 236, p. 62, 1909.
16. Cincinnati; Ohio River; filtered; average of analyses for a year of composite monthly samples of filtered water. Cincinnati Waterworks Ann. Rept., 1917-18, p. 73.
17. Cincinnati; Ohio River; raw water; average of analyses for a year of composite monthly samples of raw river water. Cincinnati Waterworks Ann. Rept., 1917-18, p. 73.
18. Minneapolis; Mississippi River; filtered; average of monthly composite samples of combined filter effluent, Minneapolis Waterworks Department, 1921. U. S. Geol. Survey Water-Supply Paper 496, p. 43 (No. 140), 1923.
19. Los Angeles; Owens River; filtered; analyzed in laboratory of Los Angeles Department of Public Service, 1921. U. S. Geol. Survey Water-Supply Paper 496, p. 31 (No. 12-A), 1923.
20. Los Angeles; Los Angeles River; analyzed in laboratory of Los Angeles Department of Public Service, 1921. U. S. Geol. Survey Water-Supply Paper 496, p. 31 (No. 12-B), 1923.
21. Birmingham; Cahaba River; filtered; average of analyses of 10-day composites of daily samples, 1906-7. U. S. Geol. Survey Water-Supply Paper 236, p. 51, 1909. Average suspended matter in raw water, 32 parts per million.
22. Birmingham; Fivemile Creek; filtered; analyzed in laboratory of Birmingham Waterworks Co., May 15, 1922. U. S. Geol. Survey Water-Supply Paper 496, p. 29 (No. 1-B), 1923.
23. Dayton [w lls about 60 feet deep. U. S. Geol. Survey Water-Supply Paper 496, p. 51 (No. 213), 1923.
24. Dayton; Miami River; not used for public supply; average of analyses of 10-day composites of daily samples 1906-7. U. S. Geol. Survey Water-Supply Paper 236, p. 72, 1909. Average suspended matter, 94 parts per million.

WATER SUPPLIES AT INDUSTRIAL CENTERS

The analyses in Table 5, which are shown graphically in Plate 3, give the chemical composition of the dissolved constituents of waters used at the industrial centers listed in Table 4. An analysis of water from the public supply at Dayton, Ohio, is added to represent a type of water used at many manufacturing centers of moderate size.

In addition to the analyses of waters from public supplies, analyses are given for river waters that can be obtained at some of the cities. The analyses as tabulated do not give the quantities of suspended matter in the river waters. The waters of public supplies are practically free from suspended matter, but the river waters at times may carry much more material in suspension than in solution. Average analyses are given for supplies from rivers. A few of the supplies from rivers are fairly uniform in composition throughout the year, especially those which are softened. Others may at times of low water carry in solution twice as much dissolved material as they carry during periods of high water. The quantity of suspended material is naturally greatest at times of high water.

The analyses in Table 5 are stated in parts by weight of the radicles reported for 1,000,000 parts of water. These results can be converted to grains per gallon by dividing the amounts stated by 17.12. Multiplying the parts per million by 0.00829 gives the equivalent pounds of material in each thousand gallons of water.

The diagrams in Plate 3 are made from the analyses in Table 5 expressed in milligram equivalents per kilogram. The milligram equivalents are obtained by dividing the parts per million by the combining weights of the radicles, as follows: Ca 20, Mg 12, Na 23, HCO_3 61, SO_4 48, Cl 35.4, NO_3 62. A unit of height on the diagrams represents the number of parts per million just given for each of the radicles. In the diagrams nitrate is included with chloride and potassium with sodium.

Hardness is expressed as equivalent calcium carbonate ($CaCO_3$), for which one equivalent is 50 parts per million. Thus the cross lines in Plate 3 designate units of 50 parts per million of hardness, approximately 3 grains per gallon. The total hardness is measured by the combined height of the two shaded parts of the left column of an analysis, the sum of the calcium and magnesium. The carbonate hardness is measured to the top of the lowest section of the right column of an analysis if the top of this section (bicarbonate) does not extend beyond the magnesium. The remainder of the total hardness is the noncarbonate hardness.

DEVELOPMENT OF INDUSTRY IN REGIONS OF SOFT WATER AND IN REGIONS OF HARD WATER

The charts in Plate 1 show that formerly industrial activity was centered in the States that are shown in Figure 2 to have soft water. Although manufacturing has steadily increased in these States, the growth has been relatively much more rapid in the States that are shown in Figure 2 to have hard water.

This movement is brought out by Figure 4, which is based on the results given in Table 6. Industrial New England and New York are taken together as representing areas where the water used in manufacturing is soft. Ohio, Indiana, Illinois, and Michigan are taken as representing areas where water is hard. The lake water at Buffalo is not very different from the lake water at Chicago, Detroit,

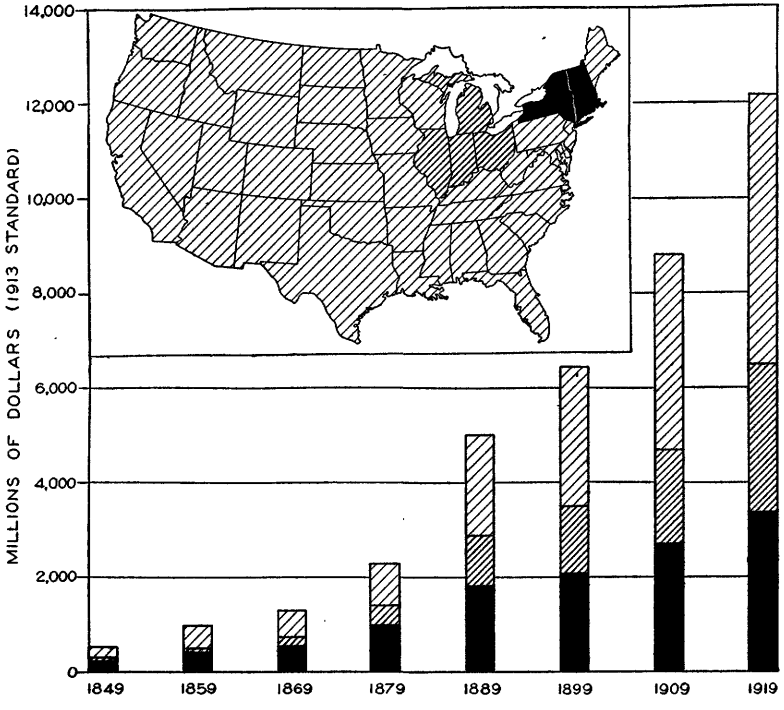


FIGURE 4.—Value added by manufacture for certain groups of States, 1849–1919

and Cleveland, but the manufacturing carried on at Buffalo and other cities in New York with water of equal hardness amounts to only a small proportion of the manufacturing of New York City and the other cities in industrial New England and New York which have even softer water. Similarly, much of the manufacturing in the Middle Western States named is done in cities where the water is much harder than in the cities along the Great Lakes.

TABLE 6.—*Value added by manufacture for groups of States*

[Adjusted to standard of 1913 by index numbers furnished by U. S. Bureau of Labor Statistics]

Millions of dollars

State or group	1849	1859	1869	1879	1889	1899	1909	1919
Industrial New England and New York	255	420	524	962	1,810	2,076	2,710	3,375
Ohio, Indiana, Illinois, and Michigan	56	120	213	428	1,085	1,419	1,993	3,104
Remainder of the United States	222	431	555	931	2,178	2,947	4,090	5,678
	533	971	1,292	2,321	5,073	6,442	8,793	12,157

Per cent

Industrial New England and New York	47.7	43.2	40.6	41.5	35.7	32.2	30.8	27.8
Ohio, Indiana, Illinois, and Michigan	11.1	12.4	16.5	18.4	21.4	22.0	22.7	25.5
Remainder of the United States	41.2	44.4	42.9	40.1	42.9	45.8	46.5	46.7
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The "remainder of the United States"—that is, the portion exclusive of the groups of six and four States which represent areas of soft and hard water—held somewhat less than half the total industrial activity of the country throughout the period from 1849 to 1919. It may be noted that Pennsylvania and New Jersey fall in this "remainder." The total industrial activity of "industrial New England" and New York in 1919 was 13 times as great as in 1849, and the total in the States that have hard water was 55 times the activity in 1849.

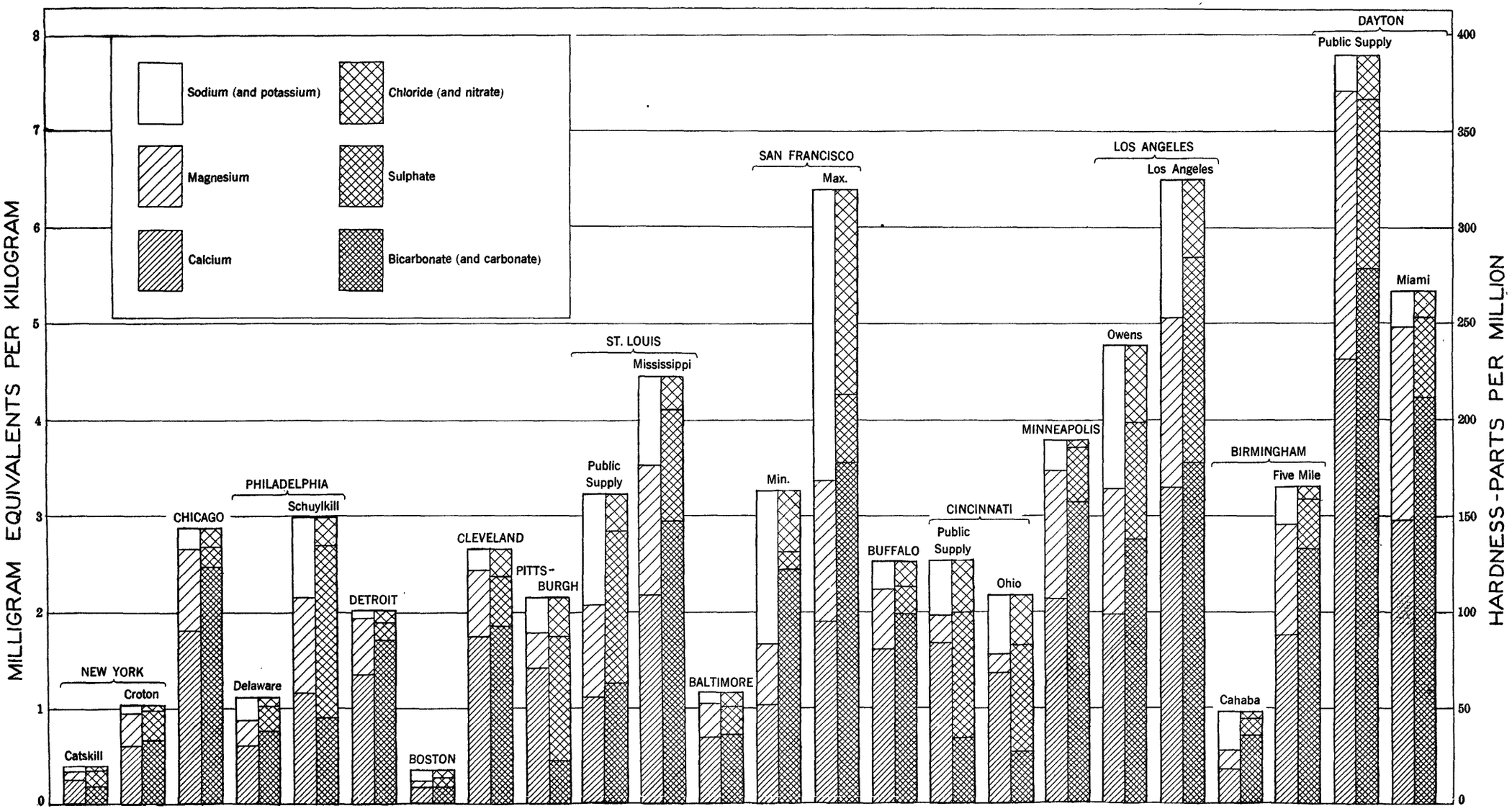
The tables and charts given farther on in this paper show that the industries which require a superior quality of water have contributed to the increase of industrial activity in the States that have soft water rather than in those that have hard water.

CAUSES AFFECTING MOVEMENT OF CENTER OF INDUSTRIAL ACTIVITY

Movement of industrial activity is affected by so many causes in such different proportions for different industries that the attempt to formulate any complete explanation would be a formidable task. A few of the well-recognized factors causing the westward movement of industrial activity may be mentioned.

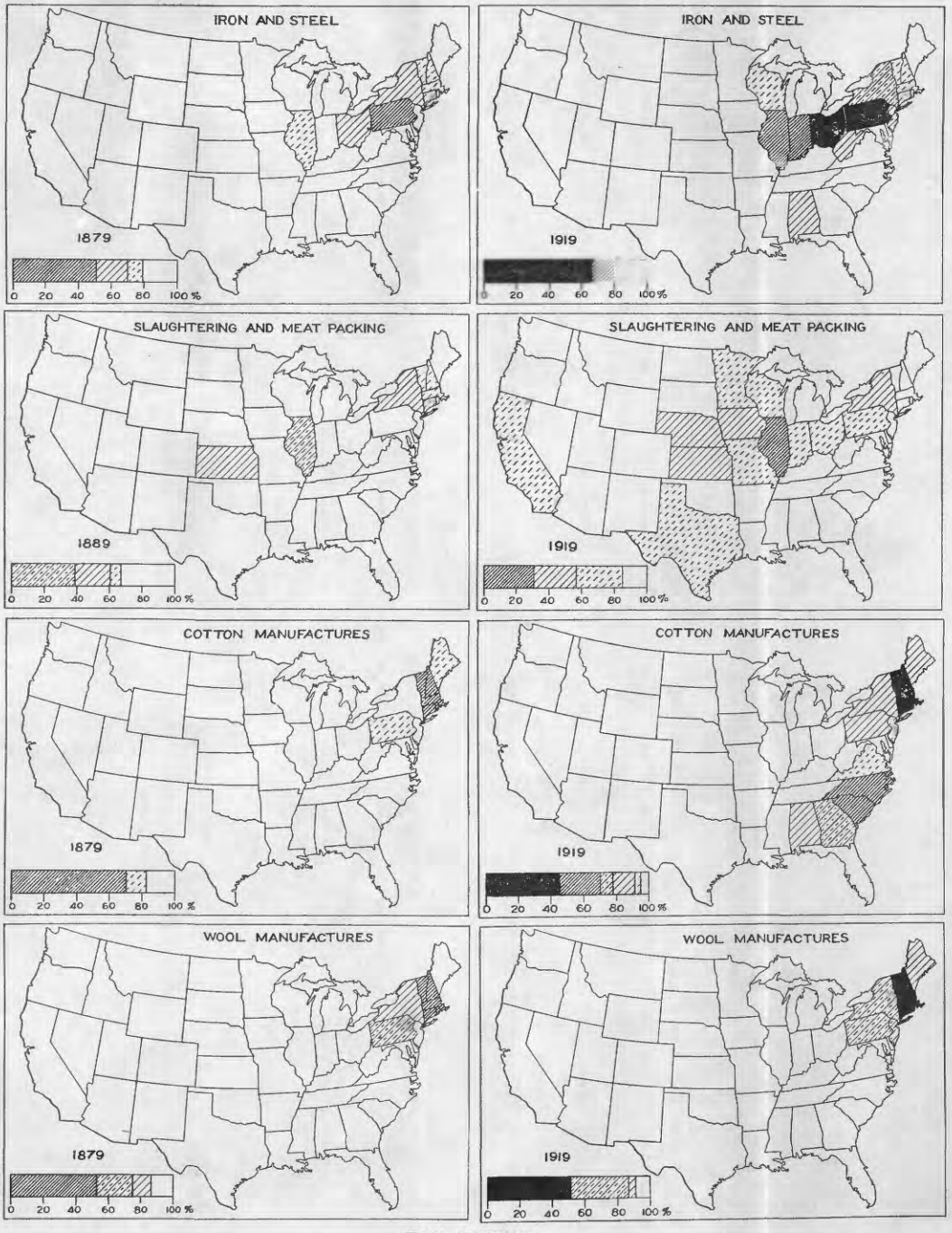
POPULATION

Although the trend of population from rural communities to cities may be a consequence of industrial activity in the cities, there is a certain amount of industry that develops with growth of population. The preparation of food products and the manufacture of articles of everyday use and of articles that are relatively bulky or heavy for their value may follow the population, to save time and cost of transportation from factory to consumer.



COMPOSITION OF WATERS AVAILABLE AT INDUSTRIAL CENTERS

100574—26. (Face p. 16.) No. 1



LOCATION OF INDUSTRIAL ACTIVITY FOR TYPICAL INDUSTRIES IN CERTAIN YEARS

100574—26. (Face p. 16.) No. 2

RAW MATERIALS

Other things being equal, a manufacturing plant will obviously be located as near as possible to the original sources of the raw materials it needs, either at places where the materials are grown or mined or at places that have good facilities for transportation of the materials to the plant.

POWER

The location of industrial plants was formerly influenced greatly by the availability of water power. In later years plants have been located near sources of fuel or at places that have good facilities for transportation of fuel from mines or oil wells to the plants. With the comparatively recent development of large installations of hydroelectric power industrial activity is again concentrated near waterpower sites, although the convenient high-tension transmission makes it unnecessary to erect the manufacturing plant exactly at the waterfall. The newest power development, the efficient high-power steam-electric plant, will also serve to attract industrial establishments. The capacity of these superpower plants is limited by the quantity and temperature of water available for use in condensers. They are therefore located only on large streams or lakes or at the seacoast.

LABOR

One of the main reasons for the concentration of many industries at certain points is that a larger supply of labor is available for the industry after the first few establishments are started. Employees can be much more easily found for a new factory in a place which already has several factories making the same product than in a place where the product has not been made before.

TRANSPORTATION

Ease of transportation of raw materials to the plant and of finished products from the plant is a prime requisite. In earlier years a place served by competing transportation lines had decided advantages over one served by a single transportation company, but this advantage is now less pronounced on account of the Federal regulation of freight rates.

WATER

Practically all industrial plants located in early years at waterpower sites in New England had abundant supplies of excellent water for use in the various processes of manufacture. There was no need to give any thought to the chemical character of the water or to take steps to improve its quality. Pollution of streams, however, with waste matter from manufacturing plants has since made it necessary for some plants to purify water from sources that in their natural condition furnished perfectly satisfactory supplies.

In selecting a location for a new plant the water supply is of prime importance, as has been noted. In addition to the quantity and quality of the natural water available, the feasibility and cost of purifying a water to make it suitable for a particular industry may have to be taken into account. The fact that the water at a certain place must be purified for use in a particular industry may not prevent the location of a plant at that place, but the treatment must be counted as a constant operating expense, whose magnitude depends on the amount of pure water needed, the degree of purity demanded, and the original quality of the water.

LOCATION AND DEVELOPMENT OF TYPICAL INDUSTRIES

Of 14 general groups of industries considered in the census of manufactures by the Fourteenth Census, the value added by manufacture was over $2,000,000,000 in only 4 groups. One of these groups, miscellaneous industries, may be omitted from consideration here. The other three in order of rank were iron and steel and their products, textiles and their products, and food and kindred products. The maps in Plate 4 show the industrial activity in 1879 or 1889 and in 1919 for typical industries in each group. The maps are based on the value added by manufacture adjusted to the standard of 1913 as given in Tables 7, 8, 9, and 10. The two unit areas for groups of States are the same as those given in the other charts. The lowest amount added by manufacture for a State in the charts of individual industries, after reduction to the standard of 1913, is $5,000,000.

IRON AND STEEL

The establishments included in census reports under the headings of blast furnaces, steel works, and rolling mills have been taken as representative of the iron and steel group. Detailed figures are given in Table 7, and charts in Plate 4 show the activity of this industry in 1879 and in 1919.

The location of the industry did not change much from 1879 to 1919. Although there was much more activity in 1919 in Alabama, Illinois, and Indiana, the percentage of the total in Pennsylvania decreased only from 50.7 to 44.3, and for Pennsylvania and Ohio together the percentage of the total increased from 61.4 to 66.0.

The iron and steel industry is typical of a number of industries whose location is determined by the presence of raw materials much more than by the quality of water available. The industry has always been decidedly localized. In 1879 the five States or groups shaded on the map had nearly 80 per cent of the industry, and in 1919 five of the States had 84 per cent of the industry. The only change in this grouping was the replacement of industrial New England by Indiana.

TABLE 7.—*Value added by manufacture in iron and steel works, blast furnaces, and steel works and rolling mills combined, 1849–1919*

[Adjusted to standard of 1913 by index numbers furnished by U. S. Bureau of Labor Statistics. Blanks indicate amounts less than $5,000,000, but these amounts are combined under "Other States"]

Millions of dollars

State or group	1849	1859	1869	1879	1889	1899	1909	1919
Pennsylvania		12.6	22.0	62.8	101.6	201.7	204.0	284.1
Ohio			6.4	12.9	25.0	63.6	77.0	139.3
Indiana						9.2	13.0	47.9
Illinois				6.6	10.8	24.8	39.0	41.9
New York			6.2	10.5	6.5	8.3	20.1	27.7
New Jersey						10.7	5.6	20.0
West Virginia						8.1	6.7	17.0
Alabama					6.1	9.8	6.0	13.5
Industrial New England				5.1	5.9	10.6	5.7	8.3
Wisconsin								7.8
Other States	6.6	13.8	17.7	26.0	26.4	28.7	34.3	34.1
United States	6.6	26.4	52.3	123.9	182.4	375.5	411.4	641.6

Per cent of total

Pennsylvania		47.7	42.1	50.7	55.8	53.7	49.6	44.3
Ohio			12.2	10.4	13.7	16.9	18.7	21.7
Indiana						2.5	3.2	7.5
Illinois				5.3	5.9	6.6	9.5	6.5
New York			11.9	8.5	3.6	2.2	4.8	4.3
New Jersey						2.9	1.4	3.1
West Virginia						2.2	1.6	2.6
Alabama					3.4	2.6	1.5	2.1
Industrial New England				4.1	3.2	2.8	1.4	1.3
Wisconsin								1.2
Other States	100.0	52.3	33.8	21.0	14.4	7.6	8.3	5.4
United States	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

SLAUGHTERING AND MEAT PACKING

The industry of slaughtering and meat packing has been taken as representative of the industries grouped under food and kindred products. It is one of the largest food industries. Data for individual States and groups of States are shown in Table 8. Charts in Plate 4 show the distribution for 1889 and 1919. Only one individual State, Illinois, would have appeared in a chart for 1879, and it had only 36.6 per cent of the whole industry in that year.

The supply of water has little effect on the location of this industry. Shipping facilities for materials and for finished products are of the greatest importance. The industry is not so concentrated as the iron and steel industry. The five States that had the greatest activity in slaughtering and meat packing had only 56.3 per cent of the total value added by manufacture, as compared with 80 per cent for the iron and steel industry in the five most active States in that industry. The general distribution throughout the country is characteristic of the food industries as a whole. In the output of bread and other bakery products the five States that had the greatest activity had only 57.5 per cent of the total value added by manufacture in 1919.

TABLE 8.—*Value added by manufacture in slaughtering and meat packing, 1879–1919*

[Adjusted to standard of 1913 by index numbers furnished by U. S. Bureau of Labor Statistics. Blanks indicate amounts less than $5,000,000, but these amounts are combined under "Other States"]

State or group	Millions of dollars					Per cent of total				
	1879	1889	1899	1909	1919	1879	1889	1899	1909	1919
Illinois	15.4	37.8	55.0	47.3	68.5	36.6	38.9	40.5	27.3	30.4
Kansas		10.3	12.6	18.3	19.3		10.6	9.3	10.6	8.6
Nebraska			10.9	14.4	15.7			8.0	8.3	7.0
New York		11.0	9.2	17.6	12.6		11.3	6.8	10.2	5.6
Iowa			5.5	6.1	10.6			4.0	3.5	4.7
Ohio				6.7	9.6				3.9	4.3
Missouri			5.2	7.7	9.0			3.8	4.4	4.0
Texas				5.3	8.9				3.1	4.0
Minnesota					8.7					3.9
Pennsylvania				7.3	7.6				4.2	3.4
California				6.0	7.3				3.5	3.2
Indiana			7.1	5.5	6.0			5.2	3.2	2.6
Wisconsin					6.0					2.6
Industrial New England		5.9	5.9	6.7			6.1	4.3	3.9	
Other States	26.7	32.2	24.6	24.0	35.2	63.4	33.1	18.1	13.9	15.7
United States	42.1	97.2	136.0	172.9	225.0	100.0	100.0	100.0	100.0	100.0

COTTON MANUFACTURES

The cotton-manufacturing industry has been a large item in the industrial activity of the United States from the time of the first census of manufactures. In 1849 the value added by manufacture of cotton goods was 5.8 per cent of the total for all manufactures reported. In 1919 this value was 3.5 per cent of the total, notwithstanding the number of large industries reported in 1919 that were not known in 1849.

The data in Table 9 and the charts for cotton manufactures in Plate 4 show that the industry has always been mainly located in a few States. The early concentration in industrial New England has persisted, and the production in this area has consistently increased, although the percentage of the whole industry that is located there decreased from 70.2 in 1879 to 45.2 in 1919.

Availability of water power was without doubt a large factor in determining the original location of the plants. The development in the Southern States has been brought about by the nearness to the raw material and has been fostered to some extent by more favorable laws relating to the employment of labor specially suited to some of the processes of manufacture. Table 9 and Figure 2 (p. 11) show that the industry has remained in areas where soft waters are generally available.

TABLE 9.—*Value added by manufacture to product of cotton manufactures, 1839–1919*

[Adjusted to standard of 1913 by index numbers furnished by U. S. Bureau of Labor Statistics. Blanks indicate amounts less than $5,000,000, but these amounts are combined under "Other States"]

Millions of dollars

State or group	1839	1849	1859	1869	1879	1889	1899	1909	1919
Industrial New England	12.8	19.7	44.1	30.4	74.1	88.2	121.0	137.1	193.2
North Carolina							14.7	24.7	63.9
South Carolina							16.6	25.5	44.4
Georgia						5.1	9.9	17.5	33.3
Pennsylvania			7.2		5.8	9.7	15.4	15.6	19.3
Alabama								8.0	13.7
Maine					7.1	8.3	10.2	10.8	13.2
New York						5.1	6.7	8.9	11.6
New Jersey								5.4	9.2
Virginia									7.3
Other States	6.6	11.3	15.1	18.3	18.5	19.7	22.5	12.0	18.4
United States	19.4	31.0	66.4	48.7	105.5	136.1	217.0	265.4	427.5

Per cent of total

Industrial New England	66.0	63.5	66.4	62.4	70.2	64.8	55.5	51.6	45.2
North Carolina							6.7	9.3	14.9
South Carolina							7.7	9.6	10.4
Georgia						3.8	4.5	6.6	7.8
Pennsylvania			10.8		5.5	7.1	7.5	5.9	4.5
Alabama								3.0	3.2
Maine					6.7	6.1	4.7	4.1	3.1
New York						3.7	3.1	3.4	2.7
New Jersey								2.0	2.2
Virginia									1.7
Other States	34.0	36.5	22.8	37.6	17.6	14.5	10.3	4.5	4.3
United States	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

WOOL MANUFACTURES

Wool manufactures have long been one of the large items of industrial activity in the United States. In 1849 the value added by manufacture of woolen goods was 4.3 per cent of the total for all manufacturing reported, and in 1919 this value was 2.0 per cent of the total.

The charts in Plate 4 and the figures in Table 10 show that the woolen industry has been located in a small area since its beginning. In 1849 New York, Pennsylvania, and industrial New England had 76 per cent of the wool manufacturing. The same States in 1879 had 86 per cent, and in 1919 they had 77 per cent.

There is hardly any industry in which the chemical quality of the water used is of more importance than in the woolen industry. The early establishment of the industry in New England was probably due as much to the available water power as to any other cause, but its persistence in New England and other areas of soft water is in no small measure due to the quality of the water.

TABLE 10.—*Value added by manufacture to product of wool manufactures, 1839–1919*

[Adjusted to standards of 1913 by index numbers furnished by U. S. Bureau of Labor Statistics. Blanks indicate amounts less than $5,000,000, but these amounts are combined under "Other States"]

Millions of dollars

State or group	1839	1849	1859	1869	1879	1889	1899	1909	1919
Industrial New England	4.9	11.4	19.8	27.4	55.8	59.5	75.0	99.3	118.6
Pennsylvania			6.0	12.8	23.6	33.0	35.5	34.0	37.5
New Jersey							7.1	14.4	22.6
New York				5.9	12.4	14.2	19.2	22.0	21.4
Maine							7.5	7.3	11.7
Other States	2.9	11.4	8.3	9.2	14.0	17.8	10.0	13.4	19.0
United States	7.8	22.8	34.1	55.3	105.8	124.5	154.3	190.4	230.8

Per cent of total

State or group	1839	1849	1859	1869	1879	1889	1899	1909	1919
Industrial New England	62.8	50.0	58.0	49.6	52.7	47.8	48.6	52.2	51.4
Pennsylvania			17.6	23.1	22.3	26.5	23.0	17.8	16.2
New Jersey							4.6	7.6	9.8
New York				10.7	11.7	11.4	12.4	11.6	9.3
Maine							4.9	3.8	5.1
Other States	37.2	50.0	24.4	16.6	13.3	14.3	6.5	7.0	8.2
United States	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

OTHER TEXTILE INDUSTRIES

The data in Table 12 (pp. 28–38) show that silk manufacture and the dyeing and finishing of textiles have always been concentrated in a few States, which also have a large proportion of the woolen and cotton manufactures. There has been no movement in the silk and dyeing industries corresponding to the development of the cotton industry in the South.

The natural location of dyeing and finishing establishments would be in the neighborhood of the plants that manufacture the materials to be dyed or finished, so that their location in areas where soft water abounds may be considered as the result of the location of the other textile plants in these places. Dyeing, however, is one of the operations most affected by the quality of the water used, and it also requires large quantities of water. Conditions favorable for dyeing may therefore have considerable weight in determining the location of a plant for the manufacture of goods that will be bleached and dyed.

PURIFICATION OF WATER IN RELATION TO THE LOCATION OF INDUSTRY

Some industrial establishments have long been located where the water was not of the best quality because other advantages of the locations outweighed this disadvantage. The quality of water can be improved at a greater or less cost, and some unsatisfactory waters are made as suitable for use as the best natural waters. The cost of treatment and the success with which the quality of the water is

made to approach that of the best natural waters depend on the process adopted and also on the requirements of the particular industry.

CLARIFICATION

The removal of suspended material from water was unquestionably the first type of purification practiced. Much of the suspended material in some waters can be removed by mere sedimentation, and practically all turbid waters are greatly improved by this treatment. Some waters can be completely clarified by filtration through sand of the proper size, but the material in suspension in other waters is so finely divided that its removal by sedimentation or by simple filtration is impossible. Such waters are commonly treated with aluminum sulphate, with or without other chemicals, in order to flocculate the finely divided material and permit its easy removal by rapid filtration.

SOFTENING

LIME-SODA PROCESS

The longest-established process for softening water depends on the addition of lime equivalent to the excess carbon dioxide, the carbonate hardness, and the magnesium in the water, and the addition of soda ash equivalent to the noncarbonate hardness. The exact proportions of the chemicals that will give the best results are finally determined by operating tests. The material that separates on treatment with the chemicals is removed by sedimentation or by filtration.

If the water used changes in composition from day to day the quantities of chemicals used must also be changed. Simple tests and apparatus have been devised for the adjustment of the quantities of chemicals with water of variable composition, but the best results can rarely be obtained without the attention of a chemist or a well-trained operator.

At best the cold lime-soda process leaves considerable hardness in the treated water. The most skillfully operated cold lime-soda softening plant will not furnish water as soft as the natural waters of many lakes and rivers of New England.

As long as the lime-soda process was the only commercial method for softening water, a plant requiring extremely soft water was compelled to locate where such water could be obtained naturally.

For many plants the lime-soda treatment of water, especially the hot process, is decidedly best, but these are not plants whose processes demand the softest water.

EXCHANGE-SILICATE PROCESS

In recent years the softening of water for industrial processes by the use of base-exchange silicates has made great advances. The process consists in passing the water through a bed of mineral material that

has the property of giving up sodium in exchange for the calcium and magnesium in the water. This exchange is practically complete, and the water is softened. When the silicate begins to lose its softening power a strong solution of common salt is allowed to act on it. After the salt is washed out the silicate is ready for use again.

Clear water is necessary for the operation of an exchange-silicate softener, and certain waters are better for boiler use if they are subjected to a preliminary treatment before the exchange-silicate softening.

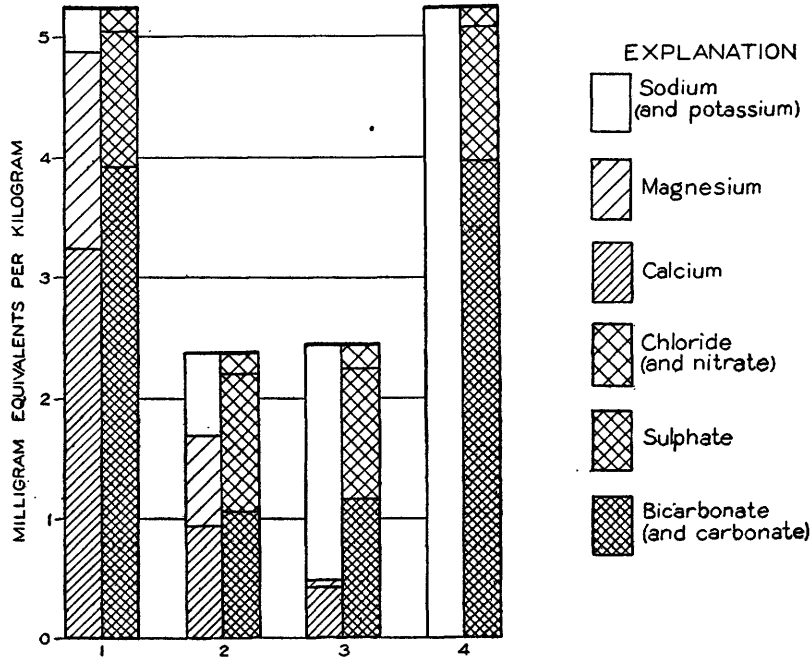


FIGURE 5.—Alteration of a natural water by chemical treatment. 1, River water before treatment; 2, water after treatment with alum, lime, and soda ash for a public supply; 3, water after hot treatment with lime and soda ash to reduce the hardness to 25 parts per million; 4, water after treatment by an exchange silicate softener

RESULTS OF TREATMENT OF WATER

The partial analyses in Table 11, which are shown graphically in Figure 5, illustrate the changes in composition of a natural water treated in different ways. No. 1 is an average analysis of Scioto River water, which is used for the public supply of Columbus, Ohio. In treating the water for the public supply aluminum sulphate is added to produce a precipitate which will assist in the removal of bacteria and finely divided silt when the water is passed through the sand filters. The aluminum is practically all precipitated and the sulphate remains in the water, increasing the total quantity as shown in column 2 of Table 11 and in diagram 2 of Figure 5. The

addition of soda ash increases the sodium, as shown in the table and diagram. As the increase in sodium is greater than the increase in sulphate the noncarbonate hardness of the water is decreased, as shown in diagram 2. Lime is added in sufficient quantity to reduce the hardness to the amount shown in the diagram and table. This reduction results from precipitation of magnesium hydroxide and calcium carbonate, which are removed with the aluminum hydroxide and silt when the water is filtered. The residual hardness shown is somewhat less than the commonly accepted standard of about 100 parts per million for the hardness of softened water for a public supply.

Hardness can be reduced further by cold treatment, but for the most satisfactory and nearly complete softening by lime and soda ash the reactions are made to take place at high temperatures, usually in connection with the heating of boiler feed water. Columns 3 in Table 11 and diagram 3 in Figure 5 represent actual results of the treatment of a water like No. 1 by the hot lime-soda process. In this particular water the total quantity of dissolved material is about the same as that in the water treated for a public supply, but the hardness is much less. Instead of having some residual noncarbonate hardness as shown in No. 2, the sodium is more than equivalent to the chloride and sulphate together.

Treatment with an exchange silicate would change the composition of water represented by diagram 1 to that represented by diagram 4. The total quantity of dissolved mineral matter is not materially changed, but the hardness is practically eliminated. It is necessary that the water be freed from suspended material before it is treated with an exchange silicate. The treatments whose results are shown in diagrams 2 and 3 do not require clear water.

TABLE 11.—*Partial analyses of raw and treated water*

	Parts per million				Milligram equivalents per kilogram			
	1	2	3	4	1	2	3	
Calcium (Ca)	65	19	8.4	Trace.	3.24	0.95	0.42	
Magnesium (Mg)	20	9	.9	Trace.	1.64	.74	.07	
Sodium (Na)	8	16	45	120	.34	.69	1.94	5.22
Bicarbonate radicle (HCO_3)	240	53	70	240	3.93	.87	1.14	3.93
Sulphate radicle (SO_4)	54	64	54	54	1.12	1.33	1.12	1.12
Chloride radicle (Cl)	6	6	6	6	.17	.17	.17	.17

1. River water before treatment.
2. Water after treatment with alum, lime, and soda ash for a public supply.
3. Water after hot treatment with lime and soda ash to reduce the hardness to 25 parts per million.
4. Water after treatment by an exchange-silicate softener.

COST OF TREATMENT OF WATER

The cost of treatment of water obviously depends on the chemical character of the water, the rate of treatment, the method used, and the degree of purification obtained. The figures given in the following

paragraphs are only general approximations based on data supplied by commercial concerns who furnish apparatus for the different types of water treatment.

For rough comparison the water of the public supply of Baltimore, Md., the Croton supply of New York City, and the Delaware River supply of Philadelphia may be taken as all having about 50 parts per million of total hardness, or 3 grains per gallon. For a margin of safety in estimating costs, these waters may be considered as having 4 grains per gallon of hardness. The hardness of the water of public supplies in the following cities is from 100 to 150 parts per million, which for calculations of cost may be considered 8 grains: Buffalo, N. Y.; Chicago, Ill.; Cincinnati, Cleveland, and Columbus, Ohio; Detroit, Mich.; Milwaukee, Wis.; Philadelphia (Schuylkill River supply) and Pittsburgh, Pa.; and St. Louis, Mo. A hardness of 24 grains per gallon, or 410 parts per million, may be used in calculation for cities in the following group, in which the hardness of the water from public supplies is between 300 and 400 parts per million: Dayton, Ohio; Des Moines, Iowa; Indianapolis, Ind.; Lansing, Mich.; Peoria, Ill.: Sioux City, Iowa; Springfield, Ill.; and Springfield, Ohio.

The cost of treating water within a steam boiler may be from 2 to 20 cents per thousand gallons, depending on the character of the water, the size of the plant, and the kind of treatment used. Some users of this type of treatment are satisfied that they would obtain no better results with a more costly type of treatment. Other operators of boiler plants desire to remove as much as possible of the scale-forming material from water before it enters a boiler, and therefore use one of the processes that require considerable expenditure for equipment in addition to the expense of the chemicals used.

The cost of a lime-soda softening plant of a given make is determined by the quantity of water to be softened; the composition of the water affects only the quantity of chemicals used. A cold-process softener that has an hourly capacity of 1,000 gallons may cost $1,500 to $2,500. A plant that has an hourly capacity of 10,000 gallons may cost from $5,000 to $10,000.

The cost of chemicals increases with the hardness and with the proportion of noncarbonate hardness. Chemicals for a cold-process plant to soften water from the supply of Chicago would cost about 2 or 3 cents per 1,000 gallons; for water from the supply of Dayton, 5 or 10 cents.

The cost of a hot-process lime-soda softener is not far from the combined cost of a cold-process softener and a feed-water heater. The cost of chemicals is about the same as for a cold-process softener.

The cost of installation of an exchange-silicate softener depends on both the rate of softening and the hardness of the water. The

cost is also affected by the frequency of regeneration. Unlike the lime-soda process, which is generally continuous, the exchange-silicate process is intermittent, because the softener has a limit beyond which it will not soften water completely. A softener in which this limit will not be reached until the end of the day must be larger than one requiring regeneration at the noon period to give the same quantity of soft water in a day. The exchange-silicate softener has a normal rate of filtration per square foot of cross section, which must also be taken into consideration. To install a plant to soften 1,000 gallons of water from the supply of Baltimore each hour for 10 hours might cost up to $1,000. For a little more a plant could be obtained which by regeneration at noon would furnish 20,000 gallons in a 10-hour day. A corresponding plant operating on water from the supply of Chicago might cost about $1,500, and on water from the supply of Dayton about $2,500. A plant to give 10,000 gallons an hour for a 10-hour run might cost for Baltimore about $2,500, for Chicago $4,000, and for Dayton $10,000. The total cost of a softener installed at any of these places will depend considerably on the freight and labor of installation. The cost of salt for regeneration in small installations is a little under 2 cents for each thousand gallons of water softened at Baltimore, 4 cents at Chicago, and 12 cents at Dayton. The cost will be much less for large installations for which salt may be bought by the carload.

If the exchange-silicate softener is used for a water that is not clear a prefilter is generally used for clarification. The cost of this equipment can hardly be set down, even approximately. Combination systems are used at some plants where the water is first treated with lime or lime soda, and after filtration is completely softened by an exchange silicate.

SOFTENING AND PLANT LOCATION

The exchange-silicate softening process gives an entirely new aspect to the relation of quality of water to the location of industrial establishments. When the softest waters obtainable were the lake and river waters in certain regions, some kinds of industry were almost obliged to locate in these places. For other industries the less desirable waters could be made satisfactory by the lime-soda treatment, and the only consideration involved was the expense of installing and operating the water-softening equipment. Now that water essentially free from hardness can be obtained by exchange-silicate treatment of any moderately hard water, the industries requiring such water are not confined to so small an area but can operate at many places hitherto out of the question simply by paying for the installation and operation of an exchange-silicate softener.

LOCATION AND DEVELOPMENT OF SELECTED INDUSTRIES

The following table shows the location and changes in location of a number of individual industries and some groups of industries for the years in which the value added by manufacture, adjusted to the standard of 1913, was as much as $5,000,000 for several States. The unit areas of industrial New England and Maryland each include the same States as in the tables presented on previous pages.

The selected industries include practically all for which the census reports show a large proportion of the total activity for the United States in States where the value added by manufacture was beyond the limit stated above. Some large industries are omitted altogether, and certain years are omitted for other industries because the data could not be published for some States where the industry was much larger than others for which figures were given, as happens when the number of establishments or companies operating in a State is so small that publication of totals for that State would reveal the business of a single company, at least to its competitors.

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*

[Values adjusted to standard of 1913 by index numbers furnished by U. S. Bureau of Labor Statistics]

Agricultural implements

State or group	Millions of dollars						Per cent of total					
	1869	1879	1889	1899	1909	1919	1869	1879	1889	1899	1909	1919
Illinois	------	8.0	17.5	30.9	33.4	30.6	------	18.4	29.2	40.5	37.7	39.3
Wisconsin	------	------	------	6.1	7.7	12.2	------	------	------	8.0	8.7	15.7
Indiana	------	------	------	5.1	9.1	9.3	------	------	------	6.6	10.2	11.9
Ohio	5.0	9.6	10.5	10.5	8.4	6.6	22	22.0	17.5	13.8	9.5	8.5
New York	5.4	7.3	9.5	7.6	8.9	5.1	24	16.7	15.9	9.9	10.0	6.6
Michigan	------	------	------	5.2	6.6	------	------	------	------	6.8	7.4	------
Other States	12.3	18.7	22.4	11.0	14.6	14.0	54	42.9	37.4	14.4	16.5	18.0
United States	22.7	43.6	59.9	76.4	88.7	77.8	100	100.0	100.0	100.0	100.0	100.0

Automobiles, including bodies and parts

State or group	Millions of dollars		Per cent of total	
	1909	1919	1909	1919
Michigan	44.0	320.7	36.3	58.0
Ohio	21.0	62.4	17.4	11.3
New York	16.5	36.6	13.6	6.6
Indiana	9.0	29.8	7.5	5.4
Wisconsin	6.3	21.5	5.2	3.9
Pennsylvania	----------	18.3	----------	3.3
Illinois	----------	15.0	----------	2.7
New Jersey	----------	8.5	----------	1.5
Missouri	----------	8.2	----------	1.5
California	----------	6.8	----------	1.2
Industrial New England	13.1	5.4	10.8	1.0
Other States	11.2	20.0	9.2	3.6
United States	121.0	553.2	100.0	100.0

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Automobile repairing

State or group	Millions of dollars, 1919	Per cent of total, 1919
California	7.6	11.4
New York	7.2	11.0
Pennsylvania	6.0	9.0
Other States	45.7	68.6
United States	66.5	100.0

Boots and shoes

State or group	Millions of dollars						Per cent of total					
	1869	1879	1889	1899	•1909	1919	1869	1879	1889	1899	1909	1919
Industrial New England	30.6	46.3	70.7	65.3	98.0	95.9	46.9	61.9	57.6	53.0	52.8	44.9
New York	8.9	8.8	13.6	13.3	19.8	40.1	13.6	11.8	11.1	10.8	10.6	18.8
Missouri	------	------	------	------	14.6	15.7	------	------	------	------	7.9	7.4
Ohio	------	------	------	9.1	13.1	14.9	------	------	------	7.4	7.1	7.0
Pennsylvania	7.3	5.0	6.4	6.7	8.5	11.8	11.2	6.7	5.2	5.5	4.6	5.5
Maine	------	------	5.4	5.2	5.8	8.6	------	------	4.4	4.2	3.1	4.0
Wisconsin	------	------	------	------	------	8.1	------	------	------	------	------	3.8
Illinois	------	------	------	5.5	6.1	6.9	------	------	------	4.4	3.3	3.2
Other States	18.5	14.7	26.7	18.1	19.7	11.5	28.3	19.6	21.7	14.7	10.6	5.4
United States	65.3	74.8	122.8	123.2	185.6	213.5	100.0	100.0	100.0	100.0	100.0	100.0

• Figures for 1909 include cut stock and findings not included in other years.

Brass, bronze, and copper products

State or group	Millions of dollars			Per cent of total		
	1899	1909	1919	1899	1909	1919
Industrial New England	19.0	22.4	33.2	51.8	42.8	38.5
New York	5.1	9.3	12.9	13.9	17.9	15.0
Michigan	------	5.1	11.6	------	9.7	13.5
Pennsylvania	------	------	5.9	------	------	6.8
Ohio	------	------	5.6	------	------	6.5
Other States	12.6	15.5	17.0	34.3	29.6	19.7
United States	36.7	52.3	86.2	100.0	100.0	100.0

Bread and other bakery products

State or group	Millions of dollars					Per cent of total				
	1879	1889	1899	1909	1919	1879	1889	1899	1909	1919
New York	8.1	17.4	26.0	34.5	46.6	30.0	25.9	24.3	21.1	21.9
Pennsylvania	------	8.3	12.9	19.1	23.9	------	12.4	12.1	11.6	11.2
Illinois	------	------	10.3	15.0	19.9	------	------	9.6	9.2	9.3
Industrial New England	------	8.7	14.5	16.2	18.1	------	12.9	13.5	9.9	8.5
Ohio	------	------	5.9	9.6	14.0	------	------	5.5	5.8	6.6
New Jersey	------	------	------	8.1	9.2	------	------	------	5.0	4.3
California	------	------	------	7.5	8.6	------	------	------	4.6	4.0
Missouri	------	------	------	7.9	8.5	------	------	------	4.8	4.0
Michigan	------	------	------	------	8.2	------	------	------	------	3.9
Maryland	------	------	------	------	6.3	------	------	------	------	3.0
Indiana	------	------	------	------	5.1	------	------	------	------	2.4
Other States	19.2	32.8	37.5	45.8	44.6	70.0	48.8	35.0	28.0	20.9
United States	27.3	67.2	107.1	163.7	213.0	100.0	100.0	100.0	100.0	100.0

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Canning and preserving

State or group	Millions of dollars			Per cent of total		
	1899	1909	1919	1899	1909	1919
California	6.4	9.2	35.4	13.4	16.0	33.8
New York	6.4	7.6	9.4	13.4	13.4	8.9
Pennsylvania	----------	5.0	5.9	----------	8.7	5.6
New Jersey	----------	----------	5.6	----------	----------	5.4
Illinois	----------	----------	5.1	----------	----------	4.9
Maryland	5.9	----------	5.1	12.4	----------	4.9
Indiana	----------	----------	5.0	----------	----------	4.8
Other States	28.9	35.4	33.2	60.8	61.9	31.7
United States	47.6	57.2	104.7	100.0	100.0	100.0

Cars and general shop construction and repairs by steam railroad companies

State or group	Millions of dollars				Per cent of total			
	1889	1899	1909	1919	1889	1899	1909	1919
Pennsylvania	15.5	26.5	35.7	62.3	20.5	18.3	16.8	16.8
Illinois	7.6	11.1	17.5	30.7	10.0	7.7	8.2	8.3
Ohio	5.1	9.3	14.8	27.6	6.7	6.4	7.0	7.5
New York	5.4	9.7	12.0	23.7	7.2	6.7	5.6	6.4
Indiana	----------	6.4	9.6	17.7	----------	4.4	4.5	4.8
Texas	----------	5.9	8.0	13.2	----------	4.1	3.8	3.6
California	----------	----------	9.5	12.7	----------	----------	4.5	3.4
Minnesota	----------	----------	6.3	11.0	----------	----------	3.0	3.0
Iowa	----------	----------	5.3	10.1	----------	----------	2.5	2.7
Missouri	----------	----------	5.9	9.9	----------	----------	2.8	2.7
Kentucky	----------	----------	----------	9.0	----------	----------	----------	2.4
Virginia	----------	----------	----------	8.9	----------	----------	----------	2.4
Maryland	----------	----------	5.3	8.8	----------	----------	2.5	2.4
Wisconsin	----------	----------	5.9	8.6	----------	----------	2.8	2.3
Kansas	----------	----------	6.2	8.6	----------	----------	2.9	2.3
West Virginia	----------	----------	----------	8.6	----------	----------	----------	2.3
New Jersey	----------	----------	5.4	8.6	----------	----------	2.5	2.3
Tennessee	----------	----------	----------	7.9	----------	----------	----------	2.1
Industrial New England	----------	5.8	5.4	7.4	----------	4.0	2.5	2.0
Alabama	----------	----------	----------	6.5	----------	----------	----------	1.8
Georgia	----------	----------	----------	5.8	----------	----------	----------	1.6
Michigan	----------	----------	----------	5.3	----------	----------	----------	1.4
Nebraska	----------	----------	----------	5.2	----------	----------	----------	1.4
Other States	42.2	70.1	59.8	52.5	55.6	48.4	28.1	14.1
United States	75.8	144.8	212.6	370.6	100.0	100.0	100.0	100.0

Chemicals

State or group	Millions of dollars			Per cent of total		
	1899	1909	1919	1899	1909	1919
Pennsylvania	8.3	6.0	22.6	22.1	10.9	20.9
New Jersey	6.9	10.9	18.9	18.4	19.7	17.5
New York	9.8	16.1	18.1	26.1	29.1	16.8
Michigan	----------	8.0	10.7	----------	14.5	9.9
Ohio	----------	----------	8.5	----------	----------	7.9
Other States	12.5	14.3	29.2	33.4	25.8	27.0
United States	37.5	55.3	108.0	100.0	100.0	100.0

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Clothing, men's

State or group	Millions of dollars						Per cent of total					
	1869	1879	1889	1899	1909	1919	1869	1879	1889	1899	1909	1919
New York	13.6	33.4	61.5	98.4	134.7	128.8	29.8	36.3	25.7	47.4	48.3	47.6
Illinois	----	7.7	18.6	27.1	45.6	51.6	----	8.4	7.8	13.1	16.4	19.1
Pennsylvania	7.3	10.0	14.5	19.5	20.4	17.0	16.0	10.8	6.1	9.4	7.3	6.3
Maryland	----	----	8.3	11.5	16.6	14.3	----	----	3.5	5.5	6.0	5.3
Ohio	----	9.4	12.9	10.4	12.3	13.6	----	10.2	5.4	5.0	4.4	5.0
Industrial New England	8.2	11.0	14.3	9.2	10.7	9.9	18.0	12.0	5.9	4.4	3.8	3.7
Missouri	----	----	----	5.7	6.5	6.6	----	----	----	2.8	2.3	2.4
Other States	16.5	20.5	109.2	25.8	32.1	28.7	36.2	22.3	45.6	12.4	11.5	10.6
United States	45.6	92.0	239.3	207.6	278.9	270.5	100.0	100.0	100.0	100.0	100.0	100.0

Clothing, women's

State or group	Millions of dollars					Per cent of total				
	1879	1889	1899	1909	1919	1879	1889	1899	1909	1919
New York	9.1	27.7	66.7	128.3	190.9	62	68	67.1	70.7	74.3
Pennsylvania	----	----	7.2	15.2	15.2	----	----	7.2	8.4	5.9
Illinois	----	----	6.4	7.6	13.1	----	----	6.5	4.2	5.0
Ohio	----	----	----	9.5	11.0	----	----	----	5.2	4.3
Industrial New England	----	----	----	6.7	8.1	----	----	----	3.7	3.1
Other States	5.5	13.1	19.1	14.2	19.0	38	32	19.2	7.8	7.4
United States	14.6	40.8	99.4	181.5	256.4	100	100	100.0	100.0	100.0

Confectionery and ice cream

State or group	Millions of dollars			Per cent of total		
	1899	1909	1919	1899	1909	1919
New York	10.9	10.2	23.1	32.5	18.6	17.7
Industrial New England	----	6.8	16.3	----	12.4	12.5
Illinois	----	5.3	15.5	----	9.5	11.9
Pennsylvania	6.0	5.5	13.9	17.8	9.9	10.7
Ohio	----	----	8.4	----	----	6.4
Missouri	----	----	5.1	----	----	3.9
Other States	16.8	27.3	48.0	49.7	49.6	36.9
United States	33.7	55.1	130.3	100.0	100.0	100.0

Druggists' preparations, patent medicines and compounds, and perfumery and cosmetics

State or group	Millions of dollars			Per cent of total		
	1899	1909	1919	1899	1909	1919
New York	16.4	24.8	27.2	28.9	27.1	25.9
Illinois	4.5	8.7	10.8	7.9	9.5	10.3
Michigan	4.4	8.5	9.8	7.7	9.3	9.3
Industrial New England	7.0	6.4	7.8	12.3	7.0	7.4
Pennsylvania	5.2	7.3	7.3	9.2	7.9	7.0
Missouri	----	5.1	6.3	----	5.6	6.0
Ohio	----	----	5.6	----	----	5.3
Other States	19.3	30.8	30.2	34.0	33.6	28.8
United States	56.8	91.6	105.0	100.0	100.0	100.0

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Dyeing and finishing textiles, exclusive of that done in textile mills

State or group	Millions of dollars					Per cent of total				
	1879	1889	1899	1909	1919	1879	1889	1899	1909	1919
Industrial New England	12.1	8.5	16.8	22.8	27.8	55.5	43.0	46.6	45.8	38.4
New Jersey			8.0	9.7	17.0			22.3	19.5	23.5
New York				5.7	10.0				11.4	13.8
Pennsylvania			5.1	6.9	11.1			14.1	13.9	15.4
Other States	9.7	11.3	6.1	4.7	6.5	44.5	57.0	17.0	9.4	8.9
United States	21.8	19.8	36.0	49.8	72.4	100.0	100.0	100.0	100.0	100.0

Electric machinery, apparatus, and supplies

State or group	Millions of dollars			Per cent of total		
	1899	1909	1919	1899	1909	1919
New York	14.8	22.5	51.5	25.8	19.4	18.5
Industrial New England	10.0	22.8	45.6	17.5	19.6	16.4
Ohio		12.0	41.1		10.3	14.8
Pennsylvania	10.3	18.4	39.5	18.0	15.8	14.2
Illinois	10.0	13.6	33.0	17.5	11.7	11.9
New Jersey		14.3	29.8		12.3	10.7
Indiana			10.1			3.6
Michigan			7.8			2.8
Wisconsin			6.9			2.5
Missouri			6.7			2.4
Other States	12.2	12.6	6.1	21.2	10.9	2.2
United States	57.3	116.2	278.1	100.0	100.0	100.0

Engines, steam, gas, and water

State or group	Millions of dollars, 1919	Per cent of total, 1919	State or group	Millions of dollars, 1919	Per cent of total, 1919
Wisconsin	22.3	18.6	New York	9.6	8.0
Michigan	21.8	18.1	New Jersey	6.8	5.7
Pennsylvania	16.4	13.7	Other States	21.5	17.9
Ohio	10.9	9.1			
Illinois	10.7	8.9	United States	120.0	100.0

Fertilizers

State or group	Millions of dollars		Per cent of total	
	1909	1919	1909	1919
Georgia	6.0	8.1	16.5	17.3
Maryland		6.0		12.9
South Carolina		5.3		11.4
Other States	29.5	27.2	83.5	58.4
United States	35.5	46.6	100.0	100.0

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Flour-mill and gristmill products

State or group	Millions of dollars						
	1859	1869	1879	1889	1899	1909	1919
Minnesota	------	------	5.2	9.4	12.5	15.3	21.1
Kansas	------	------	------	------	------	8.3	11.9
New York	6.8	7.1	7.2	9.2	8.3	9.6	9.5
Missouri	------	5.2	5.0	6.4	5.9	5.9	7.3
Illinois	------	6.2	7.1	7.4	5.5	5.7	6.5
Ohio	------	------	5.7	7.2	7.4	6.9	6.0
Pennsylvania	------	5.7	6.1	7.5	8.0	6.8	------
Michigan	------	------	------	------	------	5.7	------
Indiana	------	------	------	5.5	5.8	5.7	------
Other States	38.8	33.6	38.7	42.2	59.1	49.7	60.6
United States	45.6	57.8	75.0	94.8	112.5	119.6	122.9
	Per cent of total						
Minnesota	------	------	7.0	9.9	11.0	12.8	17.2
Kansas	------	------	------	------	------	6.9	9.7
New York	14.9	12.3	9.6	9.7	7.5	8.0	7.7
Missouri	------	9.0	6.7	6.8	5.2	4.9	5.9
Illinois	------	10.7	9.5	7.8	4.9	4.8	5.3
Ohio	------	------	7.6	7.6	6.5	5.8	4.9
Pennsylvania	------	9.9	8.1	7.9	7.2	5.7	------
Michigan	------	------	------	------	------	4.8	------
Indiana	------	------	------	5.8	5.2	4.8	------
Other States	85.1	58.1	51.5	44.5	52.5	41.5	49.3
United States	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Foundry and machine-shop products

State or group	Millions of dollars					Per cent of total				
	1879	1889	1899	1909	1919	1879	1889	1899	1909	1919
Pennsylvania	20.5	46.2	86.8	113.1	100.0	15.7	15.8	14.9	16.4	15.3
Ohio	11.5	29.3	65.9	83.8	97.1	8.8	10.0	11.3	12.2	14.8
New York	28.8	54.0	93.8	95.6	76.2	22.1	18.5	16.2	13.8	11.6
Industrial New England	25.0	50.4	99.6	118.3	70.2	19.1	17.3	17.2	17.2	10.8
Illinois	7.5	26.0	58.3	77.1	66.5	5.7	8.9	10.0	11.2	10.2
Michigan	------	9.5	19.9	27.5	48.8	------	3.3	3.4	4.0	7.5
New Jersey	6.0	14.1	26.7	36.6	35.5	4.6	4.8	4.6	5.3	5.1
Wisconsin	------	5.7	18.3	32.6	24.5	------	2.0	3.2	4.7	3.8
Indiana	------	6.6	14.0	22.0	22.9	------	2.3	2.4	3.2	3.5
Missouri	------	9.5	11.1	11.1	14.3	------	3.3	1.9	1.6	2.2
California	------	5.4	9.6	14.2	13.9	------	1.9	1.7	2.0	2.1
Minnesota	------	------	5.3	8.7	9.3	------	------	.9	1.3	1.4
Maryland	------	5.4	11.5	9.4	6.4	------	1.9	2.0	1.4	1.0
Washington	------	------	------	------	6.2	------	------	------	------	1.0
Oregon	------	------	------	------	6.0	------	------	------	------	.9
Tennessee	------	------	------	------	5.3	------	------	------	------	.8
Iowa	------	------	------	7.9	5.1	------	------	------	1.2	.8
Texas	------	------	------	------	5.1	------	------	------	------	.8
Alabama	------	------	------	5.5	------	------	------	------	.8	------
Kentucky	------	------	------	5.1	------	------	------	------	.7	------
Other States	31.3	29.0	59.8	20.7	41.4	24.0	10.0	10.3	3.0	6.4
United States	130.6	291.1	580.6	689.2	652.6	100.0	100.0	100.0	100.0	100.0

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Furniture

State or group	Millions of dollars						Per cent of total					
	1869	1879	1889	1899	1909	1919	1869	1879	1889	1899	1909	1919
New York	8.4	10.0	16.9	19.1	23.5	26.7	24.3	20.5	21.1	19.5	17.4	17.8
Michigan	------	------	7.8	11.5	17.4	19.9	------	------	9.8	11.8	12.9	13.2
Illinois	------	------	10.8	11.7	15.9	15.8	------	------	13.5	11.9	11.8	10.4
Indiana	------	------	5.3	6.3	10.3	12.1	------	------	6.6	6.5	7.6	8.1
Wisconsin	------	------	------	6.9	10.2	11.3	------	------	------	7.1	7.5	7.5
Pennsylvania	------	------	6.4	7.3	10.2	10.9	------	------	8.0	7.5	7.5	7.3
Ohio	------	------	7.6	7.3	9.3	10.2	------	------	9.5	7.5	6.9	6.8
Industrial New England	7.2	7.1	9.4	10.6	10.3	8.8	20.5	14.6	11.8	10.9	7.6	5.9
North Carolina	------	------	------	------	------	7.5	------	------	------	------	------	5.0
Other States	19.2	31.6	15.8	16.9	28.1	27.1	55.2	64.9	19.7	17.3	20.8	18.0
United States	34.8	48.7	80.0	97.6	135.2	150.3	100.0	100.0	100.0	100.0	100.0	100.0

Gas, illuminating and heating

State or group	Millions of dollars				Per cent of total			
	1889	1899	1909	1919	1889	1899	1909	1919
New York	16.6	20.1	28.1	13.7	32.1	27.3	23.8	16.5
Industrial New England	7.5	8.3	12.0	10.7	14.4	11.3	10.2	12.9
Illinois	5.3	9.1	15.2	9.2	10.2	12.4	13.0	11.0
Pennsylvania	------	6.3	12.0	6.9	------	8.6	10.2	8.3
New Jersey	------	------	7.2	6.3	------	------	6.1	7.5
California	------	------	6.5	6.0	------	------	5.5	7.2
Other States	22.4	29.7	37.0	30.5	43.3	40.4	31.2	36.6
United States	51.8	73.5	118.0	83.3	100.0	100.0	100.0	100.0

Glass

State or group	Millions of dollars					Per cent of total				
	1879	1889	1899	1909	1919	1879	1889	1899	1909	1919
Pennsylvania	6.4	14.4	20.8	20.7	25.7	41.6	41.5	38.5	34.5	30.9
West Virginia	------	------	------	5.6	14.0	------	------	------	9.3	16.8
Ohio	------	------	------	9.9	11.0	------	------	------	16.6	13.2
Indiana	------	------	13.6	7.0	8.2	------	------	25.1	11.6	9.9
Illinois	------	------	------	------	6.2	------	------	------	------	7.5
New Jersey	------	------	------	5.1	------	------	------	------	8.5	------
Other States	9.0	20.3	19.7	11.7	18.0	58.4	58.5	36.4	19.5	21.7
United States	15.4	34.7	54.1	60.0	83.1	100.0	100.0	100.0	100.0	100.0

Jewelry

State or group	Millions of dollars					Per cent of total				
	1879	1889	1899	1909	1919	1879	1889	1899	1909	1919
Industrial New England	6.7	10.1	17.3	21.5	18.6	48	45	54.2	47.7	41.0
New York	------	------	6.4	10.2	13.5	------	------	20.1	22.6	29.7
New Jersey	------	------	------	7.2	6.4	------	------	------	16.0	14.1
Other States	7.3	12.4	8.2	6.2	6.9	52	55	25.7	13.7	15.2
United States	14.0	22.5	31.9	45.1	45.4	100	100	100.0	100.0	100.0

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Knit goods

State or group	Millions of dollars				Per cent of total			
	1889	1899	1909	1919	1889	1899	1909	1919
New York	13.4	21.0	29.3	39.0	35.4	35.3	31.6	28.1
Pennsylvania	9.9	14.7	23.1	34.7	26.2	24.7	24.9	25.0
Industrial New England	8.8	11.3	15.2	17.3	23.3	19.0	16.4	12.5
Wisconsin	------	------	------	8.0	------	------	------	5.8
Tennessee	------	------	------	6.1	------	------	------	4.4
North Carolina	------	------	------	5.9	------	------	------	4.2
Other States	5.7	12.5	25.1	27.8	15.1	21.0	27.1	20.0
United States	37.8	59.5	92.7	138.8	100.0	100.0	100.0	100.0

Laundries, power

[Amount received for work done]

State or group	Millions of dollars		Per cent of total	
	1909	1919	1909	1919
New York	11.8	11.9	10.9	10.4
California	9.8	11.1	9.1	9.7
Illinois	10.3	10.0	9.5	8.7
Industrial New England	9.3	9.7	8.6	8.5
Pennsylvania	8.6	7.0	8.0	6.1
Ohio	5.6	6.1	5.2	5.3
Other States	52.6	58.8	48.7	51.3
United States	108.0	114.6	100.0	100.0

Leather, tanned, curried, and finished

State or group	Millions of dollars			Per cent of total		
	1899	1909	1919	1899	1909	1919
Pennsylvania	17.6	19.4	31.5	27.0	23.6	23.1
Industrial New England	8.4	11.7	23.6	12.9	14.3	17.3
New York	7.8	6.9	13.4	11.9	8.4	9.8
New Jersey	5.6	8.5	12.3	8.6	10.3	9.0
Wisconsin	5.3	10.1	12.2	8.1	12.3	8.9
Maryland	------	------	11.5	------	------	8.4
Illinois	------	------	8.6	------	------	6.3
Michigan	------	------	6.5	------	------	4.8
Other States	20.6	25.5	16.9	31.5	31.1	12.4
United States	65.3	82.1	136.5	100.0	100.0	100.0

Liquors, distilled

State or group	Millions of dollars						Per cent of total					
	1869	1879	1889	1899	1909	1919	1869	1879	1889	1899	1909	1919
Illinois	------	5.4	57.8	46.0	47.4	------	------	34.6	53.8	42.3	27.4	------
Kentucky	------	------	13.6	8.3	36.9	------	------	------	12.6	7.6	21.2	------
Indiana	------	------	6.2	20.0	27.7	------	------	------	5.7	18.4	15.9	------
Pennsylvania	------	------	------	5.1	11.7	------	------	------	------	4.7	6.7	------
Ohio	------	------	11.4	14.7	9.8	------	------	------	10.6	13.5	5.6	------
Other States	------	10.2	18.6	14.7	40.4	------	------	65.4	17.3	13.5	23.2	------
United States	12.4	15.6	107.6	108.8	173.9	5.8	100	100.0	100.0	100.0	100.0	100

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Liquors, malt

State or group	Millions of dollars						Per cent of total					
	1869	1879	1889	1899	1909	1919	1869	1879	1889	1899	1909	1919
New York	5.0	18.4	41.7	59.6	60.6	38.4	24.5	35.4	29.2	24.2	21.1	27.7
Pennsylvania	------	5.2	14.3	30.1	36.2	21.8	------	10.0	10.0	12.2	12.6	15.8
Wisconsin	------	------	11.3	20.3	25.0	11.8	------	------	7.9	8.2	8.7	8.5
Missouri	------	------	12.5	14.3	20.5	10.0	------	------	8.7	5.8	7.2	7.2
New Jersey	------	------	8.9	15.5	15.8	10.0	------	------	6.2	6.2	5.5	7.2
Illinois	------	------	10.9	20.9	22.1	9.8	------	------	7.6	8.4	7.7	7.1
Industrial New England	------	------	5.3	17.6	16.2	9.4	------	------	3.7	7.1	5.7	6.8
Ohio	------	------	12.8	18.7	19.4	8.8	------	------	9.0	7.6	6.8	6.4
California	------	------	------	5.1	7.0	------	------	------	------	2.0	2.4	------
Indiana	------	------	------	6.1	6.5	------	------	------	------	2.5	2.3	------
Maryland	------	------	------	6.3	6.2	------	------	------	------	2.6	2.2	------
Michigan	------	------	------	5.5	7.6	------	------	------	------	2.2	2.7	------
Minnesota	------	------	------	------	8.5	------	------	------	------	------	2.9	------
Other States	15.4	28.4	25.3	27.1	35.1	18.4	75.5	54.6	17.7	11.0	12.2	13.3
United States	20.4	52.0	143.0	247.1	286.7	138.4	100.0	100.0	100.0	100.0	100.0	100.0

Lumber and timber products

State or group	Millions of dollars						Per cent of total					
	1869	1879	1889	1899	1909	1919	1869	1879	1889	1899	1909	1919
Washington	------	------	13.0	23.8	54.1	68.8	------	------	3.3	4.5	8.1	11.9
Louisiana	------	------	------	14.5	40.0	42.5	------	------	------	2.7	6.0	7.3
Mississippi	------	------	------	13.1	29.5	31.1	------	------	------	2.5	4.4	5.4
Arkansas	------	------	7.4	20.4	27.0	28.8	------	------	1.9	3.9	4.1	5.0
Oregon	------	------	------	7.8	18.4	28.0	------	------	------	1.5	2.8	4.8
California	------	------	8.9	16.3	27.5	26.5	------	------	2.3	3.1	4.1	4.6
Wisconsin	5.9	8.2	40.4	45.0	33.4	24.2	7.6	5.8	10.3	8.5	5.0	4.2
Michigan	13.3	25.8	55.9	48.8	33.5	22.5	17.3	18.2	14.3	9.2	5.0	3.9
North Carolina	------	------	------	13.5	21.6	21.6	------	------	------	2.6	3.2	3.7
Industrial New England	6.9	9.3	22.6	28.4	28.5	20.2	8.9	6.6	5.8	5.4	4.3	3.5
Alabama	------	------	6.5	11.0	17.4	20.0	------	------	1.7	2.0	2.6	3.5
Texas	------	------	10.7	12.5	22.0	18.7	------	------	2.7	2.4	3.3	3.2
New York	9.6	13.6	28.7	29.8	31.8	18.7	12.4	9.6	7.3	5.6	4.8	3.2
Pennsylvania	12.3	13.8	31.7	38.6	31.1	17.6	15.9	9.7	8.1	7.3	4.7	3.0
Florida	------	------	------	9.3	15.0	15.8	------	------	------	1.8	2.2	2.7
Virginia	------	------	------	11.2	22.7	15.6	------	------	------	2.1	3.4	2.7
Tennessee	------	------	6.5	13.1	17.4	14.6	------	------	1.7	2.5	2.6	2.5
West Virginia	------	------	------	9.4	20.7	14.3	------	------	------	1.8	3.1	2.5
Minnesota	------	------	15.6	31.1	22.2	13.0	------	------	4.0	5.9	3.3	2.2
Illinois	------	6.1	11.4	13.6	18.1	12.5	------	4.3	2.9	2.6	2.7	2.2
Georgia	------	------	7.6	15.1	16.6	12.0	------	------	1.9	2.9	2.5	2.1
Ohio	------	9.3	16.0	20.9	15.1	10.9	------	6.6	4.1	4.0	2.3	1.9
Idaho	------	------	------	------	7.5	10.6	------	------	------	------	1.1	1.8
Maine	------	------	11.6	10.1	15.6	10.3	------	------	3.0	1.9	2.3	1.8
Kentucky	------	------	------	11.2	11.2	8.7	------	------	------	2.1	1.7	1.5
Missouri	------	------	9.0	11.4	13.0	8.6	------	------	2.3	2.2	2.0	1.5
South Carolina	------	------	------	------	9.5	8.4	------	------	------	------	1.4	1.4
Indiana	5.5	6.8	15.5	17.0	11.1	7.9	7.1	4.8	4.0	3.2	1.7	1.4
Maryland	------	------	------	5.4	6.9	5.0	------	------	------	1.0	1.0	.9
New Jersey	------	------	------	------	5.7	------	------	------	------	------	.8	------
Iowa	------	------	7.9	6.8	5.6	------	------	------	2.0	1.3	.8	------
Other States	23.8	48.8	63.9	18.7	18.4	21.2	30.8	34.4	16.4	3.5	2.8	3.7
United States	77.2	141.7	390.9	528.0	668.1	578.6	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Paper and wood pulp

State or group	Millions of dollars					Per cent of total				
	1879	1889	1899	1909	1919	1879	1889	1899	1909	1919
Industrial New England	11.1	15.1	22.4	26.8	28.8	41.9	36.1	29.6	25.4	18.5
New York	------	7.3	16.3	17.6	25.4	------	17.5	21.6	16.7	16.3
Maine	------	------	8.1	13.8	19.0	------	------	10.7	13.1	12.2
Wisconsin	------	------	5.6	9.6	17.1	------	------	7.4	9.1	11.0
Pennsylvania	------	------	7.9	8.8	14.1	------	------	10.4	8.4	9.1
Michigan	------	------	------	5.0	12.6	------	------	------	4.7	8.1
Ohio	------	------	------	6.3	9.4	------	------	------	6.0	6.0
Other States	15.4	19.4	15.4	17.5	29.2	58.1	46.4	20.3	16.6	18.8
United States	26.5	41.8	75.7	105.4	155.6	100.0	100.0	100.0	100.0	100.0

Petroleum refining [b]

State or group	Millions of dollars		Per cent of total	
	1899	1919	1899	1919
California	------	34.7	------	18.6
New Jersey	------	28.2	------	15.1
Texas	------	23.7	------	12.7
Pennsylvania	10.0	21.3	35.6	11.4
Louisiana	------	12.3	------	6.6
Oklahoma	------	11.4	------	6.1
Kansas	------	6.0	------	3.2
Ohio	------	5.5	------	3.0
Illinois	------	5.1	------	2.7
New York	5.0	------	17.8	------
Other States	13.1	38.5	46.6	20.6
United States	28.1	186.7	100.0	100.0

[b] The value added by manufacture in 1909 was 38.9 millions of dollars (standard of 1913). In order to avoid disclosing operations of individual concerns 67 per cent of the total was reported under "Other States," which included some with much larger production than those for which figures were given.

Printing and publishing

State or group	Millions of dollars						Per cent of total					
	1869	1879	1889	1899	1909	1919	1869	1879	1889	1899	1909	1919
New York	6.2	21.5	63.1	116.1	165.4	158.4	19.9	31.3	25.3	30.0	30.0	28.9
Illinois	------	5.1	28.0	42.8	64.5	67.9	------	7.4	11.2	11.0	11.6	12.4
Pennsylvania	6.4	7.2	31.5	38.9	49.3	50.7	20.4	10.5	12.7	10.0	8.9	9.3
Industrial New England	5.3	7.8	22.6	42.8	45.0	42.3	17.1	11.4	9.1	11.0	8.2	7.7
Ohio	------	5.0	14.2	22.5	30.7	35.8	------	7.3	5.7	5.8	5.5	6.5
California	------	------	------	10.6	19.3	20.1	------	------	------	2.7	3.5	3.7
Missouri	------	------	11.4	15.3	21.6	18.5	------	------	4.6	3.9	3.9	3.4
Michigan	------	------	5.5	8.2	12.8	15.2	------	------	2.2	2.1	2.3	2.8
Maryland	------	------	7.5	8.7	10.3	13.6	------	------	3.0	2.2	1.9	2.5
Minnesota	------	------	5.3	8.4	12.3	11.2	------	------	2.1	2.2	2.2	2.1
Texas	------	------	------	------	9.1	10.5	------	------	------	------	1.6	1.9
Indiana	------	------	------	8.7	10.6	10.0	------	------	------	2.2	1.9	1.8
Iowa	------	------	------	6.3	9.1	9.2	------	------	------	1.6	1.7	1.7
Wisconsin	------	------	------	6.3	8.8	8.4	------	------	------	1.6	1.6	1.5
New Jersey	------	------	------	5.9	9.2	7.6	------	------	------	1.5	1.7	1.4
Washington	------	------	------	------	7.3	6.2	------	------	------	------	1.3	1.1
Nebraska	------	------	------	------	5.4	5.0	------	------	------	------	1.0	.9
Tennessee	------	------	------	------	5.2	5.0	------	------	------	------	.9	.9
Colorado	------	------	------	------	5.4	------	------	------	------	------	1.0	------
Other States	13.3	22.0	59.9	47.2	51.4	52.0	42.6	32.1	24.1	12.2	9.3	9.5
United States	31.2	68.6	249.0	388.7	552.7	547.6	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 12.—*Location and development of selected industries as indicated by value added by manufacture*—Continued

Rubber industry

State or group	Millions of dollars, 1919	Per cent of total, 1919	State or group	Millions of dollars, 1919	Per cent of total, 1919
Ohio	122.3	46.4	New York	8.7	3.3
Industrial New England	61.6	23.3	Wisconsin	8.7	3.3
New Jersey	21.8	8.3	Other States	9.0	3.4
Michigan	14.1	5.3			
Pennsylvania	8.9	3.4	United States	264.0	100.0
Indiana	8.8	3.3			

Silk manufactures

State or group	Millions of dollars					Per cent of total				
	1879	1889	1899	1909	1919	1879	1889	1899	1909	1919
Pennsylvania	------	8.8	14.9	27.8	51.2	------	20.1	24.9	30.2	35.2
New Jersey	8.8	15.5	24.4	33.2	44.5	40.4	35.5	40.8	36.1	30.6
Industrial New England	5.1	7.1	10.3	14.5	27.1	23.4	16.2	17.2	15.7	18.6
New York	5.6	11.1	8.0	13.0	17.1	25.7	25.4	13.4	14.1	11.7
Other States	2.3	1.2	2.2	3.6	5.7	10.5	2.8	3.7	3.9	3.9
United States	21.8	43.7	59.8	92.1	145.6	100.0	100.0	100.0	100.0	100.0

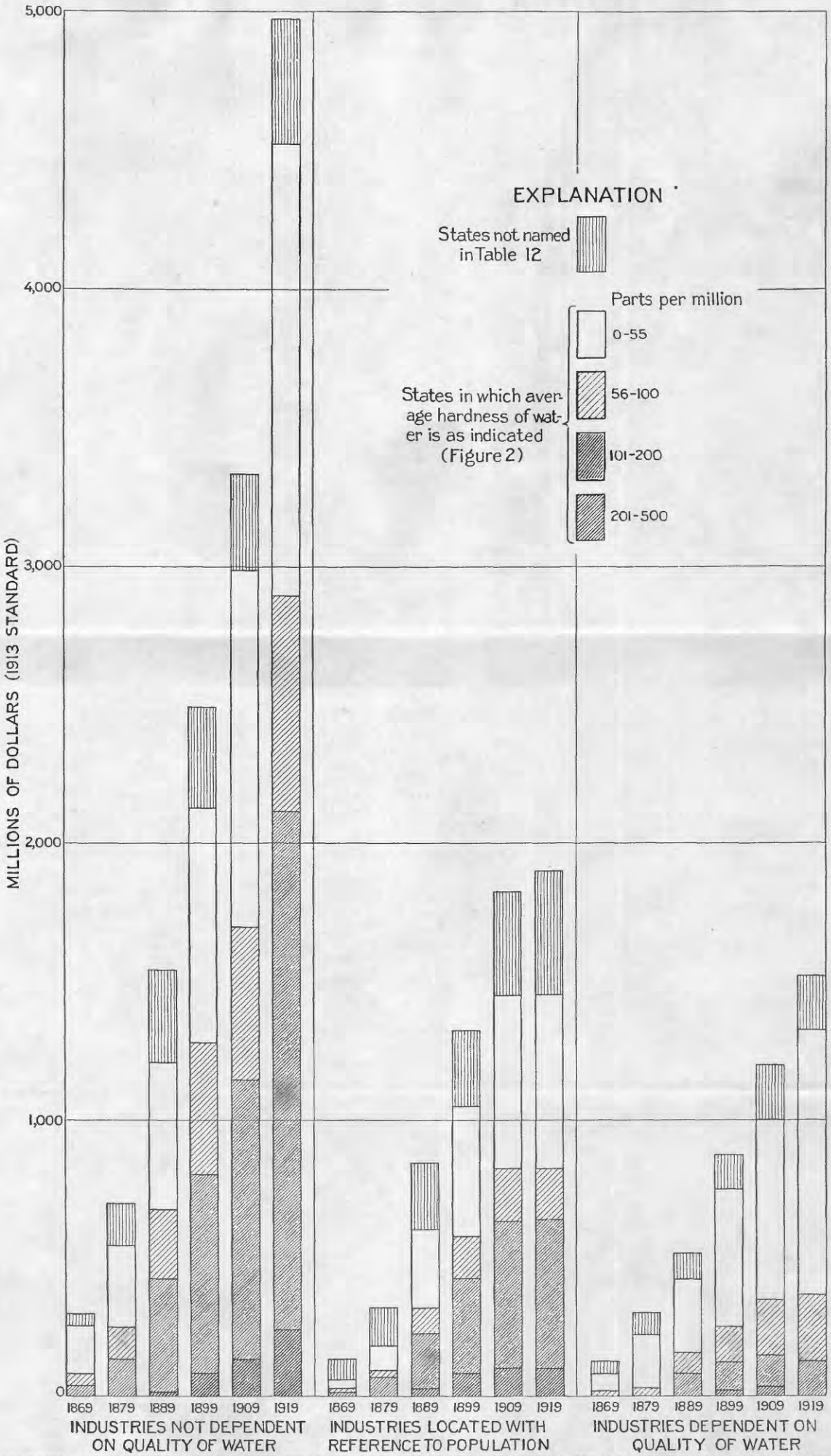
Tobacco

State or group	Millions of dollars						Per cent of total					
	1869	1879	1889	1899	1909	1919	1869	1879	1889	1899	1909	1919
North Carolina	------	------	5.5	12.7	22.9	65.0	------	------	3.9	5.6	9.3	25.3
New York	6.8	19.3	37.1	46.0	46.7	46.2	25.0	31.1	25.7	20.2	18.9	17.9
Pennsylvania	------	------	16.9	27.6	30.3	27.8	------	------	11.7	12.1	12.2	10.8
Virginia	------	6.8	12.3	13.7	14.6	15.8	------	11.0	8.5	6.0	5.9	6.1
New Jersey	------	------	------	9.3	13.8	14.6	------	------	------	4.1	5.6	5.7
Florida	------	------	5.9	8.0	13.3	10.9	------	------	4.1	3.5	5.4	4.2
Missouri	------	------	10.5	24.8	14.8	10.2	------	------	7.3	10.9	6.0	4.0
Ohio	------	------	10.2	14.9	17.3	7.6	------	------	7.1	6.6	7.0	3.0
Michigan	------	------	5.5	8.1	9.3	7.0	------	------	3.9	3.6	3.8	2.8
Industrial New England	------	------	------	6.7	7.9	6.0	------	------	------	2.9	3.2	2.3
Kentucky	------	------	6.7	14.3	10.5	5.4	------	------	4.7	6.3	4.3	2.1
Maryland	------	------	------	8.7	5.3	------	------	------	------	3.8	2.2	------
Illinois	------	------	6.4	10.3	13.7	------	------	------	4.4	4.5	5.5	------
Other States	20.7	36.0	26.9	22.6	26.5	40.5	75.0	57.9	18.7	9.9	10.7	15.8
United States	27.5	62.1	143.9	227.7	246.9	257.0	100.0	100.0	100.0	100.0	100.0	100.0

LOCATION OF TYPES OF INDUSTRIES WITH REFERENCE TO QUALITY OF WATER

CLASSES OF INDUSTRIES

The general conclusions pointed out in the discussion of the location of certain large industries (see pp. 18–22) are confirmed by a consideration of the individual industries named in Table 12 in connection with the hardness of water in the different States and industrial centers. (See fig. 2, Table 5, and pl. 3.) In order to bring out this relation more definitely the results in Tables 7, 8, 9, 10, and 12 have been summarized in Table 13, Plate 5, and Figure 6. For this



VALUE ADDED BY MANUFACTURE FOR GROUPS OF INDUSTRIES AND GROUPS OF STATES, 1869–1919

100574—26. (Face p. 38.)

summary the industries have been divided into three classes: (1) Industries not dependent on quality of water; (2) industries located with reference to population without regard to requirements as to quality of water; and (3) industries dependent on quality of water. The division is somewhat arbitrary, and some of the industries might possibly be better placed in a different class, but the classification of most of the large industries admits of little doubt.

The amounts in Table 12 when combined yield the totals for each class of industry for groups of States, divided according to the average hardness of waters from large public supplies as shown in Figure 2

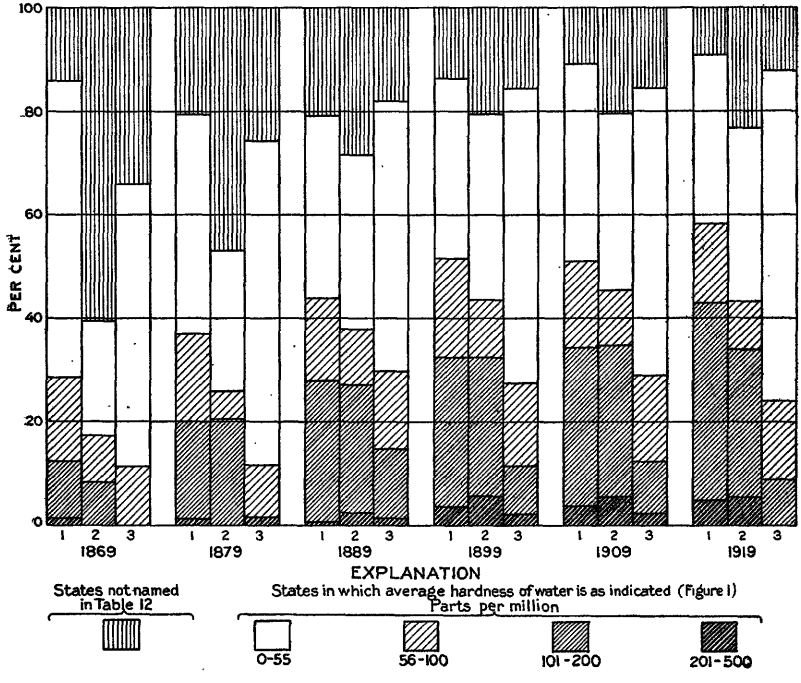


FIGURE 6.—Percentage value added by manufacture during certain census years for groups of industries and for States arranged according to the average hardness of water from public supplies of their large cities. (See pl. 5.) 1, Industries not dependent on quality of water; 2, industries located with reference to population; 3, industries dependent on quality of water

(p. 11). The amounts in Table 13 and the diagrams in Plate 5 do not refer to the total activity in the industries named for all the States in each range of hardness shown in Figure 2. The only States included for each group of industries are those for which separate figures are given in Table 12 for the different industries. The item "Other States" in Table 13 may thus include figures for States in which the waters have several different degrees of hardness as shown in Figure 2. In order to bring out more clearly the relative changes for the groups of industries at the different census years with reference

to the hardness of water the results shown in Table 13 and Plate 5 are given in Figure 6 in percentages.

TABLE 13.—*Value added by manufacture for groups of industries and for groups of States classed by the average hardness of waters used for public supplies of large cities*

[See fig. 2. Values adjusted to standard of 1913 by index numbers furnished by U. S. Bureau of Labor Statistics]

1. Industries not dependent on quality of water

Hardness of water in States considered (parts per million)	Millions of dollars						
	1859	1869	1879	1889	1899	1909	1919
0 to 55	------	170.7	298.7	538.7	867.0	1,277.9	1,637.0
56 to 100	12.6	48.9	118.5	243.2	477.2	556.5	770.8
101 to 200	------	30.6	132.3	419.7	714.1	1,014.9	1,879.7
201 to 500	------	5.5	6.8	8.5	87.7	131.1	241.9
0 to 500 [a]	13.8	42.2	143.0	330.1	342.8	358.1	450.5
	26.4	297.9	699.3	1,540.2	2,488.8	3,338.5	4,979.9
	Per cent of total						
0 to 55	------	57.6	42.7	35.0	34.8	38.3	32.9
56 to 100	47.7	16.4	16.9	15.8	19.2	16.7	15.4
101 to 200	------	10.2	18.9	27.2	28.7	30.4	37.8
201 to 500	------	1.8	1.0	.6	3.5	3.9	4.9
0 to 500 [a]	52.3	14.0	20.5	21.4	13.8	10.7	9.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] "Other States" as given in Table 12.

2. Industries located with reference to population

Hardness of water in States considered (parts per million)	Millions of dollars						
	1859	1869	1879	1889	1899	1909	1919
0 to 55	6.8	30.4	89.1	280.3	472.8	625.3	634.7
56 to 100	------	12.1	18.5	92.1	149.3	191.0	176.0
101 to 200	------	11.4	66.1	207.0	355.5	534.2	540.1
201 to 500	------	------	------	21.7	71.0	103.0	103.7
0 to 500 [a]	38.8	83.0	153.4	245.8	277.7	370.1	444.1
	45.6	136.9	327.1	846.9	1,326.3	1,823.6	1,898.6
	Per cent of total						
0 to 55	14.9	22.2	27.2	33.1	35.6	34.3	33.4
56 to 100	------	8.8	5.7	10.9	11.3	10.6	9.3
101 to 200	------	8.3	20.2	24.4	26.8	29.2	28.4
201 to 500	------	------	------	2.6	5.4	5.6	5.5
0 to 500 [a]	85.1	60.7	46.9	29.0	21.0	20.3	23.4
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] "Other States" as given in Table 12.

TABLE 13.—*Value added by manufacture for groups of industries and for groups of States classed by the average hardness of waters used for public supplies of large cities*—Continued

3. Industries dependent on quality of water

Hardness of water in States considered (parts per million)	Millions of dollars						
	1859	1869	1879	1889	1899	1909	1919
0 to 55	63.9	63.7	185.0	267.2	496.4	667.8	975.8
56 to 100	13.2	12.8	29.4	75.0	138.0	197.5	235.4
101 to 200	----	----	5.4	69.2	80.5	118.5	126.1
201 to 500	----	----	----	6.2	20.0	27.7	----
0 to 500 [a]	23.4	39.9	77.2	93.7	135.8	187.2	188.7
	100.5	116.4	297.0	511.3	870.7	1,198.7	1,526.0
	Per cent of total						
0 to 55	63.6	54.7	62.3	52.3	57.0	55.7	63.9
56 to 100	13.1	11.0	9.9	14.7	15.8	16.5	15.4
101 to 200	----	----	1.8	13.5	9.2	9.9	8.3
201 to 500	----	----	----	1.2	2.3	2.3	----
0 to 500 [a]	23.3	34.3	26.0	18.3	15.6	15.6	12.4
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] "Other States" as given in Table 12.

INDUSTRIES NOT DEPENDENT ON QUALITY OF WATER

The following industries named in Tables 7 and 12 have been classed as not dependent on quality of water:

Agricultural implements.
Automobiles, including bodies and parts.
Boots and shoes.
Brass, bronze, and copper products.
Canning and preserving.
Cars and general shop construction and repairs by steam-railroad companies.
Clothing, men's.
Clothing, women's.
Electric machinery, apparatus, and supplies.
Engines, steam, gas, and water.
Fertilizers.
Foundry and machine-shop products.
Furniture.
Glass.
Iron and steel, blast furnaces, and steel works and rolling mills combined.
Jewelry.
Lumber and timber products.
Petroleum refining.
Rubber industry.

In 1869 the States that have the softest water had 58 per cent of the activity of this group of industries, whereas in 1919 they had only 33 per cent. In 1869 the States in which the average hardness of the water was over 100 parts per million had 12 per cent of the activity, and in 1919 these States had 42.7 per cent. This group of industries

is thus shown to have contributed largely to the apparent transfer of industrial activity from regions of soft water to regions of hard water.

INDUSTRIES LOCATED WITH REFERENCE TO POPULATION

The following industries named in Tables 8 and 12 have been classed as located with reference to population regardless of quality of water:

Automobile repairing.
Bread and other bakery products.
Confectionery and ice cream.
Flour-mill and gristmill products.
Gas, illuminating and heating.
Laundries, power.
Liquors, malt.
Printing and publishing.
Slaughtering and meat packing.
Tobacco.

The percentage of the total activity for this group in States that have soft water increased from 22 in 1869 to 33 in 1919. This increase is in line with the rate of increase of population. In the States where the water has a hardness of more than 100 parts per million the increase was from 8.3 per cent in 1869 to 34 per cent in 1919. These percentages are based on the amounts in Tables 8 and 12, which do not give as complete a picture of the industries in Group 2 as is given for either Group 1 or Group 3. The industries in Group 2 have been widely distributed, so that a considerable proportion of the activity has been in States where the amount was too small to appear in the tables. The percentage of the total given for "Other States" in this group was 60.7 in 1869 and 23.4 in 1919, whereas for Groups 1 and 3 the percentages in 1869 were 14 and 34.3, and in 1919 they were 9 and 12.4.

INDUSTRIES DEPENDENT ON QUALITY OF WATER

The following industries named in Tables 9, 10, and 12 have been classed as dependent on quality of water:

Chemicals.
Cotton manufactures.
Druggists' preparations, patent medicines and compounds, and perfumery and cosmetics.
Dyeing and finishing textiles, exclusive of that done in textile mills.
Knit goods.
Leather, tanned, curried, and finished.
Liquors, distilled.
Paper and wood pulp.
Silk manufactures.
Wool manufactures.

In 1869 the States that have soft water had 55 per cent of the activity in this group, and the States that have water in which the hardness is more than 100 parts per million did not have enough activity in these industries to be shown in the table. Undoubtedly, however, some of the 34 per cent in "Other States" occurred in States where the water is hard. In 1919 the activity in this group of industries in States that have soft water amounted to 64 per cent, and in States where the water has a hardness of more than 100 parts per million it amounted to 8.3 per cent. In 1919 "Other States" had 12.4 per cent of the activity.

The industries of this group have grown in the last 50 years almost entirely in States where the waters are soft or only slightly hard, and they have contributed comparatively little to industrial development in regions where the water is hard. The industries of Group 1 have contributed largely to the development in regions where the water is hard, whereas those of Group 2 have in a general way contributed uniformly to industrial development in regions which have waters of all degrees of hardness.