DEPARTMENT OF THE INTERIOR

JNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

UALITY OF WATER

IN THE

ER OHIO RIVER BASIN AND AT ERIE, PA.

BY

SAMUEL JAMES LEWIS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

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QUALITY OF WATER IN THE UPPER OHIO RIVER BASIN AND AT ERIE, PA.

By Samuel James Lewis.

INTRODUCTION.

This paper discusses the quality of water on the most important tributaries of Ohio River in Pennsylvania, New York, West Virginia, and Maryland, and the nature of the water supply at Erie, Pa. The amount and character of the pollution is described and the results of drinking contaminated water as shown by typhoid statistics are indicated. The conditions on the tributaries of Ohio River in Ohio are discussed in Water-Supply and Irrigation Paper No. 79, United States Geological Survey, pages 129–187.

The water supplies and sewerage of small towns high up toward the head of a large drainage system do not in many cases receive the attention they should. Epidemics of a water-borne disease which affect large municipalities near the mouth of the river and therefore attract attention must necessarily have their origin in the pollution of the watershed above. It is evident, therefore, that adequate sanitation of the small towns and a water supply as carefully guarded as that of a large city would prevent disease at its very source and be far less expensive than the costly battles which are waged against epidemics in huge centers of population after disease has broken out.

Typhoid fever statistics for small towns in this section are seldom available and are more or less unreliable at best. The few figures given show the existence of virulent typhoid fever in most towns of the drainage areas in certain years, and as these towns drain into the streams the liability ofthe water to infection is evident.

The significance of typhoid fever death rates will be better understood from the statistics presented below, which have been collated from a number of cities having excellent water supplies.

Typhoid statistics of cities with good water supplies.

City and year.	Population.	Total deaths.	Typhoid deaths.	Total death rate per 1,000.	Typhoid death rate per 100,000.
Boston, Mass.:					
1900	560,892	11,678	143	20.82	25.6
1901	573,579	11,300	142	19.70	24.8
1902	584,553	10,983	139	18.79	23.8
1903	600,929	10,632	119	17.69	19.8
1904	614,522	10,757	135	17.54	22.0
Brockton, Mass.:					
1900	40,063	553	18	13.80	45.0
1901	41,606	523	6	10.17	14.4
1902	43,208	475	6	10.99	13.9
1903	44,873	495	5	11.03	11.1
1904	46,601	567	8	12.17	17.1

Typhoid statistics of cities with good water supplies—Continued.

City and year.	Popula-tion.	Total deaths.	Typhoid deaths.	Total death rate per 1,000	Typhoid death rate per 100,000.
Cambridge, Mass.:					
1900	91,886	1,547	15	16.83	16.3
1901	94,084	1,574	10	16.73	10.6
1902	96,334	1,454	17	15.09	17.6
1903	98,639	1,501	14	15.32	14.2
1904	100,998	1,444	23	14.30	22.8
Fall River, Mass.:					
1900	104,863	2,206	15	21.04	14.3
1901	108,311	2,143	21	19.78	19.4
1902	111,872	2,223	14	19.87	12.5
1903	115,549	2,290	27	19.82	23.4
1904	119,349	2,047	29	17.15	24.3
Jersey City, N. J.:					
1902	215,921	4,026	44	18.64	20.4
1903	219,462	4,130	36	18.82	16.4
Lawrence, Mass.:					
1900	62,559	1,250	11	19.98	17.6
1901	64,874	1,118	12	17.23	18.5
1902	67,275	1,163	11	17.29	16.3
1903	69,766	1,204	23	17.26	33.0
1904	72,348	1,141	11	15.77	15.2
Newark, N. J.:					
1902	258,176	4,831	50	18.71	19.4
1903	265,394	4,901	61	18.43	23.0
New York City.:					
1900	2,053,979	43,227	372	21.04	18.1
1901	2,095.686	43,304	412	20.66	19.7
1902	2,139,632	41,704	399	19.49	18.6
Yonkers, N. Y.:					
1900	47,931	810	2	16.89	10.4
1901	....	842	8	....	11.8
1902	....	865	5	....	....

OHIO RIVER BASIN ABOVE PITTSBURG, PA.

ALLEGHENY RIVER BASIN.

DESCRIPTION OF BASIN.

Allegheny River drains a quick-spilling area. The stream carries so much silt and other débris as the result of the rapid run-off that it is generally muddy. This, together with the sewage which it receives from numerous municipalities, makes it a poor source of domestic water supply. The towns at the headwaters have not generally used river water for public supply, but lower down, where pollution is greater, the unpurified water is supplied at many places. Springs are numerous and are much used, sometimes supplying towns as large as Bradford, which has 17,000 inhabitants. They fail, however, in dry seasons. Population is sparse, there being but 11 towns having over 5,000 people. Fig. 1 shows the location and approximate population of nearly all the towns within the drainage area.

The investigations prosecuted by the city of Pittsburg looking toward filtration of Allegheny River water showed conclusively that the nature of the watershed permits very little or no opportunity for self-purification by the processes which are usually more or less effective in rivers. Furthermore, "such is the peculiar character of the river, such the character of the watershed, that infection introduced at much more remote points than Oil City may be actively dangerous to the health of Pittsburg." [a] If this be the case, what is to prevent infection of towns higher up on the river by the sewage and drainage of others at less distance above them than Oil City is from Pittsburg? It can not be urged as a palliative of conditions on Allegheny River that most of the towns are not sewered, for, owing to the nature of the topography, very heavy rain will drain contamination from every town on the watershed into the river. It has long been established that the increase in turbidity in such a stream has a direct relation to the increase in the quan-

FIG. 1.—Map of Allegheny River basin, showing approximate population of towns.

tity of bacteria. The work of Mr. Copeland, of the Pittsburg filtration commission,[b] shows conclusively that bacteria abound in the turbid waters of the Allegheny and that those bacteria which can come only from extensive sewage pollution are generally present. There are always a number of cases of typhoid fever within the drainage area of the Allegheny, and the topography of the country is such that sewage or drainage containing typhoid bacteria may be delivered to any point down the river within one or two days. It is obvious that infection anywhere on the watershed may readily reach any point below.

[a] Sedgwick, W. T., Report Filtration Commission, Pittsburg, p. 19.

[b] Ibid., p. 348.

ALLEGHENY RIVER BASIN ABOVE CONEWANGO CREEK.

Port Allegany, Pa. (population, 1,000).—Has a gravity supply from three small impounding reservoirs (capacity about 3,000,000 gallons) fed by Skinners Run and its tributaries. The daily consumption is about 100,000 gallons. This is a naturally safe surface supply, as the drainage area is all uninhabited forest land. In time, safety will require regular policing of the area. The town is not sewered.

There have been few borings for ground water. The best is the 75-foot well at the Sartwell House. The water from this well is much harder than that from the public supply, which contains almost no mineral impurities and would be excellent for any industrial purpose. Field assays of water from Port Allegany are given below. Typhoid-fever figures for Port Allegany are not sufficiently full to be worth quoting, as they merely establish the presence of typhoid fever in 1897, 1898, and 1899.

Smethport and Eldred, Pa.—Gravity supplies are in use at Smethport (on Potato Creek) and at Eldred (population of each, 1,000). Neither has a sewerage system. Typhoid-fever statistics are not available for Smethport, and those for Eldred are so meager that they are of little value.

Typhoid mortality at Eldred, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.	Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1894	....	2	....	1898	....	7	....
1895	....	24	1	1899	6	2	1
1897	....	7	2	1900	16	....	2

Field assays of water from Port Allegany, Eldred, and Smethport, Pa.

[Parts per million.]

Determination.	Port Allegany.		Eldred.	Smethport.
	Public supply.	75-foot well at Sartwell House.	Public supply.	Public supply.
Turbidity	0	0	0	0
Color	27	5	17	122
Iron (Fe)	0	(a)	(b)	Trace
Calcium (Ca)	Trace.	35	28	0
Total hardness (as $CaCO_3$)	20	130+	51	10
Alkalinity	19	84	44	13
Sulphates (SO_3)	0	(b)	Trace.	0
Chlorides (Cl)	5.6	11	5.6	4.2

a Very slight trace. b Slight trace.

The Eldred water is somewhat harder than most of the spring waters of this section. It would be excellent for any purpose, the incrusting solids being practically all carbonate of lime, which is not present in quantity sufficient to cause trouble in a boiler. The supplies from Eldred and Smethport would be well adapted to industries requiring especially pure water, like paper making. The high color of Smethport water points either to a marshy drainage or to a foul condition of the reservoir.

Olean, N. Y.—At one time the water supply of Olean was pumped directly from the river, which receives typhoid-fever infection from the sources mentioned above. The supply since 1889 has been obtained from driven wells, but connection has been made with the river for emergency. In 1896 and 1897 the wells were increased from a very few to 50, making the use of river water unnecessary until very recently. The population of Olean, according to the Twelfth Census, is 9,462.

Typhoid mortality at Olean, N. Y.

Year.	Total deaths.	Typhoid deaths.	Year.	Total deaths.	Typhoid deaths.
1891	162	2	1897	99	1
1892	154	1	1898	82	1
1893	162	7	1900	130	1
1894	79	4	1901	110	2
1896	120	4	1902	117	3

It is evident that even high up on the headwaters, where no large towns pour their sewage into the stream, the raw water is unhealthy for drinking. The improvement in condition after the enlargement of the ground-water system is noteworthy. The town is sewered, and the wastes from the large tanneries located there discharge directly into the stream. It is at this point that the first extensive pollution enters Allegheny River.

Bradford, Pa.—An unusually large spring furnishes water for Bradford (population, 17,000), on Tuneangwant Creek. The plant was purchased by the city from the constructing company some years ago. In 1904 the debt was completely paid, in spite of a 40 per cent reduction in the water rate in 1904 and a 28 per cent reduction in 1901. Three masonry reservoirs, with a capacity of 59,000,000 gallons, impound the waters of a number of small spring-fed streams. The drainage area of these streams is large; over 12,000 acres immediately adjacent to the streams are now owned by the city, which maintains a strict patrol of this area. It may be considered reasonably certain that no immediate pollution of the Bradford water supply is likely. The daily consumption is now about 1,800,000 gallons, or 96 gallons per capita. The use of meters is increasing steadily, and the management appears to be efficient. There is also an auxiliary system of artesian wells averaging 175 feet in depth, for use in time of drought, from which the supply seems practically inexhaustible. The town has both sanitary and storm sewers, draining into a little stream which ultimately finds its way into the Allegheny. It is clear that disease germs may be discharged into the Allegheny from Bradford.

Typhoid mortality at Bradford, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.	Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1892	....	....	5	1899	163	3	3
1897	157	....	4	1900	172	....	15
1898	....	....	4	1901	149	20	5

That Bradford, in spite of the excellent character of its supply, may occasionally have an outbreak of disease that will greatly increase the infection in its sewage is shown by the figures for 1900. The public supply is a very pure and soft water; the high color shown in the assay (on p. 14) is probably due to the nature of a portion of the drainage area.

Salamanca, N. Y.—Salamanca, (population, 5,000) derives a very excellent gravity supply from springs and has connections with the river for pumping in periods of drought. The village is practically free from typhoid fever, the annual saving probably representing much more than the rate of interest on the plant, besides the saving in lives.

Typhoid mortality at Salamanca, N. Y.

Year.	Total deaths.	Typhoid deaths.	Year.	Total deaths.	Typhoid deaths.
1891	55	2	1897	....	0
1892	....	0	1898	....	0
1893	....	0	1900	....	0
1894	....	0	1901	....	0
1895	34	1	1902	65	2

Where the annual deaths for a period of years are so few, it seems likely, in the absence of specific information to the contrary, that the occasional mortality from typhoid fever is due to other than water-borne infection.

Mount Jewett, Pa.—At Mount Jewett (population, 1,000), on the headwaters of Kinzua Creek, the public supply is piped from springs to two large tanks. There is no sewerage system. The only available figures showing typhoid-fever mortality for the village are those for 1902, when there were two deaths from typhoid fever. In the absence of definite knowledge as to the source of infection in these cases, no conclusion can be drawn as to the character of the water supply. There is no doubt, however, of the nature of Mount Jewett's contribution to the Allegheny drainage. The field assay below shows that the public supply is very similar to that of Bradford, pure and soft, and suitable for any industrial or boiler purposes.

Kane, Pa.—Kane (population 5,000) has a sewerage system discharging into a small branch of Kinzua Creek, which empties into the Allegheny just above Warren. This run also receives drainage from Clarendon, a village of about 1,500 population, which has no public water supply, and is said to have many cases of typhoid fever. The water supply of Kane is similar to that of Bradford. It is derived from a number of springs along Kinzua Creek, and is collected in two reservoirs on that stream and pumped to a standpipe, elevated over 300 feet above the intake, supplying about a half million gallons a day. There are four wells, averaging 100 feet in depth, at the waterworks, used in case of shortage. The entire watershed is protected under an agreement with the landowners along the stream quite up to its source, whereby no sources of pollution—such as cattle pens, privies, and slaughterhouses—and no dwellings are permitted within 200 feet of the stream. It is believed that the watershed is being kept reasonably clean. No figures showing typhoid mortality are available for Kane.

For use in boilers, Kinzua Creek water is stored in a large reservoir, making an auxiliary supply entirely separate from the public supply. This creek water is never used for drinking purposes. The field assays below show pure spring waters:

Field assays of puolic watei supplies at Bradford, Mount Jewett, and Kane, Pa.

[Parts per million.]

Determination.	Bradford.	Mount Jewett.	Kane.
Turbidity	0	0	0
Color	61	22	5
Iron (Fe)	(*a*)	Trace.	0
Calcium (Ca)	0	0	0
Total hardness (as $CaCO_3$)	13	13	7
Alkalinity	12	12	17
Sulphates (SO_3)	0	0	0
Chlorides (Cl)	6.2	4.9	5

a Very slight trace.

CONEWANGO CREEK.

Jamestown, N. Y.—Conewango Creek, which enters Allegheny River at Warren, carries the sewage of Jamestown, N. Y. (population 25,000), where there are numerous industrial enterprises, all of which pour their wastes into the creek. In the most densely populated districts of the city the buildings are directly on and overhang the stream, so that dejecta from typhoid patients in these buildings enter the creek directly and are carried down Allegheny River. That there is some pollution of this kind at Jamestown is shown by the typhoid mortality figures herewith

Typhoid mortality at Jamestown, N. Y.

Year.	Total deaths.	Typhoid deaths.	Year.	Total deaths.	Typhoid deaths.
1891	240	10	1897	267	1
1892	299	10	1898	260	5
1893	395	10	1900	280	9
1894	306	7	1901	296	6
1896	224	3	1902	259	1

ALLEGHENY RIVER FROM CONEWANGO CREEK TO OIL CREEK.

Warren, Pa.—The public supply of Warren (population 10,000) was formerly derived entirely from Morrison Run, a small spring run about 4 miles from the city. In recent years drilled wells have been added to this source. During about eight months of the year (October to June) a gravity supply is furnished from a 3,500,000-gallon earth reservoir, situated on the run about 4 miles from the city. The average daily consumption is about 1,100,000 gallons. The dam is of rubble masonry, 26 feet 6 inches high; the bottom of the reservoir is of clean sand. The watershed is uninhabited, being almost virgin land. There is one farmhouse at the lower edge of the drainage area, which has been sewered out below the reservoir at the expense of the water company. Although there is no regular patrol, it would seem, from an inspection of the drainage area, that little danger of pollution exists. Five drilled wells, 58 to 66 feet deep, about 40 feet from low-water mark of Allegheny River, are pumped during the summer. The close proximity of the wells to the shore has caused considerable local anxiety as to the possibility of the river water seeping into the wells, as the town sewers into the river above and below. There is reason to suppose that no such seepage occurs. Analyses show that the waters from wells and river are radically different.

Field assays of well and river water at Warren, Pa.

[Parts per million.]

Determination.	Public supply, wells 58 to 66 feet deep.	State Hospital well, 66 feet deep.	Allegheny River.
Turbidity	0	0	[a]40
Color	5	5	122
Iron (Fe)	([b])	0	.5
Calcium (Ca)	105	96	46
Total hardness (as $CaCO_3$)	....	130+	47
Alkalinity	134	96	54
Sulphates (SO_3)	([b])	0	([c])
Chlorides (Cl)	11	6.4	5.6

a Estimated. *b* Very slight trace. *c* Slight trace.

The ground waters are similar, and, like uncontaminated ground waters, are very clear and almost colorless. The river water shows the characteristic mineral content of the streams of this section—very similar to that from French Creek, Oil Creek, Clarion River, and Redbank Creek, subsequently noted. There are but 46 parts per million of total hardness. The color is very high, and is due partly to the marshy drainage of portions of the river bottom and partly to oil and acid wastes received at Riverside, which probably contribute the traces of sulphuric acid and iron. The well waters also are hard. There is a layer of blue clay about 17 feet thick between the river bed and the gravel stratum whence the wells draw their supply. The movements of underground waters are such that wells of this depth probably draw upon water not seeping from the stream but flowing in the ground toward the river; in order that river water may enter the wells the natural flow of the underground water would have to be reversed. This is clearly shown in Professor Slichter's paper on The Motions of Underground Waters.[a] For industrial uses requiring small mineral content, such as steam making, the river water is best. The well waters will cause scale in boilers if not treated.

There is a well-developed sentiment at Warren with regard to the public health. The local board of health compiles each year a report of vital statistics, which shows that in 1904 there were 3 deaths from typhoid fever. An interesting study was made of the water supply of typhoid fever patients during this year. It was found that of the 27 cases reported 12 used water from private wells in whole or in part, 5 used city water, and the remainder used water derived from various sources. Much credit is due to the public-spirited citizens of this town for the attention they are giving to problems of sanitation and public health, as well as to the management of the public water supply. The only typhoid mortality figures at hand are obtained from the reports of the health officer, as follows:

Typhoid mortality at Warren, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1900	....	10	2
1901	....	18	2
1902	110	29	1
1903	112	20	1
1904	103	27	3

Excepting for the sudden rise in 1902, these figures compare favorably with typhoid mortality rates in most towns using pure water supplies. Again, the evidence is strong as to the kind of pollution going into the Allegheny.

Tidioute and Tionesta, Pa.—Between Warren and Oil City the population is scattered, there being along this stretch of the Allegheny but two villages, Tidioute and Tionesta, each of about 1,000 inhabitants. At these places the supply is obtained by gravity from spring-fed reservoirs in the adjoining hills, and there is no sewerage. As the villages drain directly into the river it is very likely that more or less infection enters the stream at these points at all times.

The two supplies are very different, though both are pure and excellent for any purpose. The Tionesta water is similar to the Bradford and Kane supplies. The Tidioute water contains carbonates, mainly those of either magnesium or the alkalies, with a little calcium. These are both greatly superior to the river water for any industrial uses. (See assay on p. 15.)

OIL CREEK.

Titusville, Pa.—At Oil City the Allegheny River receives the drainage from Oil Creek, on which the largest town is Titusville, with a population of about 8,000, with sanitary sewers discharging into Oil Creek. Much oil-well pollution also enters at this point. The public supply is entirely from ground water pumped from a system of 10 wells, 50 to 68 feet deep, located at the station on Oil Creek, about 1½ miles above town, and is so abundant (2,500,000 gallons daily) that very few meters are in use.

[a] Slichter, C. S., Water Supply and Irr. Paper No. 67, U. S. Geol. Survey, p. 29 et seq.

Typhoid mortality at Titusville, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.	Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1895	....	2	1	1899	91	18	1
1896	94	3	2	1900	90	20	4
1897	100	3	1	1901	84	10	1
1898	....	6	....	1902	....	10	....

This very excellent showing seems to testify to the purity of the water supply. The Oil Creek water (see assay on p. 18) is typical of this section and, although somewhat hard, is far superior to well water for use in boilers, as it contains few impurities besides a little carbonate of lime. The Oil Creek water, as previously noted, is very similar to that of Allegheny River. The high color is due in great part to the extensive oil-well pollution at this point. For industries requiring water with little mineral content, neither of these waters would be satisfactory.

Oil City, Pa.—Oil City (population 13,000) is situated at the junction of Allegheny River and Oil Creek. Up to four years ago the public water supply was pumped directly from Allegheny River without purification. It was not until the high typhoid-fever rate had become notable that a change was made in the source. Ten wells were drilled to a depth of about 50 feet at a point a mile below the town, and the water is piped to a large covered well 140 feet from the river bank. This well is walled with logs, spaced a quarter of an inch apart, in 3 feet of the loose gravel at the bottom; above this the sides are bricked up tightly. About 2,000,000 gallons a day are pumped from this protecting well, through a 24-inch main, 1½ miles to tanks and delivered by gravity to the consumers. In order to guard against a repetition of the scarcity of water experienced in the fall of 1904, four more wells are about to be drilled near those now in use. The weak point in the system is the fact that raw river water can be pumped at any time. In June, 1904, when water was scarce in this section, it was deemed necessary to use the river water, and official notices were accordingly printed in the newspapers early in June, warning all consumers of the temporary change. At the end of about ten days the well water was again used. No figures are available as to the effect of this change on the typhoid-fever rate, but data are at hand for the period in 1901, when the city well water was similarly contaminated with raw river water. Of 63 cases of typhoid fever occurring at that time, 39 originated in the city and 33 of the 39 used the polluted city water.

Typhoid mortality at Oil City, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.	Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1893	....	....	16	1898	127	36	4
1894	....	49	9	1899	172	73	6
1895	....	199	30	1900	163	98	7
1896	156	51	6	1901	201	63	6
1897	132	37	8	1902	118	16	3

The notable outbreaks in 1893 and 1895, when so many deaths from this cause occurred in the city, are examples of the ravages of this preventable disease. The residual typhoid cases are too numerous, remaining strikingly uniform until 1901, when the change was made from the polluted river water to the present ground supply. The decrease in the number of deaths is ample proof, if any were needed, that the raw river water contains the specific germ of typhoid.

Field assays of water from public supplies at Tidioute, Tionesta, Titusville, and Oil City, Pa., and from Oil Creek at Titusville, Pa.

[Part per million.]

Determination.	Tidioute.	Tionesta.	Titusville.	Oil City.	Oil Creek at Titusville.
Turbidity	0	0	0	0	[a] 50
Color	45	17	22	....	180
Iron (Fe)	Trace.	Trace.	([b])	Trace.	1.5
Calcium (Ca)	[a] 10	0	94	64	46
Total hardness (as $CaCO_3$)	20	18	130+	61	39
Alkalinity	61	21	100	77	36
Sulphates (SO_3)	....	0	[a] 5	Trace.	[a] 5
Chlorides (Cl)	5.6	4.8	10	13	5.6

[a] Estimated. [b] Slight trace.

The Oil City water is much softer than the Titusville supply. Neither, however, is as good as the pure spring waters of Tidioute and Tionesta.

FRENCH CREEK.

French Creek enters the Allegheny at Franklin, a little below Oil City. Four towns of considerable size drain into it—Corry, Union City, Cambridge Springs, and Meadville, Pa.

Corry, Pa.—Corry (population about 8,000) obtains water partly by gravity from a spring-fed reservoir and partly from deep wells. A number of circumstances have combined to give the reservoir water a poor reputation.

Typhoid mortality at Corry, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1892	....	....	3
1895	....	5	1
1899	93	2	1

These figures are so meager as to be useless except to show that typhoid fever was present in Corry in the years given. It may reasonably be conjectured, in the absence of information to the contrary, that there was at least as much of the disease in years for which figures are not available. It is not known how much sewage from Corry gets into French Creek. With more care in policing the watershed this stream should make a good supply; it is probable, however, that it will be entirely abandoned in favor of the ground water.

It would seem likely, from the absence of turbidity (see assay on p. 19), the extremely low color, and the high total hardness, that the well water is being used very largely, if not altogether, as the spring waters of this section are usually low in mineral content. This water is strikingly similar to that of the city supply at Warren and would give the same trouble in industrial uses (p. 15).

Union City, Pa.—Union City (population about 3,000), located about 10 miles below Corry, has a gravity supply from a spring-fed reservoir (see assay on p. 19). The old mains are largely wood, and are about to be replaced throughout with cast iron. A pumping station at the intersection of French Creek with the main street supplies French Creek water for fire purposes. It is so connected as to pump into the mains in times of scarcity. The town would do well either to build a larger reservoir for gravity supplies or to install a mechanical filter to handle French Creek water. The town sewers into French Creek, and there is no pretense at sanitary inspection of its drainage area. With the pumping station in a position to pump dangerous water into the mains at all times, no confidence can be felt in the supply under present conditions. There is a striking similarity between the reservoir water and the creek water in all points, and it is especially significant that their chlorine content is practically the same.

No figures of typhoid-fever mortality are obtainable for this town except for 1894, when there were two deaths.

Cambridge Springs, Pa.—Fourteen miles below Union City is Cambridge Springs, a summer resort which has about 1,500 permanent inhabitants, and is annually visited by many people. The water of the public supply has been pumped from three drilled wells 66 to 100 feet deep, but as this gains color after standing a short while it has fallen into general disrepute, and its use has been practically abandoned, French Creek water being pumped instead. As Union City sewage pollutes this relatively small stream only a short distance above Cambridge, it is extremely inadvisable for this town to resort to such a supply. If typhoid-fever infection should be carried down the creek to Cambridge Springs and pumped into the city supply enough cases may occur in a single summer to destroy the reputation of the town as a summer resort. Interest in the public supply is now at a standstill. Most residents who can do so are drinking mineral water from the numerous wells and springs which have made the place well known. The present unsatisfactory condition of the supply should be speedily remedied either by drilling for a new ground-water source or by filtration of the French Creek water. Without such precaution a serious epidemic of typhoid fever will some day occur in Cambridge Springs. The town sewers into French Creek.

Field assays of public supplies of towns on French Creek.

[Parts per million.]

Determination.	Corry.	Union City.	French Creek at Union City.	Cambridge Springs.
Turbidity	0	0	0	0
Color	5	212	106	22
Iron (Fe)	(a)	(a)	0.5	0
Calcium (Ca)	92	Some.	57	41
Total hardness (as $CaCO_3$)	130+	75	61	61
Alkalinity	96	40	50	223
Sulphates (SO_4)	(b)	Trace.	0	c5
Chlorides (Cl)	5.6	5.8	5.6	42

a Very slight trace. b Slight trace. c Estimated.

The alkalinity of the Cambridge Springs supply is so much greater than the calcium present as to point to the probable presence of the carbonates of magnesium and the alkalies. This water is by no means bad for boiler uses, being strikingly similar in hardness to that of French Creek.

Meadville, Pa.—The danger of using French Creek water is greatly intensified at Meadville (population 10,000), about 15 miles farther down the stream. In addition to the farm drainage along its course, sewage from Cambridge Springs and Union City pollutes the creek continually, and during those seasons of the year when the turbidity is high it is utterly impossible to use the water without filtering it. Conditions became so very bad that in 1901 steps were taken to introduce a ground-water supply. It is of interest in this connection to quote from the Report of the Board of Water Commissioners of the City of Meadville for 1901:

On the one hand it was asserted that the waters of French Creek were polluted, nonpotable, and dangerous to human life. On the other hand there were those who contended that the waters of French Creek were pure and wholesome. Chemical analyses made by the most eminent water specialists in America demonstrated that the water of French Creek for domestic use could hardly be worse.

Typhoid mortality figures are as follows:

Typhoid mortality at Meadville, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.	Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1893	....	....	1	1898	93	8	2
1894	....	3	....	1899	172	24	12
1895	....	9	4	1900	169	27	5
1896	122	10	2	1901	174	52	8
1897	122	7	1	1902	175	48	11

The present supply was recommended by Messrs. Hering and Fuller after consideration of the alternative proposition of filtering French Creek. It is derived from sixteen 8-inch wells 45 to 60 feet deep, drilled in the water-bearing gravel underlying much of the valley of Cussewago Creek, a layer of clay between the surface soil and the gravel affording considerable protection against surface seepage. From these wells the city is pumping about 1,500,000 gallons a day. By putting down 9 additional wells 4,000,000 gallons may be made available. The pumping station and much of its machinery is new and is the latest step in the improvement that has marked Meadville's progress since the city acquired the water-supply plant. Under present conditions the supply must be considered as good as any of its kind in the country. If its use should beccome universal in the town typhoid fever would be practically wiped out in a year or two. The experience of the local board of health in 1904 was encouraging. There were 29 cases reported, 2 of them foreign, as against 87 for 1903 and 48 for 1902. It should be remembered that the new water supply was first used late in 1902, the city water previous to that time having been pumped from French Creek. Of the 27 cases properly chargeable against the town in 1904, 15 occurred in the third and fourth wards, where most of the wells whose water is used for domestic purposes are located. These wells draw from ground water contaminated by old buried cesspools.

Field assay and analyses of public supply at Meadville, Pa.

[Parts per million.]

Determination.	Field assay.	Analyses by George C. Whipple, New York.	
		Aug. 14, 1901.	Aug. 21, 1901.
Turbidity	0	0	0
Color	5	0	0
Iron (Fe)	0.5	0.10	0.15
Calcium (Ca)	92	....	....
Total hardness (as $CaCO_3$)	87.5	127	127
Alkalinity	115	120	119
Sulphates (SO_4)	[a] 10	....	3.0
Chlorides (Cl)	9	....	7.2
Albuminoid ammonia	....	.001	....
Free ammonia	....	.006	....
Nitrates	....	.000	....
Nitrites	....	.000	....

[a] Estimated.

This water requires a little treatment; for boiler uses the creek water is much better. The figures of albuminoid and free ammonia show that there is very little nitrogen in the water, and the absence of nitrates and nitrites shows that no organic matter had recently been added to it. For drinking purposes it is excellent.

ALLEGHENY RIVER BETWEEN FRENCH CREEK AND CLARION RIVER.

Franklin, Pa.—Conditions similar to those at Meadville have caused like difficulties at Franklin (population 7,000), on Allegheny River at the mouth of French Creek. The supply for some time was obtained by gravity from several springs, the water being impounded in a clean, well-constructed reservoir lined with paving brick, and of a capacity of 11,000,000 gallons. The watershed is unpopulated and is policed immediately about the reservoir. The amount of water impounded is, however, totally inadequate in dry seasons for the needs of the town. Nine wells have been drilled in sets of three, connected by a 12-inch line to the pumps, and so equipped with gate valves that any well or set of wells can be closed while the rest are being pumped. The results are fairly good, but it is likely that a stratum of ground water containing more storage than the one now drawn upon will have to be prospected for, as the present wells become low in dry times. During the last season's drought pumping from the wells had to be stopped entirely for a time, when a temporary plan of natural filtration was attempted. A trench about 6 feet across and 8 feet deep was dug at a right angle to the river bed, and the river water was pumped into it and allowed to percolate through the ground until it reached the stratum into which the wells were drilled. Not proving very successful in yield the plan was abandoned. This was perhaps fortunate, for it is not probable that this contaminated river water was purified by the process, as the wells average but 40 feet in depth. The idea is similar to that of Doctor Imbeaux, Ingénieur des Ponts et Chaussées, of Nancy, France, who built an "open canal through the gravel and conducts through it the river water parallel to the gallery and on the opposite side of it from the bank of the river; this has the effect of making both sides of the filter gallery equally effective. This method has been entirely successful."[a] A similar supply at Albion, N. Y., was condemned by the State engineer as unsafe. The city wells were located near a canal carrying polluted water, and in order to augment the yield from the wells, the water company dug trenches from the canal, which reached to the water-bearing gravel that supplied the wells. The State engineer held that the supply would be dangerously polluted by the infiltration of the canal water and ordered the trenches closed.[b]

Six additional wells, spaced farther apart than the present bores, would probably yield enough additional water to supply the town at all times.

Field assay of public supply at Franklin, Pa.

Determination.	Parts per million.	Determination.	Parts per million.
Turbidity	0	Total hardness (as $CaCO_3$)	75
Color	5	Alkalinity	90
Iron (Fe)	0	Sulphates (SO_3)	3
Calcium (Ca)	85	Chlorides (Cl)	13

This water is not so good for boiler uses as the creek or river water, nor is it suitable for industries requiring extremely pure water.

Emlenton, Pa.—Notwithstanding the pollution that comes in from Franklin and above it, Emlenton (population 1,000) is pumping raw Allegheny River water every day in the year as a water supply. An analysis of Allegheny River water at the Emlenton intake was made in 1902 for the State board of health and is relied upon by the people of the town as showing that the water is safe for drinking. This conclusion is not justified by the analysis, which is given below. The river is known to be grossly polluted by sewage containing pathogenic bacteria; the nitrate figure in the analysis shows considerable past pollution, and it remains

[a] Bechmann. M., Purification of water for domestic use: Trans. Am. Soc. Civil Eng., vol. 54, Pt. D (International Engineering Congress), p. 184.
[b] Eng. News, Oct., 1904.

to be proved that this past pollution is completely inocuous. Certainly no assurance of safety can legitimately be derived from one or two analyses. Emlenton sewers into Allegheny River.

Analysis of water from Allegheny River at Emlenton.[a]

Determination.	Parts per million.	Determination.	Parts per million.
Total solids	70	Free ammonia	0.02
Oxygen required	1.1	Albuminoid ammonia	.02
Nitrates	.16		

[a] Rept. Pennsylvania State Board of Health, 1902, p. 45.

CLARION RIVER.

A number of important towns are located along Clarion River, which empties into the Allegheny a few miles below Emlenton.

St. Marys, Pa.—St. Marys (population 4,000) is on Elk Creek, one of the headwater streams of Clarion River. It is supplied by a gravity system from reservoirs on Laurel and Silver runs, the reservoirs being filled by pumping. Frequent analyses of this water have been made at various times for the local water company, which takes considerable pride in keeping it in good condition. It is claimed that there is no typhoid fever here. The water is excellent for any purpose, either domestic or industrial. It does not seem likely that much drainage from this town gets into Allegheny River.

Johnsonburg, Pa.—Johnsonburg is a town of about the same size as St. Marys, situated directly on Clarion River, near its source. The water supply is pumped from a small reservoir about 1½ miles from the town. This reservoir is located on Powers Run, a mountain stream with a very uniform rate of flow, and of exceptional purity so far as mineral contents go. The daily consumption is about 75,000 gallons. No dwellings or privies are allowed along the banks of the stream, but this precaution is offset by the presence of pig yards, barns, and chicken yards. During every rain, and for some time after, the run is polluted by washings from these pens. Similar conditions exist lower down, at a small settlement containing about 12 families. During the summer of 1905 a contractor's camp was located directly upon the stream at the headwaters. Many cases of typhoid fever are reported in the town and the water is in bad repute, yet the meager figures obtainable as to typhoid mortality indicate a very fair water supply.

Typhoid mortality at Johnsonburg, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.	Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1895		4		1898	23	4	1
1896		2		1899	43	1	1
1897		1		1902	45	5	1

With intelligent inspection of this watershed Johnsonburg should have a water supply as good as any in the country. As it is the conditions may readily cause an epidemic of typhoid fever. The field assay (p. 24) shows the Powers Run water to be exceptionally pure and excellent for any industrial purpose. For domestic use it would be very good if not contaminated, as shown above.

Ridgway, Pa.—Clarion River above Ridgway (population 3,500) is polluted by the domestic sewage from Johnsonburg and by contamination from the paper mills there, as well as by the wastes from a very large tannery. The public supply of Ridgway is derived partly from a spring-fed reservoir on Gallagher Creek and partly from two wells, 92 and 94 feet deep, at the lower edge of the town, from which excellent water is pumped. These wells became infected a few years ago through a defective casing, which allowed leakage from adjoining sewers. Upon analysis the water was pronounced unsafe, and though the casing has since been replaced the supply is still somewhat under suspicion by the townspeople. The mineral analysis shows no unusual features for a water drawn from this depth. If used without treatment, it would give trouble in boilers. The Gallagher Creek supply becomes scanty in times of drought, so that the pumps at the wells are now furnishing nearly all the water to the reservoir, from which it is brought into the town by gravity. The figures available to show typhoid fever mortality are too few to serve as a basis for any conclusions as to the character of the water other than to prove that the town is not free from the disease and that its sewage therefore probably contains typhoid bacilli. The most serious outbreak was in 1895, when there were 36 cases of typhoid fever with one death.

In order to determine the effect of the industrial pollution mentioned, a sample was taken from Clarion River about a quarter of a mile below the tannery. It was so highly colored as to be unreadable by ordinary means, appearing black in the river, its shade being equivalent to an iron color of 4 parts per million. It is practically a slightly diluted tan liquor at this point. Except for the difference in color and alkalinity traced to the tanning wastes the two samples at Ridgway are strikingly alike. The influence of the sulphite wastes from the Johnsonburg paper mill is noticeable in the high sulphur trioxide figure.

Brockwayville, Pa.—Brockwayville (population 1,700) is located on Little Toby Creek, a tributary of Clarion River, entering a few miles below Ridgway. It has a spring-run gravity supply from a small reservoir on Whetstone Creek, 5 miles below the town. There is little interest in the matter in the village. The company officials state that the watershed is not populated in any way; but as there is no way of guarding against pollution of the reservoir, the supply can not be called wholly satisfactory. For manufacturing purposes the water is far superior to that of Toby Creek, which receives considerable mine drainage, as shown in the field assay (p. 24).

The public supply is typical of the spring waters of the section. The assay of water from Toby Creek shows the influence of mine drainage in the high sulphates and iron contents and in the nearly complete neutralization of the natural alkalinity of the stream by the acid drainage. This water is not suitable for domestic purposes and would cause much trouble in boilers from incrustation and corrosion. The iron is probably present as ferrous sulphate.

Clarion, Pa.—The largest town on Clarion River is Clarion (population about 2,500), 25 miles from the Allegheny. Its supply is obtained partly by gravity from a reservoir upon McLains Run, and it is said that Clarion River affords part of the supply by pumping and treatment with a mechanical filter. The sample analyzed seems too soft to have come out of the river. The McLains Run water should be a very satisfactory supply if the quantity remains sufficient during the dry season. The field assay shows the public supply to be a very fine soft water suitable for any purpose. The town sewers into Clarion River.

The figures available to show typhoid fever mortality at Clarion are few, but the large number of cases and high percentage of mortality show clearly enough that the polluted river water has been in use.

Typhoid mortality at Clarion, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1896	23	19	1
1898	16	16	2
1899	....	25	....
1900	30	26	1
1902	18	4	1

Field assay of public supplies in Clarion River basin.

[Parts per million.]

Determination.	St. Marys.	Johnsonburg.	Ridgway.	Brockwayville.	Clarion River.	Clarion.	Toby Creek.
Turbidity	0	0	0	0	0	0	[a] 5
Color	35	106	5	27	45	....	17
Iron (Fe)	0	([b])	3	([c])	0	0	4
Calcium (Ca)	0	0	119	0	0	113	84
Total hardness (as $CaCO_3$)	13	22	130+	13	....	130+	90
Alkalinity	9	12	133	14	18	63	7
Sulphates (SO_3)	0	0	[a] 28	0	0	41	104
Chlorides (Cl)	6	4.8	26	2.6	4.4	30	6.1

[a] Estimated. [b] Very slight trace. [c] Slight trace.

ALLEGHENY RIVER BETWEEN CLARION RIVER AND REDBANK CREEK.

Parker, Pa.—Parker (population about 1,000) is built in a line along the Allegheny River front and on top of the bluff overlooking the river. The waterworks station is at the extreme southern end of the town, the intake being well out in the middle of the stream. All sewage and drainage from the village finds its way into the stream immediately above the intake. Besides this there are two slaughterhouses located on Toms Run, which enters into the Allegheny a few hundred yards above the northern edge of the town. The sewage of Emlenton is emptied into Allegheny River a short distance farther upstream. The pumping station is a ramshackle building, filthy inside and out (see Pl. I, *A*). A privy in the building is located at the edge of the shore, so that every rain washes pollution into the stream right at the intake. This is one of the grossest cases of ignorance and uncleanliness in water supply that has been noted in the course of this investigation. The pumping station is so located as to supply water contaminated not only with all the pollution from above, but also with that at the very doors of the town. Reliable figures as to typhoid fever here would be extremely valuable. During the few hours spent in the town 6 cases were located. This plant was installed about thirty years ago and has been in continuous operation since. It is said that the cleaning which the tank has just received was the first that it has had in many years. The first cost of the pumping plant could not have been more than the few hundred dollars necessary to purchase the tank and the small gas-engine which is doing the pumping. The plant should be replaced by a ground-water system similar to those of Warren and Oil City.

Field assays of water from Allegheny River at Parker, Pa.

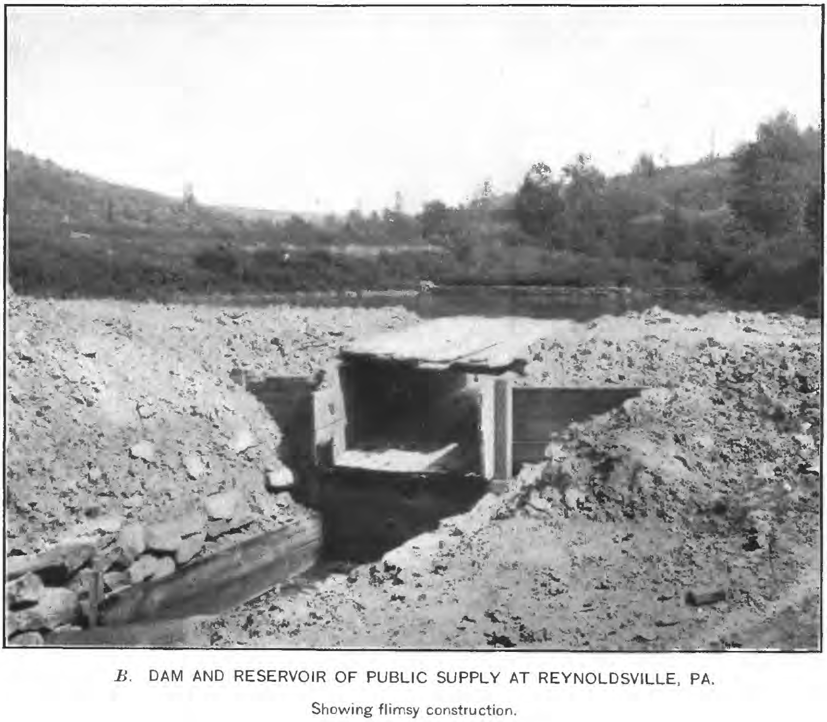
Determination.	Parts per million.	Determination.	Parts per million.
Turbidity	[a] 5	Total hardness (as $CaCO_3$)	59
Color	7	Alkalinity	54
Iron (Fe)	2	Sulphates (SO_3)	[a] 5
Calcium (Ca)	59	Chlorides (Cl)	26

[a] Estimated.

The field assay of water from the river at Warren (see p. 15) showed 5.6 parts per million of chlorine at Warren, agreeing very closely with the 5.0 parts per million shown by the analysis at Emlenton, several miles above Parker. The very high rise in the chlorine at Parker is probably traceable to the salt used at the slaughterhouses at Toms Run and seems to point to direct pollution of the river above the intake from this source.

A. PUMPING STATION AT PARKER, PA.

Showing condition of building.



B. DAM AND RESERVOIR OF PUBLIC SUPPLY AT REYNOLDSVILLE, PA.

Showing flimsy construction.

REDBANK CREEK.

Redbank Creek, an important tributary of the Allegheny, enters the main stream at Redbank Furnace, about 15 miles below Parker. There are four towns of consequence on this tributary drainage area—Dubois, Reynoldsville, Brookville, and New Bethlehem.

Dubois, Pa.—Dubois (population 10,000) has a gravity supply from large reservoirs that impound the waters of Anderson and Wolf creeks. The Anderson Creek reservoir, 9 miles from town, has a capacity of 150,000,000 gallons, the daily consumption being 1,000,000 gallons. There was no shortage here in the summer of 1904 at the time when drought was felt throughout this section. The supply is allowed to flow "wild" through the mains into town, and the excess goes on to Wolf Creek reservoir, where it is collected for storage, to be pumped back in time of need. The watershed is cleared of habitation, is partly owned by the company, and is patrolled at all times by a paid constable. The reservoirs are cleaned twice a year, and it is claimed that all cases of typhoid fever are traceable to the use of private wells, nearly all of which have been abandoned. Judgment as to the water supply of Dubois can hardly be definite in view of the meager figures at hand as to typhoid fever. The water seems to be good.

Typhoid mortality at Dubois, Pa.

Year.	Total deaths.	Typhoid deaths.
1897	66	2
1900	138	3
1901	151	3

This water shows (see assay on p. 20) a bright red coloration after being heated to boiling point. This is probably due to the presence of iron as iron carbonate, which loses carbon dioxide on heating, leaving the red ferrous oxide as a precipitate in the water, $FeCO_3-CO_2=FeO$, which combines with oxygen in the water to form Fe_2O_3 as a red precipitate.

Before the present large reservoir was in service, three deep wells, now plugged, were sunk, in search of an additional supply. Neither quantity nor quality was satisfactory. The town sewers into Sandy Creek, a tributary of Redbank Creek.

Reynoldsville, Pa.—Ten miles below Dubois is the town of Reynoldsville (population about 5,000). It has a surface supply from two small reservoirs, one of which is held in reserve. The one actually in use covers about three-fourths of an acre and does not appear to be in good condition, being apparently foul on the bottom and sides. The primitive character of the works is shown in Pl. I, *B*. The earth dam is but a temporary structure and the spillway a rough boxing of planks. The pool impounds the little run on whose course it is built, and receives the flow of two springs besides. There is evidently but a few days storage, and the supply is inadequate. In the fall of 1904 the prevalent scarcity led to the drilling of two wells right at the pumping station, the water from which is said to be a little harder than the spring water. These are not in operation at the present time, being held in reserve.

Typhoid mortality at Reynoldsville, Pa.

Year.	Total deaths.	Typhoid deaths
1899	38	2
1902	44	1

With the reservoir in its present condition, the water supply is certainly not beyond suspicion. The land around this reservoir is all in cultivation, and there is no policing of the drainage area. An assay of the water is given on page 26.

Brookville, Pa.—Brookville (population 2,400) is a rapidly growing lumber town, located between the confluence of the North Fork and Sandy Creek. The town supply is pumped directly from the North Fork, without purification, into three 3,000-barrel steel tanks, whence a daily consumption of about 290,000 gallons flows by gravity into the mains, so that there is little or no opportunity for sedimentation. A field assay is given below. Pl. II, *A*, shows the pumping station and conditions at the intake, which is in the mill pond about 30 feet out from the bank. The pond is a stagnant pool whose surface is littered with scum, chips, logs, oil, and lumber-yard refuse, and at the time the sample was taken presented a most uninviting appearance. Judging by the high-water mark here conditions must be much worse when the spring freshets sweep débris from the whole course of the stream into the pond. A mile upstream, at another sawmill, are located the houses of a few families right on the stream. The water has a high color, doubtless due to the rubbish mentioned above.

The few statistics available as to typhoid fever show the constant presence of the disease, sometimes in high rates.

Typhoid mortality at Brookville, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.	Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1895	....	3	....	1899	36	6	2
1896	34	13	2	1900	....	3	....
1897	....	1	....	1901	28	3	2
1898	24	11	2	1902	....	8	....

Sandy Creek, although most offensively polluted at Reynoldsville by the tannery, presents a perfectly clear appearance at this point.

New Bethlehem, Pa.—Near the mouth of Redbank Creek is New Bethlehem, a town of about 2,000 population. Here there is a very good, well-equipped water-supply plant. The water, which is rather hard and of the limestone type, is pumped from Redbank Creek into a settling basin holding approximately 180,000 gallons, whence a small gas pump raises it into a small mechanical filter. Washout gates on the distributing mains are used for flushing out any deposited matter. The reservoir and filters are covered, being brick and cement structures, and intelligent supervision is exercised over the entire plant. The supply seems to be good and to give satisfaction. The machinery is all modern. The low alkalinity of this water in the presence of so much calcium carbonate probably results from the acidity of chemicals added in the filtration process. This supply should cause no trouble in boilers and should be available for many other industrial uses.

Field assays of public supplies from towns in Redbank Creek basin.

[Parts per million.]

Determination.	Dubois.	Reynoldsville.	Brookville.	New Bethlehem.
Turbidity	0	0	0	0
Color	96	35	90	27
Iron (Fe)	1	(a)	Trace.	(b)
Calcium (Ca)	0	Some.	0	33
Total hardness (as $CaCO_3$)	15	30	20	39
Alkalinity	19	24	21	12
Sulphates (SO_3)	0	Trace.	0	[c] 20
Chlorides (Cl)	2.2	3.9	3.9	8

[a] Very slight trace. [b] Slight trace. [c] Estimated.

A. INTAKE OF PUBLIC SUPPLY AT BROOKVILLE, PA.

B. TYGART RIVER AT TYGART JUNCTION, W. VA.

Showing nature of stream bed.

MAHONING CREEK.

Punxsutawney, Pa.—Mahoning Creek flows through a sparsely settled country; the only important town on it is Punxsutawney, with a population of 4,375 in 1900. This obtains a gravity supply from Clover Run, whose water is used without purification. The Punxsutawney water is of the usual spring type, the great difficulty with it being its occasional turbidity. A slight amount of patrolling would make the supply quite safe. The only typhoid-fever data available for Punxsutawney are for 1902, when there were two deaths from this cause.

Field assay of water from Punxsutawney, Pa.

Determination.	Parts per million.	Determination.	Parts per million.
Turbidity	[a] 15	Total hardness (as $CaCO_3$)	15
Color	90	Alkalinity	21
Iron (Fe)	0.5	Sulphates (SO_3)	0
Calcium (Ca)	0	Chlorides (Cl)	5.6

[a] Estimated.

ALLEGHENY RIVER BETWEEN REDBANK CREEK AND KISKIMINITAS RIVER.

Kittanning, Pa.—Kittanning (population about 4,000) pumps from Allegheny River and is now installing a filtration plant, after passing through a painful experience with typhoid fever. The disease may be said to have been continuously epidemic here for years, as shown by the following figures, the number of deaths being among the highest in the country.

Typhoid mortality at Kittanning, Pa.[a]

Year.	Deaths per 100,000.	Year.	Deaths per 100,000.	Year.	Deaths per 100,000.
1898	189	1900	128	1902	109
1899	78	1901	24	1903	160

Ford City, Pa.—Ford City, Kittanning's near neighbor, had a similar experience in the epidemic conditions prevailing from March 24, 1903, to January 23, 1904, in which period eleven deaths from typhoid fever occurred, in an estimated population of 3,000.

KISKIMINITAS RIVER BASIN.

CONEMAUGH RIVER.

Johnstown, Pa.—Johnstown (population about 60,000) is on Conemaugh River, the principal tributary of the Kiskiminitas. It has a sewerage system draining into the river. The Johnstown Water Company, which furnishes water to about 7,600 private consumers, takes its supply principally from mountain runs, the water being impounded in an extensive system of storage reservoirs having a maximum capacity of 283,000,000 gallons. There is also an intake on Stony Creek for use at times of low water. The drainage areas are owned to a great extent by the Johnstown Water Company and the Cambria Steel Company, and are said to be regularly patrolled by special constables in the employ of these corporations.

The daily consumption is about 6,000,000 gallons. With the amount in storage the town usually has an abundant supply without drawing on Stony Creek; but the drought in the fall of 1904, which proved so serious throughout this section, necessitated the use of creek water after public notice. Since then the storage capacity of the reservoirs has been

[a] Eng. News, Feb. 11, 1904.

increased 131,000,000 gallons, and still another reservoir, with a capacity of 220,000,000 gallons, is in process of construction.

The Cambria and Morrellville Water Company, with about 500 consumers, takes its water from one reservoir and one deep well. The Cambria Steel Company's supply, from mountain reservoirs and from Conemaugh River, is said to be used exclusively for industrial purposes.

The typhoid fever mortality at Johnstown is shown by the following table:

Typhoid mortality at Johnstown, Pa.

Year.	Population.	Total deaths.	Typhoid deaths.	Typhoid death rate per 100,000.
1891	21,805	....	10	46
1892	22,000	....	5	22.7
1893	23,300	....	13	56
1894	23,800	....	10	42
1895	25,000	....	16	64
1896	....	427	21	....
1897	26,000	....	21	81
1898	32,000	459	10	31
1899	35,936	586	28	78
1901	37,000	689	40	108
1902	40,000	717	14	35

Approximately one-third of the cases of typhoid fever are among nonresidents under treatment at the hospitals, and the remaining two-thirds are about equally divided between those who do and those who do not use the supply of the Johnstown Water Company. There is no doubt that insanitary local conditions and the use of well water are responsible for a considerable percentage of the typhoid fever, but the distribution of the disease over the entire city among consumers of the public supply and other factors indicate that the supply is not blameless. Stony Creek is so grossly polluted above the intake that it is absolutely unfit for domestic use in its raw state. Comparison of the Conemaugh River water with the mountain water indicates that the latter is decidedly the better.

Field assays of water in Kiskiminitas River basin.

[Parts per million.]

Determination.	Indiana.	Johnstown.		
		Public supply.	Conemaugh River.	100-foot well, Hotel Crystal.
Turbidity	0	0	0	0
Color	40	96	22	27
Iron (Fe)	(a)	1	1	(a)
Calcium (Ca)	30	0	68	35
Total hardness (as $CaCO_3$)	37	22	63	60
Alkalinity	47	11	8	170
Sulphates (SO_3)	[b] 5	0	56	41
Chlorides (Cl)	8.2	4.5	7.7	141

[a] Very slight trace. [b] Estimated.

The Johnstown public supply is very soft and pure; but the high color suggests some marshy drainage. The water of Conemaugh River is much harder and makes serious trouble in boilers, and is, besides, so contaminated at times as to make its use for domestic purposes inadvisable without filtration. The well water is very much harder than the city supply.

Indiana, Pa.—Indiana (population about 5,000) on Marsh and Whites runs, branches of Two Lick Creek, which drains into Conemaugh River, has an unfiltered supply from the creek.

The chief trouble with the water supply seems to be the lack of sanitation on the creek. As far as mineral contents go, the water is of fair quality.

KISKIMINITAS RIVER BELOW COMEMAUGH RIVER.

Vandergrift, Pa.—Vandergrift (population about 5,000) has a combination spring and well water supply, and Apollo, near by, pumps from Kiskiminitas River. Both drain into the Allegheny, and the typhoid-fever figures given indicate the character of this contribution to the river water.

ALLEGHENY RIVER BETWEEN KISKIMINITAS RIVER AND PITTSBURG.

The quality of the water of Allegheny River below Kiskiminitas River is described under the heading "Natural filtration," page 57.

SUMMARY OF CONDITIONS IN ALLEGHENY RIVER BASIN.

The work of the Pittsburg filtration commission showed conclusively that in a watershed of the "quick-spilling" class, like the Allegheny, even a scattered population, not collectively a great number as compared to a great city, can and does pollute the main stream to a degree that makes its water undesirable and dangerous for drinking.

The foregoing study shows that typhoid fever exists in some form at all points on the river and its important tributaries. Owing to the character of the physical features of the country this contamination may enter the stream at any point and be delivered in virulent form at any other point below. The profile sheet (Pl. III) shows that the slope of Allegheny River is rather abrupt. The elevations used in platting in many cases represent only approximately the actual level of the river, and the distances are partly scaled from a map. This inaccuracy of data is of no consequence in a chart drawn to the scale shown, the actual differences being far too small to plat, so that the profiles given faithfully represent actual conditions.

At Port Allegany, near the source of the stream, the elevation is 1,479 feet; at Franklin, where French Creek joins the main stream, the elevation is 969 feet, a drop of 510 feet in 145 miles, or about 3.5 feet per mile. This is not an exceptionally steep grade, many irrigation canals of the West, built in earth, having a fall, roughly speaking, of 1 to 5 feet per mile, without ordinarily acquiring a velocity sufficient to damage their banks. In view of the resistance offered to the flow of water in the open channel by rocks and unevennesses of surface, it is evident that the velocity given by the slope of the river bed is not sufficient to account for the rapid delivery of storm water to a point near Pittsburg.

The character of the watershed is a factor whose importance can be surmised when one recollects the numerous and destructive floods in this stream. The sides of the valley through which the river flows are steep and the soil does not absorb water readily. Besides, numerous side gorges dissect the country in every direction, with slopes so abrupt as to deliver storm water in torrents to the main stream. Even the larger tributaries have very steep grades. This is clear from the profiles of the comparatively large tributaries, French Creek and Clarion River. Between Corry and Franklin, where it enters the Allegheny, French Creek descends 457 feet in a distance of about 70 miles, making a grade of about 6.5 feet to the mile—a slope about twice as steep as that of the main stream. Clarion River, between Ridgway and its mouth, a distance of 58 miles, has a fall of 514 feet, or 8.9 feet to the mile. The facts seem to be, therefore, that a valley with a gradient in the main as low as 3.5 feet to the mile will deliver storm water very rapidly if its side slopes are steep and covered mainly with a somewhat impervious soil.

The significance of these conditions and the justness of the judgment thereon by the filtration commission's experts will be made clear by the following description of the Monongahela River drainage.

MONONGAHELA RIVER BASIN.

DESCRIPTION OF BASIN.

Monongahela River is formed by the junction of several streams, the largest being the Youghiogheny, which enters at McKeesport. Above this point the largest tributary is Cheat River, which furnishes the greater portion of the water in the Monongahela the year round. The drainage area of this stream as well as that of West Fork and of Tygart River, other tributaries of the Monongahela, is very sparsely populated, the towns being few, small, and far between. The total population of the Monongahela River drainage area in 1900 was almost identical with that of the Allegheny, each consisting of about 184,000 people.

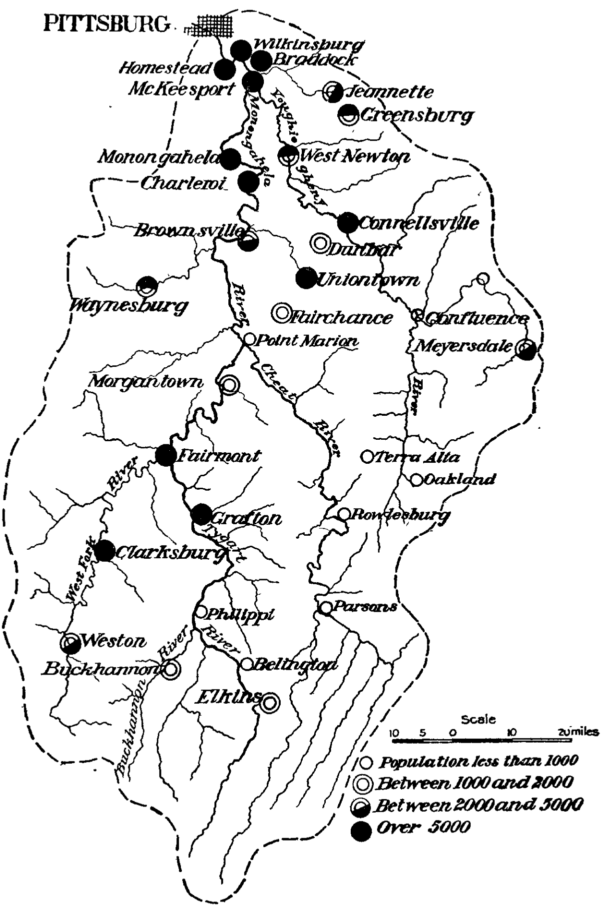


FIG. 2.—Map of Monongahela River basin, showing population.

TYGART RIVER ABOVE BUCKHANNON RIVER.

Tygart River is a rapid stream flowing over naked rock (Pl. II, *B*, p. 26) in nearly the whole of its course, through very thinly inhabited country. The heavy timber in its drainage area was cut long ago, so that very little lumbering is now carried on there, with its too frequent accompaniment of pollution of the running streams. The profile of this river (Pl. III) points to the fact that on account of the rapidity of its flow there can be but little self-purification of its water, the pollution not being detained long enough in the water to permit much sedimentation.

Elkins, W. Va.—The town nearest to the source of Tygart River is Elkins (population, about 2,500), whose water supply is pumped directly from the river without purification. A field assay of this water is given on page 33. In view of the very scanty population above Elkins, a little intelligent sanitary inspection should insure a good supply, the water being as a rule exceptionally pure and clear. There is, however, more or less pollution at all times from privies and farms along the stream, putting the city in the position of drinking from a beautiful reservoir of clear water which is liable to contamination by every one working along the river. The sewage of Elkins drains into Tygart River, and as the flow of the stream is swift the harmful character of this contribution is not much lessened in the short time it traverses the 15 miles between Elkins and Belington.

Belington, W. Va.—Belington, a town of possibly 800 population, draws its supply directly from Tygart River. It seems certain that more or less pollution from Elkins sewage is bound to come down as far as Belington; besides the same liability to careless or wanton pollution that exists above Elkins would operate to make the water unsafe for Belington. Sanitary inspection of the stream is needed. A field assay of water from Tygart River at Belington is given on page 33.

BUCKHANNON RIVER.

Buckhannon River enters the Monongahela at Tygart Junction, about 12 miles below Belington, carrying at least as much water as Tygart River does up to that point.

Buckhannon, W. Va.—The only town on this tributary is Buckhannon (population, 2,500), whose water supply is drawn directly from Buckhannon River, which is backed up for several miles above the city by an old milldam. The intake of the pumping station is above the points of exit of the sewage from the city. The plant is operated in connection with a modern ice plant using sterilized water. The same laxity exists here as at Belington and Elkins as regards sanitary inspection of the stream.

Field assays of water from Buckhannon and from Buckhannon River.

[Parts per million.]

Determination.	Buckhannon.		Buckhannon River at Tygart Junction.
	40-foot well.	City supply.	
Turbidity	0	0	0
Color	45	35	50
Iron (Fe)	2.5	Trace.	(a)
Calcium (Ca)	102	0	0
Total hardness (as $CaCO_3$)	130	28	32
Alkalinity	83	12	12
Sulphates (SO_3)	5	0	0
Chlorides (Cl)	29	9	9

a Slight trace.

The well water is obtained from a well that some years ago caused a typhoid epidemic by becoming infected with drainage from neighboring privies. The water is characteristically hard and would be very poor for any industrial or domestic use, and the liability of the well to pollution from infected drainage makes it best to avoid it as a source of water for drinking. The two analyses of the river water show practically the same mineral content and indicate that it is a very excellent water, suitable for any manufacturing or boiler purposes.

The great objection to the Buckhannon water lies in the deliberate pollution that goes on all along the river above the town. For 40 miles above Buckhannon the stream winds through forest country having a very scanty population scattered along the banks. There are eight or ten little villages along the course of the stream, and every one of them has at least two or three privies overhanging the water.

Pickens, W. Va.—Pickens, a town at the head of the river, having a population of a few hundred, is built on the steep slopes of a little valley draining into the stream. At the railroad station the privy stands directly over a tributary within 40 yards of the main stream. Farther downstream, at the mill, there are two or three more privies located directly on the stream itself. With this pollution going down the river, reinforced every few miles with more, it is difficult to see how Buckhannon water can be safe. The only protection the consumers have is the 7-mile sedimentation basin into which the river at Buckhannon has been turned, giving the pollution a chance to settle.

Field assays of water from Pickens, W. Va.

[Parts per million.]

Determination.	10-foot well.	100-foot well.	Spring.
Turbidity	0	0	0
Color	17	70	5
Iron (Fe)	a .5	18	0
Calcium (Ca)	76	62	....
Total hardness (as $CaCO_3$)	90	104	28
Alkalinity	24	78	22
Sulphates (SO_3)	a 20	a 10	0
Chlorides (Cl)	19	19	9

a Estimated.

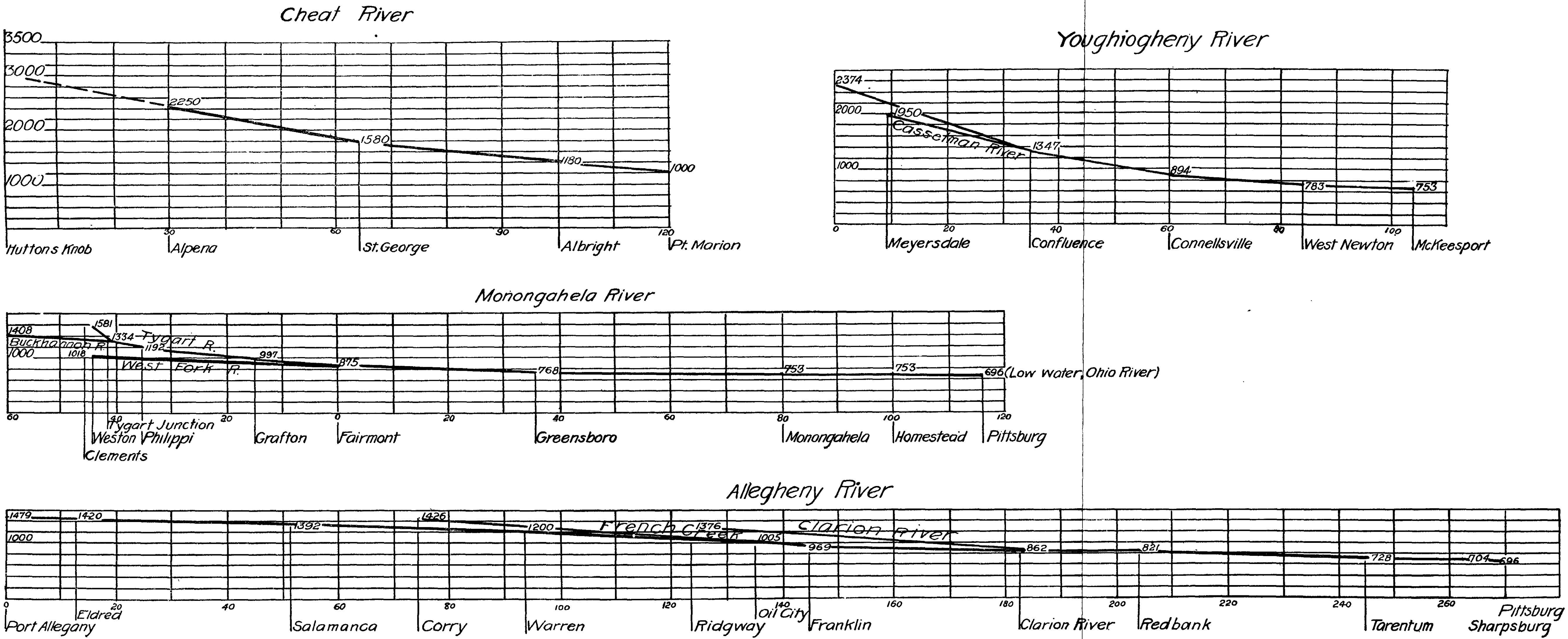
The spring furnishes a typical water of this class—soft and pure. The high mineral content of the shallow well points to a characteristic rock water, the rock being within a few feet of the surface and dipping down the hill to where the 100-foot well is located. The latter is used in boilers with unsatisfactory results, as might be expected from the assay.

TYGART RIVER BELOW BUCKHANNON RIVER.

Philippi, W. Va.—The village of Philippi (population about 1,000) is located on Tygart River, about 15 miles below Belington and about 12 miles below Buckhannon. As the sewage from the towns already mentioned pollutes the stream, it is not believed that the Philippi supply is safe, pumped as it is directly from the river without purification. It should be borne in mind that while these streams do not receive a great deal of pollution from any one of these towns, the amount of water in the river beds becomes very low in the summer and fall, so that the beneficial effects of dilution, if there are any, must be very slight, and at the same time sedimentation and storage probably play no part at all in the purification of the water, owing to the high velocity of the streams.

Although the water is naturally very pure and these little towns are about 15 miles apart, it seems certain that purification in a stream so small and rapid is not sufficient to warrant the use of the water for drinking after infection from even a few families has entered the stream. Although the drainage area as far down as Grafton is so sparsely inhabited that pollution from all sources except city sewage is extremely slight, the rugged nature of the country allows storm water to enter the stream very rapidly, increasing the liability to wash down infection. Nevertheless, the water remains very clear a great deal of the time, there being comparatively little fine soil to be washed away.

Grafton, W. Va.—Grafton (population about 5,000) is about 20 miles down the river from Philippi. The city supply, amounting to about 500,000 gallons a day, is drawn direct from the Tygart River without purification. As very little sewage is added to the



RIVER PROFILES.

stream from Philippi, there is a stretch of about 35 miles that may be regarded as relatively free from pollution above Grafton. Distance, however, in the absence of conditions permitting sedimentation, is of no avail in purifying river waters, and it is believed that this water is not safe for drinking purposes without treatment. There is so much wanton defilement in small amounts along the stream that anyone who follows its course from its source to Grafton will not be inclined to drink the raw water at any point. The city of Grafton has never taken proper care of its water supply. Until a few years ago the intake of the city system was a little below the town, so that the people of the town were drinking a dilution of their own sewage. The consequent high typhoid rate resulted in the removal of the intake up the stream, by which the conditions were somewhat improved. Filtration of the supply, however, is absolutely necessary to make the water safe.

The change in chemical content below Belington is striking, the hardness and alkalinity both being reduced about 50 per cent at Tygart Junction and the hardness still further reduced at Grafton. The reduction is probably due to the acid mine drainage along the course of the stream neutralizing the alkaline carbonates to a great extent and causing the precipitation of some of the calcium carbonate. The amounts of these present are so very small that this water is exceedingly pure, usable for any industrial purpose in its raw state.

Between Grafton and Fairmont the river flows through a country that is somewhat more rolling than that at the headwaters. There is little population, only a few hamlets being on the stream. It is noticeable, however, that every one of them has houses draining into the stream, so that pollution in small quantities is constantly entering it. There are no public supplies at these points, the inhabitants all using individual wells.

Field assays of water from Tygart River at points in West Virginia and of well water from Colfax, W. Va.

[Parts per million.]

Determination.	Elkins.	Belington.	Tygart Junction.	Grafton.	Colfax.	
					53-foot well.	36-foot well.
Turbidity	0	0	0	0	0	0
Color	83	180	35	22	17	0
Iron (Fe)	a.5	4	0	Trace.	10	0
Calcium (Ca)	0	....	0	0	52	133
Total hardness (as $CaCO_3$)	45	45	21	7	139	139
Alkalinity	25	23	13	14	96	14
Sulphates (SO_3)	0	0	0	0	0	155
Chlorides (Cl)	9	9	14	9	19	34

a Estimated.

The well waters are both in the rock, possibly in the coal seam which was uncovered at the depth of about 35 feet in building the abutments for the bridge at this point. They are both very hard. That of the 53-foot well destroys tinware rapidly, probably by the action on the metal of free CO_2 in the water. It is possible also that the iron is present as ferrous bicarbonate ($FeH(CO_3)_2$), which is decomposed in contact with the metal, giving off a little free CO_2.

WEST FORK RIVER.

At Fairmont Tygart River unites with West Fork River to form the Monongahela. West Fork River is a stream of very different character from the one just discussed. As may be seen from the profile sheet, it is practically a series of pools connected by the running stream, with a very slight fall, so that purification may go on to a great degree by the influence of sedimentation and storage. The stream is also very turbid during a large portion of the year. This adds to the possibility of purification by the heavy particles settling in the pools and carrying down the bacteria.

Weston, W. Va.—The city of Weston (population 3,000) is nearest the head of the stream. Above it there is no sewage and a scattered and scanty population. The public supply is pumped directly from West Fork River, about 200,000 gallons a day being used. The supply is to be criticised in three respects. In the first place, it becomes very scarce during the summer. Secondly, the turbidity is high at certain seasons of the year. The drainage area of this stream is different from that of Tygart River in that there is a deeper soil and much more land in cultivation, so that the frequent rains wash down much fine yellow clay, which settles very slowly in the water. The third objectionable feature, hardly less serious than the insufficient quantity, is that besides the organic matter which is washed into the stream above Weston from the dwellings and farms along the shores, the stream is wantonly polluted above the intake of the waterworks. There are several privies on the other side of the river from the waterworks just a few feet above the dam.

On the whole, a great deal of improvement is needed in the town's water supply before it can be said to be satisfactory. The water company is contemplating the purchase of a mill site farther up the river, which will add about 40,000,000, gallons of storage. If this purchase is made and vigorous measures are taken to police the area adjacent to the river, the result will be an immense improvement in the quality of the water.

The quality of ground water which it is possible to develop here for municipal use is indicated by the field assays, given herewith, of water from three deep wells sunk in search of oil and gas. The quantity of water obtained from these wells is ample. In quality the water is fairly good for drinking purposes, though too high in mineral matters for commercial use. The wells are located rather close together, the Irvin and Woodford wells being on opposite sides of the river, about a quarter of a mile apart and the Maxwell well about 2 miles distant. The remarkable agreement in the quality of the waters of the two former would seem to indicate that they are from the same water horizon. It is believed that a chain of wells sunk to the depths indicated would yield an ample water supply for the town of Weston. Such a supply could not, however, be used in boilers without treatment.

Field assays of ground water from Weston, W. Va.

[Parts per million.]

Determination.	Ervin well; 700 feet deep.	Woodford well; 700 feet deep.	Maxwell well; 635 feet deep.
Turbidity	0	0	0
Color	20	20	35
Iron (Fe)	2	2	0
Calcium (Ca)	53	65	28
Total hardness (as $CaCO_3$)	....	....	104
Alkalinity	392	393	440
Sulphates (SO_3)	0	0	0
Chlorides (Cl)	488	499	426

These waters are all hard rock waters, suitable for drinking purposes, but high in incrusting and corroding solids, and therefore unfit for use in boilers. The chlorides corrode the tubes rapidly, and no treatment has yet been discovered that will prevent this action.

The water of West Fork River itself is very similar in mineral content to that of the two streams discussed above. The field assay is supplemented by an analysis furnished by the Baltimore and Ohio Railroad Company made in October, 1900:

Field assay of water from West Fork River and analysis of water from pool.

Field assays.	Parts per million.	Analysis.	Parts per million.
Turbidity	[a] 2	Iron and alumina ($Fe_2O_3+Al_2O_3$)	54
Color	70	Calcium	6
Iron (Fe)	0	Magnesium	3
Calcium (Ca)	tr.	Sodium	13
Total hardness (as $CaCO_3$)	35	Chlorine	19
Alkalinity	30	Sulphate radicle	22
Sulphates (SO_3)	0	Carbonate	2
Chlorides (Cl)	12	Color, brown.	

[a] Estimated.

REMARKS BY ANALYST: Full of organic matter; rotten odor; unfit for use.

When the stream becomes very low in the fall, it is of uninviting appearance in the pools, and this feature makes the present supply most unsatisfactory.

Clarksburg, W. Va.—Clarksburg (population about 6,000) is about 22 miles down West Fork River from Weston. The city supply is pumped without purification from West Fork River. Between Weston and Clarksburg there is considerable rural population, the land being rolling and fertile. Although farm pollution takes care of itself to a large extent, a portion at least of the drainage from the farms finds its way into Elk Creek and West Fork River. The most important factor of pollution, however, is the sewage from Weston. If there were always plenty of water in the river its extremely low rate of flow might insure sufficient detention of the sewage to cause a high degree of purification. The stream becomes so nearly dry, however, that, as at Weston, isolated pools have to be drawn upon for the city supply at certain seasons of the year. Plans are under way for rebuilding the Clarksburg pumping plant and adding to it a settling basin. If efficiently operated this will improve the appearance of the water and probably lower the bacterial content to some extent. It is not believed, however, that this water is safe for public supply without filtration. It is claimed by the townspeople that it is not used for drinking, spring and well water being sold and used extensively. A similar claim is made in nearly every town in West Virginia that has a bad water supply, but in most cases the statement is not warranted by the facts. Experience has shown that no matter how bad the quality of the water, if it has not an offensive appearance and odor, and frequently if it has, a large percentage of the population on the taps will drink it habitually, trusting to luck to escape disease. It is safe to assume that every dangerous public water supply in West Virginia—and there are many of them—which it is claimed by the residents is used only for washing, is being drunk by precisely those who should not drink it—the poorer inhabitants, who can not buy pure water or take care of themselves after they are infected.

West Fork River water would not be unusually difficult to filter, the experience of the Hotel Waldo with a small Loomis apparatus, with alum sedimentation, being very encouraging. This device is in the form of a compact tank inclosing a so-called cutting plate or diaphragm screen, through which the sand has to pass up and down in washing, breaking up the dirty material caught on the sand. An assay of the water treated with this apparatus shows a remarkable improvement in quality, due largely to the heating of the raw water.

Three analyses of ground water from wells at Clarksburg are given below. These waters are derived from widely different levels, the shallowest being in one of a group of flowing wells 46 feet deep at Union Heights. This well furnishes water for domestic use, but like the 160-foot well of the Standard Milling Company its yield is not sufficiently great to make it important for anything but private supply. Not until the drill is sunk to the extreme depth shown at the Hotel Waldo—500 feet—is a body of water found great enough to stand pumping. Its quality, however, approximates that of mineral water, its chlorine and iron contents being extremely high. The well, which is a 4-inch one, was pumped all summer and supplied a large portion of the town until the excessive drought of 1904 so exhausted the stratum as to necessitate a stoppage of pumping. It would seem, however, that an adequate city supply could be obtained by drilling a number of wells; but the expense of this system and the fact that the water is unfit for boiler use indicates that it would be better and cheaper to install a plant for mechanically filtering the water of West Fork River.

Field assays of water from Clarksburg, W. Va.

[Parts per million.]

Determination.	46-foot flowing well, T. J. Francis.	160-foot well, Standard Co.	500-foot well, Waldo Hotel.	West Fork River.	
				Raw.	Filtered.
Turbidity	0	0	0	(a)	0
Color	0	17	27	88	17
Iron (Fe)	0	6.5	24	[b]1.5	2
Calcium (Ca)	88	56	64	0	0
Total hardness (as $CaCO_3$)	104	....	....	63	21
Alkalinity	312	257	381	20	14
Sulphates (SO_3)	0	(c)	0	[b]10	0
Chlorides (Cl)	60	19	423	9	4

[a] Decided. [b] Estimated. [c] Very slight trace.

The well waters are too high in mineral contents to be used in industrial plants without treatment. The river water is shown in its natural state and as improved by filtration with the Loomis apparatus, the process rendering it extremely soft and the diminution in bacterial content making the effluent safer for drinking. It is not known whether the process can be made cheap enough for use on a large scale.

Salem and Wallace, W. Va.—Salem and Wallace, on the branch lines of the Baltimore and Ohio Railroad radiating from Clarksburg, present conditions typical of towns that rely on ground water for their supply. Salem (population 700) derives its supply from six wells, about 100 feet in depth, all in the sandstone, the source of all the drilled-well water in this section. The first water stratum is tapped at about 56 feet. Springs in the section are neither numerous nor strong and practically all fail in times of drought.

The spring water is considerably more mineralized than the pure mountain springs in this drainage area, yet it may be considered a soft water. The public supply (assay on p. 37) is very hard, not usable for industrial or boiler purposes without treatment. The high alkalinity suggests the presence of alkaline carbonates, besides the calcium compounds.

At Wallace, W. Va., a little oil town (population 400) there is no public supply. The town is built along a little creek draining into West Fork River, and in every case where it was possible to do so the outhouses have been constructed to overhang the creek, the latter becoming practically an open sewer.

The extensive drilling for oil has developed the geological structure in this section enough to show that water may be had at depths ranging from 20 to about 200 feet—in large quantity and reputed good quality—at the latter depth. The assays (p. 37) are of water from shallower wells in common use, the 108-foot well being on a farm at the edge of the town. Most of the shallower wells become very low in summer.

The water from the 108-foot well is remarkable for its softness, the probability being that the carbonates are present as sodium and potassium carbonates, and that calcium and magnesium are lacking. As the great difficulty with the ground waters of northern West Virginia is their hardness, which unfits them for boiler uses, this well is important as indicating a vein of soft water at this depth. The other water assayed is fair, the incrusting solids being chiefly calcium carbonate. The yield from the well furnishing this is small, sufficient only for a half dozen families.

Shinnston, W. Va.—Between Clarksburg and Fairmont there are many small coal-mining camps and coke ovens. Shinnston (population 600), on West Fork River, is the largest of these places. The public supply is pumped unpurified from the river into a 1,000-barrel tank. This is said to be used for fire service only, drinking water being obtained entirely from shallow wells 10 to 40 feet deep, the depth depending on the elevation of the top of the well, the water in all being derived from beds at the same horizon apparently. The town is located just below the Pittsburg coal seam, which is pierced at East Shinnston, about 3 miles farther northeast, where there are flowing mineral wells. Some years ago a drilling made through the first rock (40 feet) by William Blair gave good water in great quantity. There is the usual string of outhouses overhanging the river.

Field assays of water from Salem, Wallace, and Shinnston, W. Va.

[Parts per million.]

Determination.	Salem.		Wallace.		Shinnston.
	Spring.	100-foot well.	42-foot well.	108-foot well.	
Turbidity	0	0	0	0	0
Color	45	45	10	166	45
Iron (Fe)	0	1	Trace.	1.25	1.5
Calcium (Ca)	....	156	53	0	100
Total hardness (as $CaCO_3$)	56	....	77	25	139+
Alkalinity	19	249	180	103	73
Sulphates (SO_3)	0	47	0	0	47
Chlorides (Cl)	19	59	29	29	59

MONONGAHELA RIVER FROM TYGART RIVER TO CHEAT RIVER.

Fairmont, W. Va.—Fairmont (population 5,000), about 30 miles below Clarksburg, pumps Monongahela River water for filtration. This was formerly effected by two mechanical filters of the Buffalo type, but during the summer of 1905 two slow sand filters 75 feet square were installed and are now used. With proper operation of these filters the city ought to have an excellent water supply, the mine drainage up to this point not being sufficient to make the water objectionable and the other mineral impurities being slight. Analyses of the raw and the filtered waters, given below, agree very closely.

Field assays of Monongahela River water at Fairmont, W. Va.

[Parts per million.]

Determination.	Raw water.	Filtered water.	Determination.	Raw water.	Filtered water.
Turbidity	0	0	Total hardness (as $CaCO_3$)	35	35
Color	83	83	Alkalinity	14	14
Iron (Fe)	[a] .8	[a] .8	Sulphates (SO_3)	[a] 5	[a] 5
Calcium (Ca)	([b])	Trace.	Chlorides (Cl)	9	9

[a] Estimated. [b] Slight trace.

The three analyses following, furnished by the Baltimore and Ohio Railroad Company, show that the variation in quality at different seasons of the year is great enough to cause considerable difficulty in handling the water, either in filtration for drinking or in treatment for industrial purposes.

Analyses of water from Monongahela River at Fairmont, W. Va.

[Parts per million.]

Determination.	Feb. 26, 1900.	June 9, 1903.	Sept. 26, 1903.
Color	(a)	(b)	Slight.
Turbidity	(c)	Decided.	Slight.
Calcium (Ca)	8.9	7.2	25
Magnesium (Mg)	1.8	2.6	5
Carbonic acid (CO_3)	11.6	12.8	9
Sulphuric acid (SO_4)	9.9	7	65.8
Iron and alumina (Al_2O_3 and Fe_2O_3)	10.3	32	5
Alkali chlorides	3.2	9	23.3
Alkali sulphates	0	0	13
Total solids	45.7	70.6	146.1

[a] Yellowish, clay. [b] Yellow, muddy. [c] Considerable.

The variation in total solids is seen to be as high as 100 per cent between June and September, though the June sample was taken after a heavy rain.

Buffalo Creek, which enters the Monongahela at Fairmont, drains an extensive country having a population of several thousand. The most important town is Mannington (population 2,500), which has a very complete waterworks system. The supply is derived from 11 wells, 100 feet in depth, driven close together near the creek about half a mile from town. As it was feared that summer demands would make it necessary to draw upon the polluted waters of the creek, a mechanical filter was installed for treating the creek water. It is claimed that up to date it has not been necessary to use the filter. The creek carries the town sewage as well as that of Farmington and other small communities, receiving also drainage from numerous coal camps along its course. A field assay of the water is given on page 39.

It should now be sufficiently evident that from this point on down stream the Monongahela River water is dangerous for drinking purposes unless it can be shown that it has completely purified itself by sedimentation in the lower reaches of the river. The influence of the Weston and Clarksburg sewage in a stream so small and so subject to failure as West Fork River certainly extends as far as Fairmont. Besides this the pollution from Grafton must necessarily add much fresh contamination to the stream above Fairmont. That city is considering the removal of its waterworks intake so as to draw from Tygart River, which would certainly be better than the present source, for the West Fork contamination would thus be completely eliminated.

Morgantown, W. Va.—Morgantown (population 1,800), about 20 miles farther down the stream, has one of the most complete waterworks systems in West Virginia. The water is pumped from Monongahela River into a settling basin, whence it passes to four mechanical filters. There is no clear-water reservoir, the filtered water going directly into the mains to the average amount of 1,200,000 gallons a day. The water seems to be satisfactory. The old gravity supply, from a mountain stream about 6 miles from the town, has been allowed to fall into bad repair with the perfection of the filtration plant on the river.

Field assays of water from Mannington and Morgantown, W. Va.

[Parts per million.]

Determination.	Mannington.		Morgantown, city supply.
	City supply.	Buffalo Creek.	
Turbidity	0	386	0
Color	17	(a)	96
Iron (Fe)	.5	0	1
Calcium (Ca)	52	....	Trace.
Total hardness (as $CaCO_3$)	63	70	35
Alkalinity	163	47	20
Sulphates (SO_3)	[b]20	0	0
Chlorides (Cl)	24	19	14

[a] Too high to read. [b] Estimated.

For industrial purposes requiring a water free from any acid content this water might not prove satisfactory at certain seasons on account of the mine drainage emptying into the stream. Otherwise it is of good quality, very suitable for a public supply.

CHEAT RIVER.

At Point Marion, Pa., Monongahela River receives its great tributary, the Cheat. This fine stream flows for much of its length through a deep canyon in rough country, having almost no population on the watershed. There are but three important villages on the stream, none of them having over 800 people. The pollution from these is very slight, none of the towns being sewered, so that the most serious contamination is from the sawmills and tanneries on the river. A profile of Cheat River is shown on Pl. III, page 30.

Shavers Fork and Dry Fork, which unite to form Cheat River, at Parsons, carry waters of good quality which differ only in the trace of sulphate in that of the former. (Assays on p. 40.) The higher color of Dry Fork is due to tannery pollution, which persists in the main stream a mile or two lower down, as is shown in its equally high color. Both the color and the sulphur-trioxide content diminish markedly in the course of the flow to Rowlesburg, about 20 miles down the river, and in this stretch there is also a slight temporary diminution of the alkalinity. (See assay on p. 40.)

Parsons, W. Va.—At Parsons (population 600), at the junction of Shavers Fork and Dry Fork, there are two tanneries, the effluents from which stain the water perceptibly. Sawmills are located at various points along the stream, but, as the merchantable timber will soon be gone, pollution from these may be regarded as only temporary. In its present state the water of the river is exceptionally fine, not greatly contaminated by sewage, and the flow is sufficient to supply a million people. A field assay is given on page 40. The drawback to its use, however, lies in the extremely steep grade of the stream, which is shown on the profile sheet. The very rapid fall evidently makes self-purification almost impossible, and it is by no means improbable that typhoid fever contamination far up on the headwaters of the stream may be delivered in virulent form at points as far down as its mouth, or even in Monongahela River itself.

Tunnelton, W. Va.—The divide between the Cheat and the Youghiogheny is very narrow at the highest point, which is Tunnelton, W. Va., a village of about 500 inhabitants. There is practically no permanent water supply here; the supplies are derived from individual wells not over 50 feet in depth, nearly all of which dry up in spells of drought. Much money has been expended by the coal company in boring for water, without success; and it may yet be necessary to pump from the river, costly as such an expedient may be.

The well assayed (p. 41) furnishes water longer than the majority in dry times. The water is of very poor quality for any purpose except drinking. The very low alkalinity would indicate that the calcium present occurs as calcium sulphate and chloride, with similar salts of magnesium, and probably very little alkaline salt.

Point Marion, Pa.—Point Marion (population about 600) has diverted a small portion of the flow of Cheat River into an earth reservoir some miles above, holding about 1,000,000 gallons. At Point Marion the mineral content of the water is practically the same as at Parsons, 60 miles upstream. The water is of excellent quality for all industrial purposes. The daily consumption is about 60,000 gallons, of which half is used by the Baltimore and Ohio Railroad Company. Figures as to typhoid fever are available for only two years, but their evidence is strong as to the unhealthfulness of the raw water.

Typhoid mortality at Point Marion, Pa.

Year.	Population.	Total deaths.	Typhoid cases.	Typhoid deaths.
1899	550	2	5	1
1900	575	10	15	3

The significance of these figures will be understood from the fact that in Allegheny City there were, in 1899, 895 cases of typhoid fever reported, the population by the census of 1900 being 129,000; in other words, 0.7 per cent of the population contracted the disease in one of the worst typhoid plague spots in the world, while here in Point Marion in 1899 0.8 per cent of the whole population and in 1900 2.6 per cent were ill with typhoid fever. The evidence is strong that the infection was general. Such conditions are usually chargeable to the quality of the water and seem to settle the class in which raw Cheat River water belongs, as the public supply is widely used. Incidentally, the figures are important in further suggesting that rivers with such a high rate of flow as the Cheat, and with such a quick-spilling watershed, do not purify themselves appreciably in their courses—in this case about 60 miles.

Field assays of water from Cheat River basin.

[Parts per million.]

Determination.	Dry Fork at Parsons.	Shaver Fork at Parsons.	Cheat River at Parsons.	Cheat River at Rowlesburg.	Cheat River at Point Marion.
Turbidity	0	0	0	0	0
Color	106	61	106	60	78
Iron (Fe)	[a] 0.5	1	0.8	1.5	1
Calcium (Ca)	Trace.	.....	.....	.....	.....
Total hardness (as $CaCO_3$)	35	35	32	35	35
Alkalinity	25	17	19	14	22
Sulphates (SO_3)	0	[a] 20	[a] 20	([b])	([b])
Chlorides (Cl)	9	9	9	14	9

[a] Estimated. [b] Very slight trace.

MONONGAHELA RIVER FROM CHEAT RIVER TO YOUGHIOGHENY RIVER.

Where Cheat River enters the Monongahela, at Point Marion, the difference in the clearness of the waters of the two streams is strongly marked, a sharply defined line appearing right across the mouth of the stream where the clear water of the Cheat meets the muddy yellow water of the main stream. From this point on to Greensboro, Pa., a distance of perhaps 12 miles, the steep slopes of the tributary streams quickly disappear, until the Monongahela River becomes practically a series of slack-water basins, extending from Greensboro to Pittsburg.

Waynesburg, Pa.—Waynesburg, with a population of about 2,500, is at such a distance from Monongahela River, about 22 miles, as to make its drainage of slight importance in the discussion of that stream.

It has a mechanically filtered supply from Tenmile Creek, pumped to a distributing reservoir, and the company is now improving the plant, placing fresh sand and gravel. The water is very hard for a surface supply, and is unsuitable for laundry or industrial uses. (See assay below.) Although few figures concerning typhoid fever are available, those given below show that in the main the filters have been a protection in the past:

Typhoid mortality at Waynesburg, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1894	....	7	1
1895	....	27	4
1896	....	1	....
1897	....	4	....
1898	37	8	1

The figures for 1895 show a general infection, possibly traceable to the water supply.

Fairchance, Pa.—The borough of Fairchance (population 1,200), situated between Monongahela and Youghiogheny rivers, drains into a small creek emptying into the Monongahela. There is no public supply, water being drawn from individual wells of the kind noted below The town's contribution to the drainage is not innocuous. Records of typhoid-fever mortality are available for this place only for 1896 and 1897, but they show a grave situation in those years.

Typhoid mortality at Fairchance, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1896	20	80	8
1897	13	4	1

The figures for 1896 point to either a general infection from one source or a general use of water from contaminated wells. The drainage from a town with such a record of typhoid deaths certainly can not improve the quality of any water.

Field assays of water in Monongahela basin.

[Parts per million.]

Determination.	Tunnelton, W. Va., 30-foot well.	Waynesburg, Pa., public supply.	Fairchance, Pa.	
			39-foot well (Richey).	77-foot well (J. W. Byers).
Turbidity	0	0	0	0
Color	11	35	57	22
Iron (Fe)	Trace.	Trace.	0.8	1.5
Calcium (Ca)	179	81	173	0
Total hardness (as $CaCO_3$)	130+	130+	132	....
Akalinity	10	97	77	228
Sulphates (SO_3)	106	[a]10	[a]20	[a]20
Chlorides (Cl)	70	5.6	19	39

[a] Estimated.

Both the Fairchance waters are hard rock waters, unfit for laundry use. The carbonates of the 77-foot well are probably those of magnesium or the alkalies. If properly cased either one would make a good drinking water, in spite of the red deposit formed by the oxidation of the iron a few hours after the water is drawn.

Uniontown, Pa.—The city of Uniontown, Pa. (population 10,000), has a gravity supply from large mountain springs. The water is of excellent quality and suitable for any purpose (see assay on p. 44), but the supply proves entirely inadequate as soon as the summer drought sets in. In 1904 the necessities of the town were so urgent that arrangements had to be made at considerable cost with the water system of the H. C. Frick Coal and Coke Company, which has large coking plants here, by which the water consumers could tide over the summer.

An adequate supply for Uniontown must necessarily come from either Cheat River or Youghiogheny River, the use of ground water being out of the question. Assays of water from wells sunk to various depths at Fairchance and Dunbar show that ground water in this section is undesirable for public supply where surface waters can be had. Pumping from either river would involve considerable expense for pipe line and machinery. Cheat River would always furnish an adequate supply, as shown by the following table of flow: [a]

Estimated monthly discharge of Cheat River near Uneva, W. Va.

[Drainage area, 1,375 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches on drainage area.
1899.					
July			1,370	1.00	1.00
August	2,232	357	924	.67	.77
September	3,210	404	952	.69	.77
October	465	273	336	.24	.28
November	3,070	538	1,732	1.26	1.41
December	6,442	1,000	2,387	1.74	2.01
1900.					
July	4,610	730	1,888	1.37	1.58
August	1,956	273	614	.45	.52
September	730	190	254	.18	.20
October	730	190	340	.25	.29
November	3,070	273	903	.66	.59
December	7,270	1,136	2,682	1.95	2.03

Assuming that the number of people to be provided for is 50,000 and that the average consumption is 100 gallons a day, the amount needed would be 5,000,000 gallons a day. The foregoing table shows that the lowest actual flow recorded is 190 cubic feet per second in September, 1900. This would amount to 122,735,574 gallons a day, an amount sufficient to supply Uniontown many times over.

It would be well if Cheat River could be diverted for this purpose at such an elevation as to give a gravity supply, but such diversion is impracticable at a reasonable cost, as it would be necessary to take water out no nearer to Uniontown than Kingwood, a distance of about 40 miles, and as the river runs through a deep ravine it would be necessary to carry the pipe line downstream nearly to the Monongahela, doubling its cost. Another scheme involves pumping the water up several hundred feet before starting it across country in a

[a] Water-Sup. and Irr. Paper No. 75, U. S. Geol. Survey.

shorter pipe line. The former plan seems out of the question, owing to the great distance to be traversed and the consequent great expense; but if pumping is to be resorted to, it is not necessary to make the diversion at a point so far up the river. The topographic sheets issued by the U. S. Geological Survey show that the shorter line would begin near Cheathaven, where the elevation at the bank of the river is about 800 feet above sea level. The hill immediately southeast of Cheathaven rises to an elevation of about 1,130 feet, so that a reservoir on this hill could be filled by pumping about 330 feet. From Cheathaven the line would go 15 miles northeastward across the country, approximately parallel to the line of the Baltimore and Ohio Railroad. It can be kept below the 1,100-foot contour without tunneling except at two points—the first at Outcrop, where the line cuts through the ridge for 1,500 feet; the second about 4 miles from Uniontown, where a tunnel three-quarters of a mile long would have to be built through the rise at that point. The rest of the line seems to present no notable difficulties, the greater part of the town lying under the 1,000-foot contour.

If Cheat River were uncontaminated, the above would perhaps be the ideal plan, but in view of the figures as to typhoid fever at Point Marion, it is evident that this water would either have to be filtered or sedimented with great care. Sedimentation might not be completely efficacious, as is shown below, and if filtration is to be resorted to in addition to the pipe line the cost is prohibitive. The alternative seems to be to arrange for the use of filtered Youghiogheny water from Connellsville. It seems improbable that Indian Creek water from the new pipe line under construction by the American Pipe Manufacturing Company for private interests will be available for Uniontown. The work consists of a rubble masonry and concrete dam on Indian Creek about 4 miles upstream from the railroad station of that name. The dam is located just below the mouth of Mill Run, where the drainage area of the two streams is about 109 square miles. The structure impounds about 250,000,000 gallons. The 36-inch supply pipe runs down to the Baltimore and Ohio Railroad and follows it to Connellsville, where there is a 10,000,000-gallon distributing reservoir. From that point a 30-inch pipe goes to Everson and thence to Radebaugh Junction via County Home Junction. Thence it extends toward Pittsburg, its terminus not yet being decided on. There is a distributing reservoir at Hawkeye (capacity, 13,000,000 gallons), one at Youngwood (capacity, 1,000,000 gallons), and one at Radebaugh Junction (capacity, 8,500,000 gallons).

The water of Indian Creek, as will be seen later, is excellent. Extension of this line from Connellsville to Uniontown, if practicable, would solve the question of that city's water supply most satisfactorily, as the Indian Creek drainage basin could be patrolled at very little expense, there being little pollution on the banks of the stream.

Greensboro to Monongahela, Pa.—Between Greensboro and Monongahela a large and dense population takes its water unpurified from Monongahela River. Brownsville, which pumps the river water raw, is only 15 miles above Charleroi. Between these towns the river receives the sewage of Brownsville, with about 1,800 population; Bridgeport, with 2,000; West Brownsville, with about 1,000; California, 2,500; Coal Center, 1,000; Stockdale, 1,000; Fayette City, 2,000, and Bellevernon, 2,000, besides that of a number of smaller communities, aggregating not far from 15,000 people. Charleroi is drinking this dilute sewage raw. Its own population is about 7,000. Monessen, below it, has a population of about 2,500, and a dozen smaller places are scattered along the stream, so that at Monongahela the water contains the sewage from about 26,000 persons.

Typhoid fever mortality statistics for Charleroi are too meager to be of use. The few available for Monessen show a state of affairs such as might be expected. Every case visited by the medical inspector of Washington County in Monessen was traceable to the use of river water.

Typhoid mortality at Monessen, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1899		9	
1900	30	50	10
1901	60	17	4
1902	75		9

Even if a number of these cases were foreign, conditions here are very bad. So high a percentage of mortality from typhoid fever means that the town has a highly contaminated water supply.

The conditions in all of these towns are bad; each one pumps its water supply from the stream raw and pours its sewage back into the stream for the next town below to pump into its mains. The sole protection of the consumers is the natural purification taking place in the river.

Monongahela, Pa.—At Monongahela, 10 miles below Charleroi, the supply is pumped from a filter well on the shore of the river, about 100 feet below low-water mark. The inefficiency of such a form of purification is shown on p. 55, and the water from the filter well here is so turbid as to show that it is coming from the river practically without change.

Field assays of water of Monongahela River at Brownsville and Monongahela and of public water at Uniontown, Pa.

[Parts per million.]

Determination	Monongahela River.		Public supply, Uniontown.
	Brownsville.	Monongahela.	
Turbidity	a 10	a 30	0
Color	180	250	5
Iron (Fe)	.5	1	0
Calcium (Ca)	46	44	0
Total hardness (as $CaCO_3$)	46.6	49	28
Alkalinity	27.6	24.9	14
Sulphates (SO_3)	31	38	0
Chlorides (Cl	9	6.5	9

a Estimated.

The sulphates shown in the Monongahela River assays are due to drainage from mines and wells along the stream, which contribute a little ferrous sulphate and at times a small quantity of free sulphuric acid. The extremely high color is also due in part to this cause, but chiefly results from the large amount of sewage in the stream, which makes it practically a septic tank. So far as mineral contents go, this is a very fair water for boiler purposes, the difficulty being with the varying amount of corrosive acid and sulphate appearing in the water at different times.

YOUGHIOGHENY RIVER BASIN.

The Youghiogheny does not carry so much water as the Cheat, but it is, nevertheless, a stream of great importance, because of the large population in its drainage area. Its source is in the mountains of Maryland, whence it flows northward as far as Confluence, where its principal tributary, Casselman River, enters. Up to this point the drainage area comprises only chiefly rural communities and the two small Maryland towns of Terra Alta and Oakland, the former with a population of about 800, the latter with about 1,000. A profile of the river is shown on Pl. III, page 30.

YOUGHIOGHENY RIVER ABOVE CASSELMAN RIVER.

Oakland, Md.—Oakland is built along Little Youghiogheny River, and drains directly into it. There is no public supply, most of the stores and some dwellings getting water from the large Offut wells, pumped by the principal merchants in the town. The water is too high in mineral content for industrial uses, for which the Youghiogheny water is much better.

Field assay of water from Oakland, Md.

[Parts per million.]

Determination.	Offut well.	235-foot well (B. and O).	Youghiogheny River 2 miles from town.
Turbidity	0	0	0
Color	5	31	81
Iron (Fe)	1.5	[a].8	1
Calcium (Ca)	88	0	0
Total hardness (as $CaCO_3$)	150	91	28
Alkalinity	35	97	([b])
Sulphates (SO_3)	49	[a]15	0
Chlorides (Cl)	39	39	9

[a] Estimated. [b] Water very faintly acid.

The Offut water, or quasi-public supply, is a typical hard well water from the rock. Its use for any purpose but drinking would lead to trouble, unless treatment were resorted to. The 235-foot well at the Oakland Hotel apparently contains considerable magnesium carbonate, the total hardness being high, with calcium too small to be determined by field methods. The identical chlorine content is interesting.

The Youghiogheny water is very pure and soft, but even up here near the source of the stream the acid of the mine wastes is determinable.

Terra Alta, Md.—Terra Alta has a supply of a similar nature, derived from a deep well at the planing mill. The water seems too high in incrusting solids to be best for boiler use. A very good city supply could be drawn from Terra Alta Lake, about 2 miles from the town, a body of water covering several acres, whose shores could be patrolled very easily. This lake, as well as Snowy Creek, drains into the Youghiogheny, which carries more or less drainage from adjacent farms. Analysis of the waters of the lake and creek are given below.

Field assays of water from Terra Alta, Md.

[Parts per million.]

Determinations.	Public supply 100-foot well.	Terra Alta Lake.	Snowy Creek.
Turbidity	0	0	0
Color	20	122	40
Iron (Fe)	2	1	1
Calcium (Ca)	116	0	0
Total hardness (as $CaCO_3$)	90	21	21
Alkalinity	44	17	19
Sulphates (SO_3)	[a]10	0	0
Chlorides (Cl)	14	14	9

[a] Estimated.

The public supply is at present piped to but twelve places, but the quantity of water is sufficient for many more. The two surface waters would undoubtedly be better, however, on account of their softness, if suitable measures could be enforced to keep pollution out of them. The high color of the lake water is probably due to vegetable matter in solution, the drainage area being well covered, The creek is a very small stream, flowing little water in the summer, so that storage would be necessary if it were used for public supply.

Addison and Somerfield, Pa.—From Terra Alta to Confluence, a distance of nearly 40 miles, the population is very scanty, the chief pollution of the stream being from mine waters. Several small villages drain into the main stream, the most important being Addison and Somerfield. At neither place is there a public supply, water being obtained from individual wells. Addison is about 4 miles from the river and has a population of about 300, that of Somerfield being the same.

Field assays of water from Addison and Somerfield, Pa.

[Parts per million.]

Determination.	20-foot well, Addison.	52-foot well, Somerfield.	Youghiogheny River at Somerfield.
Turbidity	0	0	0
Color	17	74	45
Iron (Fe)	0	2.5	(a)
Calcium (Ca)	130	88	0
Total hardness (as $CaCO_3$)	139+	139+	35
Alkalinity	45	95	15
Sulphates (SO_3)	25	15	0
Chlorides (Cl)	70	9	9

a Slight trace.

Both these wells furnish typical hard rock water, unsuitable for laundry or boiler uses, in quantity too small to be of importance except for private supplies. The sample of river water analyzed was taken below the National Pike bridge, about 100 yards below the mouth of a small creek. The acidity found at Oakland is not present at this point, the mineral contents of the stream being precisely similar to those of the West Virginia mountain stream waters and of the spring waters considered below. The alkalinity is important in connection with the later discussion of the germicidal influence of acid drainage, as it shows that the influence of the acid does not extend far.

CASSELMAN RIVER.

Casselman River, a typical mountain stream with an exceedingly swift current, drains a great deal of coal country, so that its waters are nearly always stained a bright yellow with mine drainage. The drainage area is not densely populated, but along the course of the stream there are many little villages and coal-mining camps, so that in the aggregate the drainage is a serious factor. The water supplies of the small communities at the headwaters are all derived from springs, though many people use individual wells.

Field assays of waters in upper Casselman River basin.

[Parts per million.]

Determination.	Elk Lick well.	Elk Lick Spring.	Boynton Spring.	Flaugherty Creek at Keystone Junction.
Turbidity	0	0	0	0
Color	45	5	22	36
Iron (Fe)	([a])	0	Trace.	([a])
Calcium (Ca)	92	0	0	0
Total hardness (as $CaCO_3$)	132	49	35	35
Alkalinity	68	11	12	16
Sulphates (SO_3)	0	0	0	0
Chlorides (Cl)	19	19	14	9

[a] Slight trace.

Flaugherty Creek at Keystone Junction, Pa.—Flaugherty Creek, which enters Casselman River at Keystone Junction, above Meyersdale, presents a typical normal water of this section, soft and pure. It is a very rapid little stream, draining an area having but little population. Nearly all the inhabitants, however, chiefly coal miners, are collected along the creek, and all their wastes go into the stream sooner or later. This section is rich in springs of the type shown, and a group of these may yield enough water to supply 2,000 or 3,000 people, as at Meyersdale.

Meyersdale, Pa.—This town, with a population of about 3,000, has a gravity supply from a spring-fed reservoir in the hills about 5 miles distant. The water is piped to near-by hamlets, supplying in all about 4,000 people, and until recently, in seasons of drought, proved sufficient in quantity. It is probably as free from contained solids as any natural water.

Field assays of waters from Meyersdale, Pa.

[Parts per million.]

Determination.	Public supply at Meyersdale.	Casselman River 3 miles south of Meyersdale.
Turbidity	0	[a] 2
Color	5	122
Iron (Fe)	0	[a] 5
Calcium (Ca)	0	0
Total hardness (as $CaCO_3$)	14	91
Alkalinity	6	7
Sulphates (SO_3)	0	[a] 20
Chlorides (Cl)	9	19

[a] Estimated.

It is evident from several points in the assay that Casselman River receives much mine drainage up to this point. The lack of calcium would indicate the presence of magnesium, the alkalinity being so low as to make the presence of any great quantity of alkaline carbonates improbable. The low alkalinity and the trace of sulphates point to the partial neutralization of the alkalinity of the unpolluted water by ferrous sulphate and free sulphuric acid from the mines. The small iron content indicates that the sulphate pollution results principally from free acid.

Meyersdale to Confluence, Pa.—Between Myersdale and Confluence are several small villages, none having public supplies but Berlin and Garrett. The analyses subjoined show that the quality of normal waters here is excellent. They are characteristic of this section.

Field assays of waters collected between Meyersdale and Confluence, Pa.

[Parts per million.]

Determination.	Laurel Creek near Hays Mill.	Public supply, Garrett (spring.)	Public supply, Berlin (spring.)	Spring at Markleton.	Spring at Ursina.	18-foot well at Casselman.	20-foot well at Beachdale.	20-foot well at Rockwood.	Coxes Creek at Rockwood.
Turbidity	0	Slight.	0	0	0	0	0	0	([a])
Color	45	122	22	5	22	22	17	5	113
Iron (Fe)	Trace.	0	([b])	0	0	0	([b])	0	0
Calcium (Ca)	0	0	0	0	70	107	38	162	15
Total hardness (as $CaCO_3$)	35	42	28	35	132	139	97	160	35
Alkalinity	20	17	15	13	80	28.5	44	29	14
Sulphates (SO_3)	0	0	0	0	20	63	([b])	41	[a] 5
Chlorides (Cl)	9	9	9	14	14	49	19	181	12

[a] Decided. [b] Estimated. [c] Very slight trace.

The first five analyses show normal spring waters of excellent quality for all industrial purposes. The high color of the Garrett water is probably due to a foul condition of the reservoir, for the town comprises only a few hundred people and the supply is left to take care of itself to some degree. The well waters are too hard to be of use for anything but drinking. Beachdale is a mere handful of coal-miners' huts and a few farm houses, and Rockwood is a village of about 400, with no public supply. The Baltimore and Ohio Railroad Company pumps Casselman River water to its tank at Rockwood for boiler uses, supplying it to a hotel also. The assay of the shallow well at this point shows the nearness of the rock to the surface, the chlorides in particular being unusually high. None of these supplies are important for anything but private uses, except perhaps Coxes Creek, which enters the Casselman at Rockwood. This is a fine stream, flowing through a lumber country, chips and sawdust in quantity polluting the water. The spring at Markleton is piped to the sanitarium at that point, supplying several hundred persons in the summer. The Ursina spring fills a 1-inch iron pipe, gushing out under a strong head. Casselman is a hamlet of a few dozen families, all water supplies being either springs like those noted or individual wells.

Confluence, Pa.—This town, which stands at the confluence of Laurel Creek, Casselman River, and the Youghiogheny, formerly used Laurel Creek as a source of water supply. The pollution from coal mines along this creek, however, became so great that a new source of supply was found in Drakes Run, an exceptionally pure mountain water (see assay on p. 49) rising in practically uninhabited country and flowing through a sparsley populated farming section. The town has about 1,500 people, with a very large tannery located on the river. The town sewage as well as the tannery refuse all go directly into the stream.

The notable thing about the river assay at this point (see p. 49) is the nearly complete disappearance of the mine drainage, the only traces left being the iron content and the comparatively low alkalinity, showing that the acid wastes are not considerable enough to keep the water acid more than a short distance below the points where mine drainage enters.

YOUGHIOGHENY RIVER BELOW CASSELMAN RIVER.

There is no town of over a few hundred population between Confluence and Connellsville. The water supply between these points is derived entirely from individual wells, such as those at Ohiopyle, which are not important except as private supplies (see assays on p. 49). The water of the 50-foot well at Ohiopyle probably contains some magnesium carbonate, with iron probably present as a carbonate also. The other well shows a remarkably low alkalinity, considering its hardness, perhaps due to the carbonates being almost entirely those of the incrusting solids. The deeper well penetrates the sandstone, the shallower one only touching the top of the rock.

Indian Creek, Pa.—At Indian Creek station the Youghiogheny receives its large tributary of that name, a very beautiful and relatively unpolluted stream with a watershed comprising about 125 square miles. This creek was seriously considered for Pittsburg's water supply by a gravity system, the quality of the water being excellent. The report of Mr. Kuichling on the plan showed an estimated first cost of about $13,000,000 for storage reservoir, pipe lines, etc., as compared with $2,000,000 or $3,000,000 for a filtration plant.

Field assays of waters from Confluence, Ohiopyle, and Indian Creek.

[Parts per million.]

Determination.	Confluence.		Ohiopyle.		Indian Creek.
	City supply, Drakes Run.	Casselman River.	50-foot well on north bank of river.	19-foot well on south bank of river.	
Turbidity	0	0	0	0	0
Color	27	45	0	5	17
Iron	0	1	10	0	0
Calcium	0	0	0	57	0
Total hardness	21	32	132	132	28
Alkalinity	14	9	50	10	13
Sulphates	0	(a)	[b]10	15	0
Chlorides	9	9	17	44	9

[a] Slight trace. [b] Estimated.

This assay shows that Indian Creek is a spring stream carrying pure water like the normal waters shown above.

The only available measurement of the Youghiogheny near this point is that made during the drought of October, 1892, by Kenneth Allen, for the Frick interests, showing a flow of 106 cubic feet per second. By taking the October flow of Indian Creek at 15 feet, it may therefore be said that the Youghiogheny at the very driest time carries not less than about 120 cubic feet per second, while during floods it may carry 2,500 cubic feet per second.

Connellsville, Pa.—Connellsville, a city of perhaps 9,000 people, is about 28 miles below Confluence. Its water supply is pumped from Youghiogheny River for filtration in mechanical filters of the Pittsburg type. The plant seems to be efficiently operated, but there is more or less local dissatisfaction with the quality of the water, which contains a strong trace of mine drainage. The only remedy for this condition is a new source of supply. The new pipe line from Indian Creek, mentioned above, may remove the objection.

Typhoid-fever statistics are not available for any of the towns of this section except Connellsville, and even there only for a few years. In 1894, when the population was 5,629, there were 3 cases and 1 death reported in Connellsville from typhoid fever; in 1895 there were 5 deaths from this cause; in 1897, out of a total mortality of 71, there was 1 death from typhoid, with 6 cases; in 1898 there were 5 deaths in a total mortality of 104, or 4.8 per cent. These figures are too meager to be of much value except to show the probable presence of typhoid bacilli in Connellsville sewage, which finds its way into the Youghiogheny.

A sample of the city water was taken from a hotel tap, and its assay (p. 50) shows that the mineral impurities in the river have greatly increased. The lack of iron and the small trace of sulphates indicate that very little mine drainage enters the stream here.

On account of the use of coagulant in the filters it is likely that the raw river water is a little softer.

From this point down to Pittsburg the population is dense, towns of from a few hundred to a thousand people dotting either shore closely. The sewage and drainage from all these places goes into the stream, making it practically a sewer. Ground waters are of poor quality a little distance away from the stream, as is shown by the field assay (below) at Dunbar, which has no public supply, though the population is about a thousand. This is a very hard water, and none of the wells give a very abundant supply. This town could very well take water from the Connellsville-Uniontown pipe line suggested above. It drains into the Youghiogheny above West Newton.

West Newton, Pa.—West Newton (population about 2,500), 15 miles below Connellsville, uses well water as a city supply, the wells being owned by private parties. The wells are 190 feet deep, pumping to a tank, whence the taps are supplied by gravity. The water is higher in color than it should be for a deep ground water, owing probably to fouling in the tank or in the pipes. A field assay of the water is given below.

This is a remarkably soft water, considering the depth from which it comes. It would not be suitable for steam making, the high chlorides being very corrosive. Its softness and high alkalinity indicate the presence of carbonates and chlorides of the alkalies in large quantity.

If care is used in casing the wells this supply should be very fair for drinking and domestic uses.

The few typhoid-fever statistics available for this town indicate that many of its people are drinking water from individual wells.

Typhoid mortality at West Newton, Pa.

	Total deaths.	Typhoid cases.	Typhoid deaths.
1895	....	4	4
1897	....	....	4
1900	30	....	3

It is evident that West Newton also is a contributor of typhoid drainage to Youghiogheny River.

McKeesport, Pa.—The largest city on the Youghiogheny is McKeesport, with an estimated population in 1904 of 37,000. The city water supply is the worst on the Youghiogheny watershed. It is a mixture of two waters—raw water from the river and well water from wells about 40 feet deep. The field assay herewith shows the quality of the mixture:

Field assays of waters from West Newton, Dunbar, Connellsville, and McKeesport.

[Parts per million.]

Determination.	West Newton, 190-foot wells.	Dunbar, 117-foot wells.	Youghiogheny River. Connellsville.	Youghiogheny River. McKeesport.
Turbidity	0	0	0	(a)
Color	78	17	22	54
Iron (Fe)	0	Trace.	0	2
Calcium (Ca)	38	119	67	126
Total hardness (as $CaCO_3$)	42	139	56	95
Alkalinity	340	132	22	48.5
Sulphates (SO_3)	....	59	[b] 5	108
Chlorides (Cl)	132.3	29	9	9.8

[a] Slightly cloudy. [b] Estimated.

The dilution of the river water by the pure ground water is insignificant so far as the healthfulness of the supply is concerned, the mixture being analogous to seeding a pure water with sewage bacteria, a process that produces conditions under which, as is well known, the organisms will grow faster for a time than in foul water. When it is remembered that in many of the towns along the stream there is always some typhoid fever, and that there is some at some time in all, it is difficult to understand how an American community can drink such disease-polluted water. Furthermore, the river valley for 10 or 15 miles immediately above McKeesport is thickly populated, and small hamlets along the stream have outhouses along the banks, so that a trip up the river from McKeesport ought to convince the most skeptical, by the evidence of their eyes, of the polluted character of the supply. These facts can fortunately be supplemented by figures showing typhoid mortality at McKeesport for many years.

Typhoid mortality at McKeesport, Pa.

Year.	Population.	Total deaths.	Typhoid cases.	Typhoid deaths.	
				Number.	Rate per 100,000.
1893	....	464	123	....	....
1894	....	454	63	8	....
1895	....	444	299	29	....
1896	....	537	144	13	....
1897	....	468	86	8	....
1898	....	528	100	15	43.8
1899	....	589	151	14	40.9
1900	34,227	684	315	23	67.3
1901	35,576	693	275	29	81.5
1902	36,925	799	262	30	81.2
1903	38,274	788	313	43	112.3
1904	....	796	324	48	....

It is noteworthy that 162 of the total number of deaths for 1904 from violent causes were over 20 per cent. If this ratio were not so high the typhoid percentage mortality would be even more serious.

In 1904 the death rate from typhoid fever in McKeesport was 129 per 100,000 of population, or 6 per cent of the total mortality. This figure is enormously high, placing McKeesport in the same class with Allegheny and Pittsburg as a hotbed of water-borne disease. Even in the city of Washington, which is popularly thought to be a center of this disease, the number of deaths per 100,000 in 1904 was only 47, yet the situation there was considered so grave as to necessitate the erection of a filtration plant. McKeesport, like Pittsburg and Allegheny, is in the condition of having a continuous epidemic of typhoid fever. The highest death rate from this disease in Lowell, Mass., before the change from a polluted river supply to ground water, was 112 in 100,000 from 1886 to 1890, inclusive. The highest recorded typhoid-fever death rate for Indianapolis was 101 per 100,000 in 1895. This has been lowered year by year to 56 per 100,000 in 1903, which is considered so high as to necessitate a change in the source of supply. Pittsburg, whose water supply from Monongahela and Allegheny rivers has for years been unspeakably bad, had 144 deaths per 100,000 in 1900, 125 in 1901, 144 in 1902, and 139 in 1903. Grand Rapids, Mich., which has been very seriously considering the question of a purer water supply than its present one, has from 31 to 51 deaths from typhoid fever per 100,000 for the years 1899 to 1903, inclusive. It is evident that McKeesport is supplied with water that is dangerous and in no sense potable or fit for consumption by human beings. The ground-water supply should be so extended as to furnish sufficient for the needs of the town, or, if this extension is impracticable, Youghiogheny water should be filtered. Analyses of Youghiogheny River water made by Pittsburg engineers are relied upon by the city officials to prove its potability. The degree of confidence which may be placed in them may be shown by a comparison of the dates of collection and analysis. The samples were collected January 19, February 3 and 16, and March 3 and 31, 1903. The secretary of the local board of health states over his signature that the analyses were made "about April and May." Therefore all the determinations, except as to inorganic constituents, are worthless, for the conditions under which the samples were kept determined whether the organisms would increase or die out. There may have been, and probably were, thousands of bacteria in the samples when they were collected. By the time the samples were analyzed, a few days to a few weeks after collection, the food content of the medium may have been exhausted and the organisms very naturally died. If the samples had been kept a little longer there would probably have been no bacteria at all left in them. To be of value bacteria determinations should be made within six hours after collection of the samples.

The principal claim made for the water is the fact that it contains so much iron and sulphuric acid as to make it germicidal to bacteria. The purifying action of the iron sulphate is discussed in detail under the heading "Self-Purification" on pages 69–73. In August, 1905 (see field assay), there were but 2 parts per million of iron in the sample taken, although the analyses of the river water referred to show 12 to 44 parts per million. Evidently, as in the Monongahela water, the coagulating action of the ferrous sulphate could not be relied upon to go on regularly, on account of the variation in the amount of iron, which sometimes went far below the required quantity.

MONONGAHELA RIVER BELOW YOUGHIOGHENY RIVER.

Below McKeesport Monongahela River is lined on both banks with little towns, two of which, Braddock and Homestead, have a population exceeding 15,000. Although these two are the only large towns along the river, there are so many smaller ones that the banks present an almost continuous succession of dwellings and mills. All of these drain into the river, some of them by modern sewers. The drainage of a number of towns in Westmoreland County, chief among which is Greensburg, also finds its way into the stream through small tributaries, although in comparison with the direct pollution by the towns noted above, those away from the river are negligible so far as sewage is concerned.

Greensburg, Pa.—Greensburg (population 6,500) has a gravity supply from a system of impounding reservoirs on Chestnut Ridge and Dry Ridge, having a capacity of 75,000,000 gallons, the daily consumption being from 1,700,000 to 2,000,000 gallons. The supply is similar in quality to that of Bradford and Kane, being typical mountain spring water. An effort is made here to assure safety from pollution by sanitary inspection of the watershed. The company owns 1,200 acres of land on the two main drainage areas, covering nearly all the watershed drawn upon, and cooperates with the monastery of St. Vincent, which owns one-third of the entire watershed, in guarding the drainage area. All dwellings and farm buildings have been cleared off and an arrangement has been made with farmers having holdings around the drainage area whereby they are furnished constable's badges and are paid $10 a year to warn trespassers off the land. This plan seems to work well and has helped to crystallize public opinion in favor of a pure supply. The company claims to be supplying about 30,000 people all told, including Greensburg, Derry, Jeanette, Youngwood, and Lycippus.

Field assay of Greensburg water.

[Parts per million.]

Determination.		Determination.		Determination.	
Turbidity	0	Color	35	Iron	(a)
Calcium	....	Total hardness	22	Alkalinity	22
Sulphates	0	Chlorides	6		

a Very slight trace.

Typhoid-fever statistics for Greensburg are too meager to be of use.

Braddock, Pa.—Many of the towns along the banks of the Monongahela use water from driven wells. Others, like Braddock, pump the river water raw. The danger is at this point somewhat disguised by "natural filtration" through a covered well 20 by 20 feet, situated about 30 feet from the river. A drilled well about 40 feet deep in the bottom of the large one is drawn on at the same time. From the facts already stated it is evident that the purity of the well water will by no means diminish the toxicity of the river water. The work of Frankland and Klein shows that disease germs may live longer in unpolluted well water than in surface water. The inefficiency of this form of filtration has already been shown (p. 54 et seq). It should be abandoned, either for ground water or proper sand filtration.

The only statistics at hand to show typhoid-fever mortality at Braddock are for 1900, when, in a population of 15,654, there were 10 deaths from this disease, representing probably 100 cases, enough to show that in that year, and probably in others, typhoid fever was prevalent in the town to a dangerous extent.

Homestead, Pa.—With regard to the other towns on Monongahela River above Pittsburg, the facts are similar as to what they take from the river and what they put back into it. The largest is Homestead, with about 15,000 inhabitants, which, after years of costly experience with typhoid fever resulting from drinking raw river water, is filtering Monongahela River water for its public supply. Its own sewage, however, still pours into the stream for the next town below to drink.

SUMMARY OF CONDITIONS IN MONONGAHELA RIVER BASIN.

The discussion of conditions on the Monongahela above McKeesport has shown the dangerous character of the water of that stream for drinking purposes; the discussion of Youghiogheny River drainage shows the existence, at all points along its course where typhoid statistics are obtainable, of sewage pollution containing the germs of water-borne disease. The smaller stream flow of the Youghiogheny makes dilution of the contamination to any great degree impossible, and its high rate of flow over most of its course puts detention out of the question until West Newton is reached, coincidently with a great increase in the number of centers of population. From Oakland to West Newton, a distance of approximately 80 miles, the river falls 1,591 feet, with a slope of nearly 20 feet to the mile. The discussion of the Allegheny and Monongahela drainage areas has been sufficient to show that the stream flow through this mountain country, with a fall of 3½ feet to the mile, is too rapid to permit effective sedimentation, and it is clear that the high grade of the Youghiogheny River channel puts purification by detention out of the question. Casselman River, carrying the sewage of Meyersdale, has a fall of about 600 feet in about 30 miles, making, roughly, a fall of 20 feet to the mile. It seems evident that the sewage of Meyersdale, Confluence, and Connellsville are practically unpurified when they come down to West Newton. On page 67 it is shown that self-purification of Illinois River is not complete within 100 miles of the source of the pollution. With a slope about seven times as great, the Youghiogheny above McKeesport is expected to perfectly purify, by one agency or another, the sewage of about 20,000 people, in a stream flowing sometimes only about 125 cubic feet of water per second, or, roughly, 7,500 cubic feet per minute; while below McKeesport, with a very low slope, there is a population of approximately 100,000 to take care of with about the same amount of water. What chance is there for complete self-purification in Youghiogheny River in the 15 miles intervening between West Newton and McKeesport?

It has been shown in the discussion of the Cheat River drainage that even so comparatively unpolluted a stream may and does carry typhoid bacilli down from remote and small sources of pollution to breed disease in a large proportion of the population drinking the water.

In no way can the conclusion be escaped that water from Youghiogheny River used raw is in a high degree dangerous to public health. The claim made with respect to the germicidal influence of mine drainage results from a misapprehension of the action of such drainage. Though this water occasionally carries much free acid, the purifying action, such as it is, results principally from the sedimentation which goes on through the coagulating properties of the calcium in the water and the ferrous sulphate coming from the mines. This action is fully discussed on pages 65–73, it being shown that even when most efficient, under the most favorable and well-controlled conditions, such purification is not sufficient by itself to make a water supply reasonably safe. Finally, if the mine drainage did actually operate to free the water of pathogenic organisms, the typhoid-fever death rate at McKeesport, where this water is drunk freely without purification, ought to show the effect of such purification. On the contrary, as the figures given above show, the condition there is extremely bad and the death rate from typhoid fever is going up.

The foregoing discussion of the Monongahela watershed shows that its waters are as badly contaminated and as unfit for drinking as those of the Allegheny.

AGENCIES COMMONLY SUPPOSED TO COUNTERACT THE EFFECTS OF POLLUTION.

NATURAL FILTRATION.

GENERAL STATEMENT.

There is a strong popular belief that a polluted river water will purify itself in a flow of from 7 to 30 miles. It need hardly be said that this is not true. Sedimentation, the chief factor in the self-purification of natural waters, goes on more rapidly in standing than in running water. Many cities which take water from running streams upon whose drainage areas typhoid fever is prevalent have been visited by epidemics of the disease. The historical Plymouth, Pa., epidemic, the Mohawk Valley epidemic of 1891, the Lowell-Lawrence epidemic of 1891, all show that a stream polluted with typhoid sewage retains toxic material for a long time.

Experiments made with the typhoid-fever organism have shown that it is able at times to retain its vitality in potable waters for weeks and months. Even if pollution at any particular point should be intermittent, the polluted water might contain the bacilli of disease, and its use for drinking purposes is therefore attended at all times with uncertainty and danger. The great majority of towns situated on running streams draw their supplies from those streams in too many cases without purification of the water.

The delivery to the people of unpurified water is nowadays regarded everywhere as extremely dangerous, as such water has too often been found to be a fruitful source of typhoid fever and kindred diseases. There is not a town in the eastern United States taking its water unpurified from a large stream which has not either an abnormal typhoid mortality rate or has been visited by a typhoid epidemic.[a]

In modern practice it is an axiom that raw surface water is safe as a city supply only when the entire drainage area of the stream used is subjected to rigid sanitary control. "All surface waters must be considered dangerous, and their use in the raw state for a general supply in each particular case either has been, is now, or is likely to be the cause of disease and death,"[b] except when properly guarded, when they have no superior as water supplies. New York City's water supply is impounded from the run-off of a large drainage area from which whole villages have been removed, the entire area being cleared of habitation. The typhoid-fever death rate of New York City is very low.

The plan of natural filtration, by causing the polluted waters of a running stream to seep through the sand and gravel of its own bed, was for a long time considered adequate purification; the annual decimation by typhoid fever in towns so supplied has demonstrated the ineffectiveness of the plan in its three best-known forms. These are, first, filter wells, with permeable bottom and sides, such as are used at Monongahela, Braddock, and many West Virginia towns; second, filter galleries, such as those of Lowell, Mass., before 1891, and Columbus, Ohio, at the present day; third, filter cribs, in extensive use all over the country, and particularly in the vicinity of Pittsburg.

Reliable data as to the efficiency of filter wells are not available. Filter galleries and cribs, however, have long been in use in places where continuous analyses and fairly accu-

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[a] Sedgwick, W. T., Test, Chicago Drainage Canal Com., vol. 3.
[b] Kemna, Dr. Adolph. Trans. Am. Soc. Civil Eng., vol. 54, Pt. D, p. 157.

rate statistics of typhoid mortality have been kept, making it possible to determine with accuracy what effect natural filtration has on the quality of polluted surface waters.

A very important distinction must be made between galleries and cribs. Cribs are invariably located in the beds of more or less polluted streams, the waters of which seep through the superincumbent sand into the interior of the structure and are pumped into the city mains. Water so obtained is, therefore, practically surface water, the only purification being produced by its passage through a few feet of sand and gravel. Filter galleries, however, being excavated in the river bank, are in a position to impound ground water on its way to the stream, besides allowing the seepage of surface water from the river. The experience of communities using such supplies goes to show that bacterial purity of the supply is directly proportional to the ratio between the ground water and the river water in the gallery, as will be evident from facts presented below. Properly speaking, therefore, galleries do not effect filtration of contaminated water, being successful only when the contaminated water has no access to them, paradoxical as that may seem. This point should be kept in mind in accounting for the wide discrepancies in the bacterial content of water treated by natural-filtration schemes in various towns.

FILTER GALLERIES.

Woburn, Mass.—At Woburn, Mass. (population 4,000), the supply is taken from so-called filter galleries impounding ground waters on their way to Horn Pond, which has a drainage area of 7¼ square miles and a surface of 103 acres. Prior to 1899, when the galleries were installed, the typhoid mortality rate was high, as may be seen from the figures below:

Deaths per 100,000 from typhoid fever at Woburn, Mass.

Years.	Deaths.	Years.	Deaths.
1871-1875	57	1891-1895	48
1876-1880	20	1896-1900	13
1881-1885	25	1901-1903	2
1886-1890	38		

Although conditions did not immediately improve after 1889, the remarkable reduction between 1891 and 1903, bringing the death rate from this cause down to only 2 per 100,000, shows conclusively that the galleries are supplying good water. That this is ground water on its way to the pond, and therefore more thoroughly purified than river water can ordinarily be, is shown by the experience of Lowell, Mass.

Lowell, Mass.—Prior to 1891 Lowell took its public supply from filter galleries near the Merrimac River. The figures showing typhoid death rate are as follows:

Deaths per 100,000 from typhoid fever at Lowell, Mass.

Year.	Deaths.	Year.	Deaths.
1871-1875	98	1891-1895	73
1876-1880	43	1896-1900	25
1881-1885	79	1900-1903	20
1886-1890	112		

Prior to the abandonment of the galleries in 1891 and the substitution of deep wells for the supply the death rate at Lowell from typhoid fever was steadily increasing. The steady decrease in the number of deaths since the wells were put in service indicates the badly polluted condition of the former filtrate from Merrimac River.

The striking difference in results in these two cases, and the fact that no less than 20 towns in Massachusetts get their supplies wholly or in part from filter galleries or similar devices, mostly with good effect, shows that a filter gallery is inadequate to purify contaminated river water for drinking. The filtration only clears the water of visible impurities, frequently making it doubly dangerous by masking the pollution. The device, when successful, is merely a form of well that has a much greater collecting surface than an ordinary well can have, collecting ground water in the same way as an ordinary shallow well and subject to the same contamination from accidental pollution. When unsuccessful, it is nothing but a device for straining out turbidity and visible impurities in polluted river water, frequently making it clear and inviting in appearance, when in fact it is dangerously charged with the germs of water-borne disease. A few cases are cited below in support of this statement, out of the many instances on record.

Indianapolis, Ind.—In Indianapolis, Ind., the number of deaths from typhoid fever per 100,000 is given by Mr. Fuller in his report on the supply as follows:

Deaths per 100,000 from typhoid fever at Indianapolis, Ind., 1895–1904.

Year.	Deaths.	Year.	Deaths.
1895	101	1900	47
1896	56	1901	36
1897	43	1902	48
1898	42	1903	56
1899	46	1904	82

As a death rate from this disease of over 20 per 100,000 is generally considered sufficient to justify a serious investigation of the source of infection, it is evident that the figures given put Indianapolis in the class of cities with notoriously bad water supplies. The supply is derived from filter galleries about to be abandoned.

Columbus, Ohio.—Similar conditions have existed at Columbus, although the figures are not nearly so high. In the United States there are so many towns with typhoid death rates as high as those of Pittsburg, with 132, and Allegheny, with 129, that the significance of the figures at Columbus is not appreciated as it should be.

Deaths per 100,000 from typhoid fever at Columbus, Ohio, 1898–1903.

Year.	Deaths.	Year.	Deaths.
1898	28	1901	36
1899	23	1902	37
1900	42	1903	34

The supply is partly from filter galleries about to be abandoned.

Findlay, Ohio.—Findlay, Ohio, formerly took part of its water supply from filter galleries in Blanchard River, also pumping directly from that stream.

Typhoid mortality at Findlay, Ohio, 1897–1903.

Year.	Population.[a]	Deaths.	Rate per 100,000.
1897	16,000	8	50
1898	16,500	2	12
1899	17,000	10	59
1900	17,613	16	91
1901	18,000	6	31
1902	18,500	7	38
1903	19,000	5	26

[a] Estimated, except for 1900.

The figures for 1899 and 1900 show a general infection, indicating a polluted water supply

Springfield, Ohio.—In Springfield, Ohio, with a population of 38,253 in 1900, and a supply in part from filter galleries of this kind, the typhoid fever death rate has been as follows:

Deaths per 100,000 from typhoid fever at Springfield, Ohio, 1898–1903.

Year.	Deaths.	Year.	Deaths.
1898	24	1901	20
1899	64	1902	51
1900	44	1903	42

Plainly this is contaminated surface water.

Grand Rapids, Mich.—In Grand Rapids, Mich., where water is taken from three filter galleries beneath the river bed, the mortality as shown in the table is too high.

Deaths per 100,000 from typhoid fever at Grand Rapids, Mich.

Year.	Deaths.	Year.	Deaths.
1898	34	1901	35
1899	31	1902	51
1900	42	1903	35

These galleries were installed in 1890, the raw Grand River water being pumped before then. The death rate since has risen.

Summary.—The evidence shows that filter galleries have no bacterial efficiency, and that these to be successful must be so constructed as to impound ground water only.

FILTER CRIBS.

Tarentum, Pa.—At Tarentum (population 7,000), about 19 miles above Pittsburg, a crib in Allegheny River, designed by Messrs. Chapin and Knowles, is the only means of purification at hand. The sample taken shows such high turbidity as to make it evident that the crib is out of commission, probably having been damaged by the spring freshets.

Field assay of water from Allegheny River at Tarentum.

[Parts per million.]

Determination.		Determination.		Determination.	
Turbidity	[a]30	Color	180	Chlorides	24.5
Calcium (Ca)	66	Total hardness (as $CaCO_3$)	51.4	Iron (Fe)	4 +
Sulphates (SO_3)	33			Alkalinity	41

[a] Estimated.

The statistics of deaths from typhoid fever at Tarentum are too few to justify conclusions as regards the supply. In 1896 there were 48 cases; in 1897 there were 27 cases, 2 dying; in 1898 there was 1 death from this disease.

Montrose, near Brilliant, Pa.—The figures below show the results of analyses of Allegheny River water before and after it had passed through the Montrose crib, 4 miles above Brilliant, which furnishes also a portion of Allegheny's water supply.

Analyses showing efficiency of Montrose crib, near Brilliant, Pa.

[Parts per million.]

Date.	Water analyzed.	Turbidity.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Bacteria per c. c.
1897.								
July 28	River water, raw	Muddy	0.310	0.034	None.	1.036	9.1	9,150
	Effluent from crib	Muddy	.315	.046	None.	1.165	10.2	9,200
Aug. 9	River water, raw	Slight	.197	.011	None.	.888	12.0	700
	Effluent from crib	Slight	.250	.027	None.	.666	14.0	725
Aug. 16	River water, raw	Very turbid	.340	.060	None	.750	47.0	2,225
	Effluent from crib	Decided	.174	.050	None.	.375	15.0	15,050
Aug. 23	River water, raw	Slight	.190	.020	None.	.750	12.4	3,050
	Effluent from crib	Slight	.195	.020	None.	.525	13.0	2,575
Aug. 30	River water, raw	Decided	.190	.028	None.	1.200	18.6	4,550
	Effluent from crib	Slight	.175	.018	None.	.750	17.5	10,050
Sept. 7	River water, raw	Slight	.140	.024	None.	.600	20.9	15,050
	Effluent from crib	Slight	.176	.032	None.	.675	21.5	17,500
Sept. 22	River water, raw	Very slight	.122	.014	None.	.712	10.8	2,250
	Effluent from crib	Very slight	.180	.034	None.	.300	29.6	2,425

It has already been shown that typhoid fever is constantly present in severe form at nearly every important town on the watershed of the Allegheny, and the sewage from these towns unquestionably carries disease-producing bacilli into the river. The efficiency of any plant for purifying the river water may therefore be rated by its effect on the bacterial content.

Inspection of the above figures, bracketed together to permit convenient comparison of analyses made on the same day, shows that the effluent water usually contains many more organisms than the raw water and never appreciably less. Average analyses of the effluent water, each representing the average results for one month, follow:

Average analyses of effluent water at Montrose crib, near Brilliant, Pa.

[Parts per million.]

Date.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Bacteria per c. c.
1897.						
October	0.128	0.014	None.	0.637	30.0	97,262
November	.135	.020	None.	.731	33.0	29,250
December	.090	.017	None.	.975	46.7	27,000
1898.						
January	.090	.045	None.	.637	119.4	30,400
February 16	.058	.028	None.	1.125	231.0	13,900
March	.076	.024	None.	5.000	257.5	7,967
April	.070	.024	None.	.675	120.5	7,850
May	.099	.042	None.	.300	110.0	7,600
June	.126	.026	None.	.225	51.5	43,000
July	.094	.017	None.	.975	24.1	19,300
August	.111	.025	None.	.562	41.8	21,000

Not one of these effluents can be truthfully called a filtered and safe water, and it is evident that so far as bacterial purification is concerned the crib might as well not be there. The crib is of approved form, about 2,500 feet long, 32 feet wide, and 7 feet deep, its framework having been built of 6 by 8 hemlock timbers, laid flat. The timbers are spread by blocks

4 inches thick, spaced about 3 feet apart. It is tightly planked over on top with 3-inch planks, but its sides and bottom are open. In placing the crib an excavation somewhat larger than the area of the structure was made and the crib was floated over and sunk into place. It is covered with stones and coarse gravel with sand upon top. The average depth of gravel and sand on the crib is 5 feet. The depth of the crib below the surface at low water is 16 feet at the upper end and 10 feet at the lower. Upon two occasions fresh sand and gravel have been dumped in places upon the crib to replace material thought to have been washed away.

Hulton, Pa.—At Hulton, about 11 miles above Pittsburg, a crib similar to that at Montrose was built in 1894. Its timbers are 2 by 4 inch hemlock. It is 96 feet long, 16 feet wide, and 4 feet deep, and is covered to a depth of about 4¼ feet with large stones, sand, and gravel. The average depth of water at low water is about 7 feet. Here similar exhaustive analyses were made both of the raw water of Allegheny River and of the effluent from the crib.

Analyses showing efficiency of crib at Hulton, Pa.

[Parts per million.]

Date.	Water analyzed.	Turbidity.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Bacteria per c.c.
1897.								
Aug. 9	River water, raw......	Slight............	0.215	0.021	None.	0.815	11.7	650
	Effluent from crib.....	Clear.............	.108	.009	None.	.592	35.3	135
Aug. 16	River water, raw......	Decided..........	.208	.021	None.	.900	11.0	525
	Effluent from crib.....	Slight............	.130	.014	None.	.605	24.0	1,071
Aug. 23	River water, raw......	Slight............	.185	.016	None.	.638	11.0	1,150
	Effluent from crib.....	Very slight.......	.130	.018	None.	.528	44.8	135
Sept. 14	River water, raw......	Slight............	.133	.024	None.	.450	19.7	250
	Effluent from crib.....	Very slight.......	.094	.016	None.	.450	29.7	68
Sept. 28	River water, raw......	Slight............	.174	.028	None.	.900	20.1	3,300
	Effluent from crib.....	Slight............	.102	.014	None.	.750	39.0	2,250
Oct. 5	River water, raw......	Very slight.......	.162	.012	None.	.775	31.2	12,250
	Effluent from crib.....	Clear.............	.096	.014	None.	.825	36.8	6,336
Oct. 12	River water, raw......	Slight............	.108	.010	None.	.600	28.4	5,700
	Effluent from crib.....	Very slight.......	.118	.005	None.	.825	39.7	3,846
Oct. 19	River water, raw......	Very slight.......	.105	.012	None.	.600	27.9	90,000
	Effluent from crib.....	Very slight.......	.090	.010	None.	.675	38.0	34,560
Oct. 26	River water, raw......	Very slight.......	.078	.014	None.	.375	37.5	87,000
	Effluent from crib.....	Very slight.......	.080	.016	None.	.525	51.4	39,825
Nov. 2	River water, raw......	Clear.............	.060	.012	None.	.450	35.1	32,000
	Effluent from crib.....	Very slight.......	.084	.014	None.	.450	53.4	27,000
Nov. 9	River water, raw......	Slight............	.122	.016	None.	.525	34.5	7,800
	Effluent from crib.....	Clear.............	.088	.018	None.	.525	63.1	2,100
Nov. 16	River water, raw......	Decided..........	.266	.054	None.	1.200	18.5	15,010
	Effluent from crib.....	Clear.............	.160	.058	None.	.825	62.2	100
Nov. 23	River water, raw......	Slight............	.140	.010	None.	.675	14.4	15,700
	Effluent from crib.....	Clear.............	.068	.014	None.	.450	60.7	167

In all but one of these thirteen sets of analyses a reduction of bacterial content is noted in the effluent, varying from the 6 per cent, removed September 28, to the 93 per cent, removed November 16. The highest efficiency, 93 per cent, is not sufficiently high to warrant the use of this water as a public supply; the lowest needs no comment. Lest it may be claimed that some further reduction in bacterial content takes place in the taps the following analyses are presented to show the condition of the effluent from the crib, side by side with that of samples from the taps in Verona, supplied from this source.

Analyses of water from Hulton crib and Verona tap.

[Parts per million.]

Date.	Water analyzed.	Turbidity.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Bacteria per c.c.
1897.								
Dec. 7	Effluent	Clear	0.048	0.016	None.	0.975	68.1	48
	Verona tap	Clear	.064	.014	None.	.825	65.1	175
Jan. 4	Effluent	Clear	.044	.018	None.	.750	22.7	93
	Verona tap	Very slight	.040	.022	None.	.675	26.0	444
Jan. 18	Effluent	Clear	.040	.028	None.	.825	50.4	952
	Verona tap	Clear	.038	.026	None.	.600	52.1	323
Feb. 1	Effluent	Clear	.028	.020	None.	.750	51.8	333
	Verona tap	Clear	.032	.014	None.	.825	49.2	1,980
Feb. 16	Effluent	Clear	.040	.016	None.	.825	44.5	861
	Verona tap	Clear	.042	.010	None.	.750	49.2	130

Analyses are available through August, 1898, but it is unnecessary to quote further. It is evident that the quality of the water in the taps is sometimes improved and sometimes not. In the five cases given three show an increase in bacteria; two a decrease. If pathogenic bacilli are in the water, there is absolutely nothing to prevent this water from carrying contagion from the infected river to every tap in Verona.

Sharpsburg, Pa.—At Sharpsburg (population about 7,000), on the west side of the Allegheny, a mile below Brilliant, the supply is derived from the river through a crib 100 feet long, 8 feet wide, and 5 feet deep. It has been in use since 1893. There is about 2½ feet of river material over it, but it is tight near the top, being open on the bottom and the lower part of the sides. Timbers and openings are 6 inches wide. Low water is about 3 feet above the top of the crib. There are no analyses at hand of the raw Allegheny water at Sharpsburg, but the average analyses of the Sharpsburg effluent, taken in connection with analyses made to determine the efficiency of the Etna crib, shown below, furnish sufficient data for judgment on the supply of the former.

Average analyses of effluent from Sharpsburg crib.

[Parts per million.]

Date	Turbidity.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Bacteria per c.c.	Bacteria range in number.
1898.								
May		0.056	0.019	None.	0.375	18.9	3,710	800- 7,450
June		.124	.016	None.	.300	19.4	15,800	11,100-20,500
July		.096	.016	None.	.750	20.5	13,400	13,000-13,800
August		.085	0.19	None.	.525	22.3	25,500	18,800-32,200

Evidently, whatever may be the nature of the purification this has undergone, its efficiency in removing bacteria is not high. Disease-infected water would therefore pass through this crib without sufficiently complete loss of organisms to make it reasonably safe for drinking.

Etna, Pa.—Comparative analyses of water at Etna show similar conditions. At this point there is also a crib in the river. It is a wooden box 40 feet long, 16 feet wide, and 4 feet deep, perforated with many openings and covered to the depth of about 4 feet with stone, river gravel, and sand. The following analyses show the efficiency of the crib:

Analyses showing efficiency of Etna crib.

[Parts per million.]

Date.	Water analyzed.	Turbidity.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Bacteria per c.c.
1897.								
Sept. 7	River water, raw......	Slight............	0.222	0.028	None.	0.750	21.0	6,125
	Effluent...............	Clear.............	.126	.018	None.	.975	30.2	1,288
Sept. 21	River water, raw......	Slight............	.186	.012	None.	.600	28.0	2,625
	Effluent...............	Very slight.......	.118	.014	None.	.900	42.3	133
Sept. 28	River water, raw......	Very slight.......	.118	.024	None.	.812	22.1	5,250
	Effluent...............	Very slight.......	.098	.026	None.	.900	28.7	1,841
Oct. 5	River water, raw......	Very slight.......	.188	.014	None.	.900	29.4	7,200
	Effluent...............	Clear.............	.090	.018	None.	1.500	41.0	1,652
Oct. 12	River water, raw......	Very slight.......	.160	.032	None.	.600	32.0	28,750
	Effluent...............	Very slight.......	.148	.018	None.	.750	45.8	2,730
Oct. 19	River water, raw......	Very slight.......	.122	.022	None.	.600	46.1	27,300
	Effluent...............	Very slight.......	.096	.010	None.	1.275	48.3	13,260
Oct. 26	River water, raw......	Very slight.......	.144	.048	None.	.750	40.0	75,000
	Effluent...............	Clear.............	.056	.014	None.	.750	49.4	38,220
1898.								
June 7	River water, raw......	[a]0.3	.084	.042	None.	.300	23.8	65,800
	Effluent...............	Clear.............	.040	.006	None.	.300	51.5	5,200
June 21	River water, raw......	[a]9.0	.124	.028	None.	.150	14.0	16,400
	Effluent...............	Very slight.......	.030	.008	None.	.225	48.0	325
July 6	River water, raw......	.09	.130	.030	None.	.750	18.7	1,630
	Effluent...............	Very slight.......	.058	.016	None.	.675	44.2	1,520
Aug. 2	River water, raw......	1.8	.168	.036	None.	.450	30.0	239,000
	Effluent...............	Slight............	.068	.018	None.	.525	48.6	10,850
Aug. 16	River water, raw......	1.6	.120	.044	None.	.675	18.4	159,000
	Effluent...............	Clear.............	.070	.026	None.	.525	54.1	1,600

[a] Reciprocal scale.

These analyses indicate a higher degree of efficiency at times than has been previously noted, but they bring out strikingly the greatest drawback to crib filtration; that is, the lack of regularity in efficiency. During the summer of 1898, when the structure had been in place a year and should have shown as good results as it ever will, the efficiency is seen to vary from 98 per cent on June 21, already quoted, to less than 7 per cent on July 6. Before a city ventures to use the water of Allegheny River it should demand better assurance of purification than this.

Millvale, Pa.—At Millvale (population about 7,000), about 4 miles below Brilliant, on the western side of the river, there are two cribs, one of which is owned by the Bennett Water Company. This crib is 100 feet long, 16 feet wide, and 4 feet deep, built of 2 by 4 inch timber, and covered with stone, gravel, and sand. The flow of the current has necessitated frequent refilling to replace material washed away. At this crib the bacterial purification is so slight as to make detailed figures unnecessary. The averages are given below:

Determinations showing efficiency of Millvale crib.

1897.	Average number of bacteria in river water per c. c.	Average number of bacteria in effluent water per c. c.
August..........	4,600	7,533
September..........	3,762	4,144
October..........	69,126	41,669

That the crib had not improved much by the following August is shown by the fact that a sample of the effluent water taken August 2, 1898, showed 18,200 bacteria per cubic centimeter, and a sample taken August 16 showed 19,500 bacteria per cubic centimeter, both numbers too large to speak well for the process.

Wildwood, Pa.—A large quantity of water is pumped from the Wildwood crib, on Allegheny River, about 1½ miles above the Brilliant pumping station, to supply the town of Wilkinsburg, part of Pittsburg, and some neighboring places. The crib is in the middle of the river, 304 feet long, 32 feet wide, and 4 feet deep, built of 2 by 8 inch planks, with 2-inch open places on top and sides, and open bottom. Upon it and around it there were placed large stones to the depth of 1 foot, then 1 foot of coarse gravel, and then 3 feet of river sand. There is said to be 30 feet of gravel in the bed of the stream under the crib, which should improve the quality of the water. It was installed in June, 1897.

Analyses showing efficiency of Wildwood crib.

[Parts per million.]

Date.	Water analyzed.	Turbidity.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Bacteria per c.c.
1897.								
July 13	River water, raw	Slight	0.162	0.016	0.003	0.015	18.0	520
	Effluent	Clear	.046	.012	.001	.010	18.5	269
July 29	River water, raw	Muddy	.280	.031	None.	1.334	9.5	11,350
	Effluent	Clear	.032	.023	.005	.445	22.0	59
Aug. 4	River water, raw	Slight	.240	.030	.001	.950	11.5	1,225
	Effluent	Clear	.062	.018	.004	.592	14.5	88
Aug. 11	River water, raw	Muddy	.395	.035	None.	.814	37.5	3,600
	Effluent	Clear	.110	.024	.003	.370	21.2	50
Aug. 18	River water, raw	Slight	.268	.018	None.	.600	15.6	11,200
	Effluent	Clear	.052	.023	.003	.300	18.1	262
Aug. 24	River water, raw	Very slight	.204	.028	None.	.450	13.1	5,200
	Effluent	Clear	.060	.028	None.	.375	19.9	106
Sept. 7	River water, raw	Very slight	.122	.014	None.	.600	18.8	7,425
	Effluent	Clear	.048	.026	.001	.450	20.3	78
Sept. 14	River water, raw	Slight	.112	.012	None.	.575	21.4	300
	Effluent	Clear	.062	.018	None.	2.250	21.9	12
Sept. 21	River water, raw	Slight	.108	.028	None.	.300	26.2	825
	Effluent	Clear	.056	.012	None.	.225	21.5	160
Sept. 27	River water, raw	Slight	.118	.012	None.	.675	25.1	3,600
	Effluent	Clear	.040	.014	None.	.450	26.2	148

It is evident, taking the records pair by pair, that this crib has effected a very remarkable reduction in the organic content of the river water if the effluent really is filtered river water. On August 24 the efficiency was 98 per cent; on September 7, 99 per cent; on September 14, 96 per cent; on September 21, 80 per cent; on September 27, 96 per cent. During the month of October, 1897, it was steadily about 96 per cent. This is as high a percentage of efficiency as many mechanical filters make; but a noteworthy difference appears in the drop to 80 per cent on September 21. It is impossible to know just why this happened in the crib, whereas in the mechanical filter the difficulty could be found and remedied. In other words, the crib filter may, as in this case, give wonderfully high efficiency at times—even most of the time—but no one knows when it may fail for a brief period. Its operation is uncontrollable and uncertain, and in a stream so badly polluted with pathogenic organisms as the Allegheny the risk is too great to be taken. It is unfortunate that typhoid-fever statistics are unobtainable for this town except for 1899, when there were 5 deaths from this cause in a population of 11,886 (census of 1900), the death rate thus being 42 per 100,000.

If the efficiency previously noted were maintained, there should not be over 25 deaths per 100,000 from typhoid fever.

Summary.—The foregoing statement discusses filtering cribs operating under different conditions. Where the crib has been placed in a swift current of water its efficiency is practically too low for serious consideration; under peculiarly favorable conditions, such as those at the Wildwood crib, an amazingly high efficiency is realized for a time. The mass of data compiled as to the operation of slow sand filters shows that in time, whether it be one, two, or three years, the filtering sand and gravel must either become so much clogged as to diminish seriously the supply, or the bacteria caught by the particles of sand must pass farther and farther into the mass until the effluent is no longer pure enough to drink. It is possible to remove the polluted sand from a sand filter and allow the filtering action to begin over again on fresh material, but no such removal can occur in the case of a crib except through the scouring of the river bed in time of flood, etc., a very irregular and uncertain agency. The important point is that such a mode of filtration is beyond control by ordinary means and is only properly efficient when favorable conditions happen to be met more by good fortune than by anything else.

The inefficiency of the cribs at Allegheny and Pittsburg is well known. The city of Allegheny installed a crib in Allegheny River in 1897 at an immense cost. The inefficiency of this structure in filtering the polluted water may be seen from the following figures showing typhoid-fever mortality:

Deaths per 100,000 from typhoid fever at Allegheny, Pa., 1898–1902.

Year.	Deaths.	Year.	Deaths.
1898	38	1901	101
1899	107	1902	120
1900	93		

For Pittsburg, filter cribs in Monongahela River supplying the South Side and six boroughs of the city gave the following results:

Deaths per 100,000 from typhoid fever at Pittsburg, Pa., 1898–1903.

Year.	Deaths.	Year.	Deaths.
1898	71	1901	125
1899	110	1902	144
1900	144	1903	139

These figures are worse than Allegheny's. It is evident that the water supplied to these consumers was totally unpurified, so far as disease bacteria are concerned.

At Sharpsburg the figures are few, but sufficient to show a general infection every year. In 1895 there were 47 cases, with 4 deaths; in 1898, 33 cases, with 7 deaths; in 1899, 57 cases, with 6 deaths out of a total mortality of 72, or $8\frac{1}{3}$ per cent. In 1902 there were 73 cases. As the population of the town is only about 7,000, the above figures have startling significance. Evidently in 1902 one person in every hundred had typhoid fever, many of them probably through drinking the polluted river water.

The foregoing discussion of crib filtration has reviewed figures showing bacterial purification and typhoid-fever mortality derived from absolutely reliable sources for several cities. In every case it has been shown that crib filtration, no matter how excellent the results may be at times, is absolutely unreliable as a means of ameliorating a public water supply.

FILTER WELLS.

General discussion.—The third method of natural filtration is by wells sunk in river sand and gravel, varying in diameter from a few inches to 20 or 30 feet, and so constructed as to allow the polluted river water to seep through its own bed into the well. As has been already stated, this method of filtration produces a water of excellent appearance, but the data given relating to filter cribs and filter galleries show that there can be no real purification of the water by this means. It has seemed to be very possible that efficient filtration could be obtained by a modification of this plan where local conditions are favorable, as in some islands in Ohio River. If wells are drilled to a moderate depth on some of these islands of clean river sand, through which the water may percolate before entering the wells, very efficient purification ought to be secured until the outer layers of sand become clogged. The frequent scourings to which these islands are subject by the rise and fall of the river as well as by its strong current should be favorable to the periodical removal of the clogged layers. The idea is not new.

M. Leforte, Ingenieur des Ponts et Chaussees, engaged in improving the water supply of the city of Nantes, proposed a dozen years ago to secure artificially the most favorable conditions for natural filtration by creating at many places in the bed of the Loire, a little above the city, islets of fine sand, in the middle of which were established wells provided with suitable works for their control, from which water was to be taken. Notwithstanding a satisfactory trial of the process it was not applied.[a]

The same procedure was suggested by M. Janet, engineer of mines, who recommended that water be pumped from the Seine and the Oise to the summits of sandy hills at Montmorency, Fontainebleau, etc., and allowed to percolate to the bottom of the sand to be collected, thus making use of a natural filter over 50 meters thick.

Gallipolis, Ohio.—It has remained for an American municipality to apply this plan and to demonstrate its ultimate inefficiency. The city of Gallipolis, Ohio (population about 6,000), gets its water supply from filter wells drilled on an island in the Ohio River. The records of typhoid fever mortality show a wonderful temporary efficiency, not a single death from this cause being reported during two years, at the end of which former conditions recurred.

Typhoid mortality at Gallipolis, Ohio.

Year.	Total deaths.	Typhoid deaths.	Year.	Total deaths.	Typhoid deaths.
1897	116	2	1901	57	0
1898	146	3	1902	83	8
1899	101	7	1903	65	4
1900	64	0			

Evidently if the decrease in deaths is to be ascribed to the filtration of Ohio River water through this river sand the return to the epidemic conditions shown in 1902 and 1903 must have had a similar origin. It is probable that the pathogenic organisms carried in the river water have grown completely through the sand, so that even the scouring of the top does not carry away all the polluted sand. The experiment shows the uncontrollable character of such a purification scheme.

Similar supplies exist at Moundsville, W. Va., and Point Pleasant, W. Va., both described later in this paper (pp. 87, 92–93).

CONCLUSION.

Every form of natural filtration so far attempted has been unsuccessful except the rather rare type last described, and that was successful only for a time. At many other places which could be cited the death rate shows that these devices have no efficiency in removing bacteria from polluted water, so that towns which attempt to purify water by natural filtration are likely to spend more money annually in avoiding epidemics of water-borne diseases than many times the interest on the cost of an efficient sand-filtration plant.

[a] Trans. Am. Soc. Civil Eng., vol. 54, Pt. D, p. 184.

SELF-PURIFICATION.

OXIDATION, DILUTION, AND SEDIMENTATION.

The conditions on the Monongahela (see pp. 54–55) show the existence of sources of pollution sufficient to make the river water unsafe as a source of public supply without purification, unless complete self-purification takes place in the river. If Professor Sedgwick is correct in his conclusion[a] that the population of the Allegheny basin scattered along the main stream and its tributaries is practically equivalent under present conditions to an equal population massed at the lowest point considered, then the same conclusion applies to the more concentrated population of the Monongahela basin with drainage slopes as far down as Greensboro steeper than those of the Allegheny. It would seem, then, that the contamination in Monongahela River from above Point Marion is probably equivalent to that of a city of 25,000 or 30,000 population located at Point Marion, and the question arises whether complete self-purification takes place below that point.

From a drainage area of 11,400 square miles Allegheny River discharges, as is shown by official measurements made by the U. S. Geological Survey, from 1,312 cubic feet per second (September, 1903) to 40,000 cubic feet per second or more at flood stages. Monongahela River has a drainage area of 7,625 miles, 67 per cent of that of Allegheny. Its discharge can not be given with accuracy since few figures are available. The discharge of the Youghiogheny at Ohiopyle, Pa., measured by Kenneth Allen in 1892, was 106 cubic feet per second at a very dry time; Indian Creek, entering some miles below, usually carries 50 to 100 feet per second, but has been known to go as low as 12 cubic feet per second in periods of extreme drought. The table herewith shows the flow of Indian Creek as computed by the Geological Survey[b] from data furnished by Charles H. Knight, Rome, N. Y., in 1893.

Estimated mean flow of Indian Creek from August, 1892, to July, 1893.

	Sec.-ft.		Sec.-ft.
August	31.4	February	659.0
September	15.2	March	290.5
October	12.6	April	278.0
November	48.8	May	523.3
December	102.8	June	41.3
January	193.5	July	13.1

The table giving the discharge of Cheat River shows that that stream at times carries less than 200 cubic feet per second. In October, when Indian Creek is at its lowest, Cheat River carries about 700 cubic feet per second. It may be roughly estimated that Cheat River, Indian Creek, and Youghiogheny River together contribute about 825 cubic feet per second to the Monongahela in the fall. The discharge of Tygart and West Fork rivers aggregates about 75 cubic feet per second. No figures are available for these streams, and this is merely a rough estimate based on experience in measuring similar streams. Altogether the Monongahela may be said to carry about 900 cubic feet per second in the fall, or about two-thirds the volume of Allegheny River at that time. The flood flow of the Monongahela is considerably over 40,000 cubic feet per second, or about the same as that of the Allegheny. The facts about the Monongahela are therefore as follows:

1. The drainage area of Monongahela River is 67 per cent of that of the Allegheny, and its discharge is about 70 per cent of that of the latter.
2. The flood discharge is nearly the same for the two streams.
3. As far down as Greensboro the Monongahela drainage area is rugged, the soil lacks fertility and therefore absorbs very little storm water, and the run-off is rapid.
4. The region is practically deforested.

These facts indicate that the Monongahela, as far down as Greensboro, is by far the quicker

[a] Rept. Pittsburg Filt. Com., p. 20.
[b] Water Sup. and Irr. Paper No. 65, U. S. Geological Survey.

spilling of the two streams, and as it has at its headwaters about the same population per square mile of drainage area it will deliver as much pollution to any point above Greensboro in the same time or less.

From Greensboro to Pittsburg, a distance of approximately 80 miles, the Monongahela has a fall of about 72 feet, or about 0.9 foot to the mile. This is so little compared to that above Greensboro that evidently it is on the conditions prevailing in this stretch of the stream that self-purification of the stream will depend. The element of time is of the greatest importance in this process. If the rate of flow of the water is so low as to detain pollution a long time, then the river will be practically a long, narrow reservoir, affording conditions more or less favorable for self-purification. But the rate of flow depends on slope, cross section, and quantity of water. The slope of the Allegheny from the mouth of Clarion River to Pittsburg, a distance of approximately 85 miles, is about 1.95 feet to the mile. The lower slope of Monongahela River would tend to lessen the velocity of the water and lengthen the period of detention. The latter may be said to be inversely proportional to the rapidity of flow, or

$$\text{Detention} = \frac{1}{V}, \quad \text{where } V = c\sqrt{rs}$$

the Chezy formula usually employed in computation of flow in open channels. If fairly accurate data were obtainable for cross sections of the two streams at numerous points, the formula could be used to express numerically the degree of detention, and hence the degree of self-purification going on in a given stream. In this case the lack of such data is complicated by the fact that the Monongahela is so completely canalized below Greensboro as to make the slope above calculated valueless for this discussion, as the fall of each slack-water basin is practically zero. At low water, therefore, the velocity of the water is so very slight as to give an enormously high value for detention in the proposed formula, pointing to an infinitely high degree of purification. For streams not canalized the degree of self-purification would seem to be directly determinable.

If pollution be supposed to enter the Monongahela at Greensboro only and all sources of contamination below that point to be eliminated, the degree of self-purification going on in the 80 miles under discussion is so high that it is conceivable that the water might be completely purified. But it is not at all certain that this is the case. It is now agreed by sanitarians that the process of self-purification can hardly be complete and perfect, and that therefore it can not be depended upon as sufficient in itself to assure a pure supply.

The main factors in self-purification are evidently oxidation, dilution, and sedimentation, and for the last the term "detention" is proposed as more properly expressing the time element necessary. As far as oxygen is concerned it has long been known that the typhoid bacillus, the very organism it is desired to eliminate from water, "grows most abundantly in the presence of free oxygen," though "it may also develop in its absence."[a] It is well known to bacteriologists that "the great majority of pathogenic bacteria are facultative anaërobes"[b]—that is, they may develop with or without oxygen. As to dilution of sewage, Professor Sedgwick believes that 1 gallon of sewage dumped into Illinois River might cause trouble in the water supplies below. Without going to this extreme, it is perfectly evident that no lines can be drawn between "sufficient" and "insufficient" dilution. It takes little sewage, compared to the volume of the stream, to cause an offensive appearance. Very little is necessary to poison the water for drinking. The question resolves itself into one of the vitality of pathogenic organisms in water, a question discussed later in this paper.

The exact amount of self-purification due to sedimentation can not be stated positively. Turbidity has a great influence on purification by sedimentation, for turbid water contains many heavy particles which settle to the bottom, entangling and carrying with them great numbers of bacteria as they go down. Long detention, therefore, will cause turbid water to become not only clearer, but remarkably better in quality, by causing the greater part of the pollution to settle to the bottom. In running water sedimentation can not occur to any great degree unless the current is retarded by obstacles, natural or otherwise, which convert

[a] Sternberg, Bact., 1896, p. 358

[b] Muir and Ritchie, Bact., 1899, p. 23.

the river into a chain of pools, and the greater the number of pools or reaches on the river and the closer together they are the more will self-purification be assisted.

The mill pond at Lowell, Mass., is 16 miles long. The well-known epidemic of typhoid fever at this place was traced to déjecta, principally from one patient, which entered a large brook from an overhanging outhouse, was delivered into the Merrimac, and reached the intake of the waterworks. At Lawrence, Mass., an equally well-known epidemic was caused by contaminated water which had been kept in the storage reservoir two weeks, with excellent opportunity for sedimentation. At Covington, Ky., the badly polluted water of Ohio River is kept at times as long as thirty-two days, yet Covington suffers severely from typhoid fever. At New Albany, Ind., the water supplied to the city is stored for a month before it is used, yet there is much typhoid fever.[a] These instances show that sedimentation alone, under the best conditions, does not make contaminated water safe. Settling basins alone are not an efficient and adequate means of purifying the sewage discharged into a stream.

Decisive evidence on this head is supplied by the schematic representation made for the Report of Streams Examination for the Sanitary District of Chicago, showing the belief of some water bacteriologists that the polluted water from Chicago is completely purified by the time it reaches Averyville. The drawing shows pollution in heavy black shading; lightening as the purification goes on, proceeding down the river. The pollution is heaviest at Chicago and gradually thins out until it reaches Averyville, when it disappears, to be renewed presently by the sewage of Peoria. This diagram is the result, presented in graphic form, of numerous bacteriological analyses of the river water by the commission. The distance from Chicago to Henry, where the sewage has very largely disappeared, is about 114 miles; from Chicago to Averyville, where apparently it has wholly disappeared, about 142 miles; from Peoria, with its heavy pollution, to Kampsville, where it is claimed that that pollution has disappeared, about 150 miles. Therefore, without going into the merits of the Chicago-St. Louis controversy at all, it may be said that both parties agree that within about 100 miles of the source of pollution self-purification is so incomplete that contamination is recognizable, and that the infection of a stream of the character of the Illinois by the sewage of Chicago may be dangerous to the health of communities using the infected water raw within that distance.

Conditions on one stream can not be exactly like those on another. Illinois River, carrying the sewage of an immense population, is not in any respect exactly like the Monongahela. Yet a comparison of the two streams brings out similarities. The discharge of the Monongahela has been computed at roughly 900 cubic feet per second or 54,000 cubic feet per minute. That of Illinois River at Peoria at the same season of the same year, in September, 1903, was about 15,000 cubic feet per second or 900,000 cubic feet per minute. The population of the Monongahela drainage area above and including McKeesport may be assumed at about 134,000. That of the Illinois River drainage area above Peoria would probably be at least 2,250,000. These figures show the proportion—

$$54{,}000 : 134{,}000 :: 900{,}000 : x, \text{ whence}$$
$$x = 2{,}233{,}000,$$

almost exactly the population of the Illinois drainage area. The volumes of the two streams therefore, even allowing for errors in estimating, are practically directly proportional to the population served. There are numerous lakes and sluggish reaches on Illinois River where the fall is practically zero, so that there is probably as much opportunity for self-purification by detention in that stream as in any. It is unnecessary to enter into further details. It is evident that the uncertainty of self-purification on over 100 miles of Illinois River applies with great force to the conditions on the Monongahela, notwithstanding the difference in population.

The history of epidemics has repeatedly shown that it is not necessarily an extensive outbreak of typhoid that starts another below it, but that one or two cases may infect a large population. A few instances will be given. The typhoid-fever epidemic at Lowell, pre-

[a] Sedgwick, W. T., Test., Chicago Drain. Com. vol. 3

viously referred to, was traced to contamination from but one or two cases. The New Haven epidemic was caused by dejecta from typhoid-fever patients in one family passing into the water-supply reservoir. In the Windsor epidemic infection was washed by ordinary rains into a small thread of a stream and thence into a larger brook, which delivered it into the reservoir. The epidemic at Ithaca, which attracted so much attention, was due to the washing into the city supply of fecal matter deposited on the watershed. Scores of similar cases could be cited. The smaller population of the Monongahela is therefore no bar to the spread of typhoid fever by the use of the raw water. The industries along the river employ many foreign laborers—ignorant, uneducated, and of uncleanly habits—whose dejecta all go into the stream. This fact is well known, and the sole protection of the communities using the water has been the germicidal effect of detention in the chain of slack-water basins that constitute the lower Monongahela. It is clear that such purification is not certain nor perfect, and that there is grave risk in using this water raw.

The foregoing discussion started from the tentative assumption that no pollution enters the Monongahela below Greensboro, and it has been shown that contamination introduced at that point may live to reach the mouth of the river. As a matter of fact, however, fresh and dangerous sewage pollution enters the stream at hundreds of places below Greensboro, sometimes in enormous quantity. The real efficiency of the detention going on in the 80 miles of slack water is therefore measured by the efficiency of the last basin receiving pollution or the last basin on the river. The above discussion makes it evident that such a basin, even several miles long, can not be relied upon to completely purify polluted water.

Nor should it be forgotten that to settle the bacilli to the bottom of the basin is by no means to get rid of them. If by any means the mass of corruption at the bottom is disturbed, there is nothing to prevent it from being returned to the stream to be carried down to breed disease in towns below. This has been shown by the typhoid epidemic at Detroit, which resulted from the disturbance of sewage deposits in the bed of Black River at Port Huron. This caused sediment to be carried down St. Clair River through St. Clair Lake into the intake of the waterworks.[a] Professor Sedgwick well sums up the situation as follows:

> Dams undoubtedly so far as they produce slack water or quiescence favor purification and the disappearance of disease germs for the time being; but if the sediment or sludge is allowed to remain in the bottom of the stream and not removed artificially or taken out and put off out of a position of danger the chances are good, as experience shows, that in freshets it may be returned to the stream again, become a part of it, travel with it, and produce trouble below. That was the case at Newburyport. * * * The Merrimac is often a series of mill ponds or a series of quiet lakes in which sedimentation goes on nicely, and the water shows great purification at such times, but just as soon as a thunder shower comes [scouring takes place with the rise of the stream].

In other words, detention while undoubtedly of very great value in many cases does not and can not take the place of steady and regular purification of the stream by such a process as sand filtration, so that however great may be the improvement by detention the detained water must always be regarded with suspicion and once polluted can not be considered perfectly safe for drinking without being filtered.

It can not be held that the greater dilution of sewage in the Monongahela in times of flood is of assistance in purification. In the first place it is sufficiently evident that mere dilution can not be a complete safeguard. In the second place all the beneficial effects of detention gained by the slow current in the river may be nullified by a slight increase in velocity.

> The addition of such a volume of liquid as passes through the Drainage Canal must often materially quicken the flow of the Illinois River. It must, therefore, hinder effective sedimentation, and by thus shortening the time required for infectious germs to pass through the river and by interfering with their detention aggravate the danger of their arrival at the mouth of the river. * * * The time allowed in these matters is very important, so that any quickening of flow is a grave consideration.[a]

How much more grave becomes the interference with purification when a stream like the Monongahela rises within a few days, as it did twice in March, 1905, from about 9,000 cubic

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[a] Sedgwick, W. T., Test, Chicago Com., vol. 3.

feet per second to over 40,000 cubic feet per second, or from 540,000 cubic feet per minute, about six-tenths of the discharge of Illinois River at Peoria, to over 2,400,000 cubic feet per minute, nearly three times the discharge of the Illinois. This enormous increase in volume is bound to wash out the great mass of pollution that has accumulated at the bottom, which will be carried downstream into the water supply of every city that uses the river water raw. Any increase in the speed of the current increases the liability to the spread of typhoid fever under the conditions given.

ACID MINE DRAINAGE.

There remains for discussion the theory held by some persons that the mine wastes that enter Monongahela River along much of its course containing much acid are sufficiently germicidal in their effects to insure reasonable safety in the use of this water in its raw state. This conclusion is not warranted by the facts.

The mine wastes present in this stream enter principally in the form of ferrous sulphate, though free sulphuric acid is sometimes distinguishable. The lime content of the stream is considerable, and this, together with the free acid and sulphate of iron, evidently brings about a coagulation and sedimentation which also drags down the organic impurities. This action is similar to that of the coagulating processes used extensively in mechanical filter plants as a preliminary to filtration. As is shown by the tables given below, this process is useful in clearing a muddy or highly colored water, such as that of Mississippi River; but it is the practically unanimous opinion of engineers that such purification, although exceedingly valuable in many cases and indispensable in some, can be regarded only as a preparation of the water for filtration and is by no means as adequate in itself to assure its safety for drinking.

The treatment of the St. Louis water supply by this process has attracted attention, and is regarded by local authorities as sufficient to safeguard the public health. Doctor Snodgrass, city bacteriologist of St. Louis, admitted before the American Public Health Association, in 1905, that the chemicals are added for coagulating purposes only, and that the completion of the process of purification must be accomplished by filtration. This treatment of contaminated water for use as a source of city supply, without filtration, can be regarded only as a device for diminishing danger, not as a means of abolishing it. "It does not provide pure water for the city. It is simply a makeshift."[a]

Its percentage of efficiency in removing bacteria seems at first glance very high, as is shown in the table herewith:

Efficiency of coagulation at St. Louis waterworks in removing bacteria.

Week commencing—	Number of bacteria in river water.	Number of bacteria in outlet water.	Number of bacteria in tap water.	Percentage of bacteria removed between river intake and outlet.	Percentage of bacteria removed between river intake and tap.
1904.					
March 28	19,000	8,700	937	55	91
April 1	187,500	....	9,200	....	95
April 22	34,000	8,225	1,550	76	95.5
April 29	136,500	2,850	3,950	98	97
May 6	22,500	1,800	550	92	98
May 13	103,500	37,500	16,250	64	85
May 27	45,000	600	750	99	98
June 3	30,000	3,500	600	89	98
June 10	24,000	1,100	2,000	95.5	92
June 17	16,000	550	500	97	97
June 24	38,000	1,600	650	96	98
July 15	26,000	4,300	323	84	98.8

[a] Weston, Am. Pub. Health, XXX.

Efficiency of coagulation at St. Louis waterworks in removing bacteria—Continued.

Week commencing—	Number of bacteria in river water.	Number of bacteria in outlet water.	Number of bacteria in tap water.	Percentage of bacteria removed between river intake and outlet.	Percentage of bacteria removed between river intake and tap.
1904.					
August 12	27,000	2,500	1,100	91	96
August 15	14,000	3,200	1,550	77	89
August 19	10,575	450	590	96	94.5
August 26	9,150	300	30	97	99.6
September 2	2,100	200	20	91	99
September 9	17,750	....	75	....	99.6
September 16	11,275	4,550	600	60	95
September 23	14,375	300	375	98	97.5
September 30	25,475	300	55	99	99.8
November 18	8,125	300	950	97	89
November 25	40,000	6,100	1,000	85	76
Average	....	....	....	87.4	94.7

The efficiency of a purification system may very justly be held to be the lowest percentage of removal of bacteria that it accomplishes. On this basis the efficiency of this system would be low indeed, sometimes going down to 76 per cent, and apparently not under such influences as can be controlled or regulated. The average removal of bacteria at the outlet of the sedimentation reservoirs is 79 per cent, and in the city taps is 94 per cent. If the latter figure be accepted as the regular daily performance of the process, it can not be considered thorough enough to warrant the use of the treated water without filtration. Effective sand filtration will remove over 99 per cent of the bacterial contents of polluted waters. The difference—about 5 per cent—may mean a great deal if the original bacterial content of the water be high and the sources of pollution not far removed. The experience of Lawrence, Mass., is significant. At this city 93 or 94 per cent of the total number of the bacilli in the polluted Merrimac River water were removed by storage in the city reservoir. Nevertheless typhoid-fever epidemics recurred year after year, showing that enough pollution was left to spread disease. The death rate from typhoid fever in this city is now one of the lowest in Massachusetts, with the filters removing 99 per cent of the pollution. The difference of 5 per cent there was evidently the difference between a poisoned supply and a healthful one.[a]

The treatment at St. Louis is made with great care, under the best conditions, calculated quantities of chemicals being added to the water, which is sedimented in basins not exposed to uncontrolled or irregular variations in depth, wind action, velocity of flow, quantity of water, etc. Nevertheless, as shown above, the degree of purification is not sufficient to make a water so treated safe without subsequent filtration.

How much efficiency, in the face of the above evidence, can be claimed for the coagulating process going on in the Monongahela River, with every element of the problem dependent on chance? Even if the process were carried on under the most favorable conditions purification could not be expected in the Monongahela water, because the chemicals are not present in sufficient amount. At St. Louis, iron is added to the water at the rate of from one-half to three grains per gallon. The minimum rate, one-half grain, is equivalent to 8½ parts per million of iron, which is necessary to purify the water in the partial degree already described; the water of the Monongahela River generally contains less than one part per million of iron, and seldom more than four.[b]

[a] Clark, H. W., Am. Pub. Health, XXX.
[b] Rept. Pittsburg Filtration Com., Analyses, p. 271.

The possibility that there is enough free acid in the water to destroy pathogenic bacteria is worthy of consideration.

The experiments made by various workers to determine the germicidal efficacy of sulphuric acid have been sufficiently numerous and extended to permit definite conclusions on the question to be formed. Many years ago Koch[a] first announced that the cholera bacillus was fatally affected by acid solutions. Subsequently, Kitasato[b] showed that cholera bacilli are destroyed in a few hours by hydrochloric and sulphuric acids. Davaine[c] had shown that the bacilli of anthrax are destroyed by sulphuric acid in the proportion of 1 to 5,000 and that the bacilli of septicemia are destroyed by the acid in the strength of 1 to 1,500. In Sternberg's experiments of 1885 it was shown that the multiplication of putrefactive bacteria was prevented by the presence in a culture solution of sulphuric acid in the strength of 1 to 800, and the micrococci of pus were destroyed in two hours by the presence of the acid in a solution of 1 to 200. The work of Boer, quoted by Sternberg,[d] showed the germicidal effect of sulphuric acid on the following organisms:

The anthrax bacillus was destroyed in two hours in a solution of 1 to 1,300.

The diphtheria bacillus was destroyed in two hours by a solution of 1 to 500.

The typhoid bacillus was destroyed by a solution of 1 to 1,550.

The spirillum of Asiatic cholera was destroyed in two hours by a solution of 1 to 1,300.

Stutzer showed[e] a solution of 0.05 per cent of sulphuric acid was fatal to cholera bacilli in fifteen minutes. A weaker solution (0.02 per cent) took twenty-four hours to kill the organisms, while a 0.03 per cent solution failed to kill the bacteria in five hours. As a result of his experiments, he estimates that 100 kilos of sulphuric acid at 60° Beaumé would disinfect 40,000 liters of water, a strength of 1:400, or 1 pound of acid to 40 gallons of water.[f] In the same year Doctor Ivanhoff showed[g] that a 0.04 per cent solution of sulphuric acid destroys cholera bacilli in Berlin sewage and an 0.08 per cent solution destroys the organisms in Potsdam sewage. Rohe showed that sulphuric acid in a proportion of 1 to 800 is antiseptic in some cases. He does not believe, however, that it can be depended upon as a general antiseptic.[h] The experiments of Kitasato quoted by Rideal[e] show that in a 0.049 per cent solution of sulphuric acid there is growth of bacteria; in a 0.065 per cent solution growth is restrained; in a 0.08 per cent solution growth cases. The experiments of Rideal and Parkes in 1900, to devise a portable disinfectant for use by soldiers in purifying drinking water, showed that chemically pure sulphuric acid diluted in the proportion of 20 minims to the pint of infected water reduced the number of bacilli in fifteen minutes and killed them in forty-five minutes. The amount of water used was 750 cubic centimeters, which was infected with 1 drop of a twenty-four-hour 37-degree broth culture of bacillus typhosus. Further, 100 cubic centimeters of boiled water infected with 1 cubic centimeter of the same culture gave the following results, the plus (+) sign indicating the presence of the organisms, the minus (=) sign their absence:

Effects of sulphuric acid on bacilli.

Minims per pint of infected water.	Results.					
	7½ minutes.	15 minutes.	30 minutes.	45 minutes.	60 minutes.	2 hours.
20	+	+	+	+	−	−
15	....	....	+	+	+	−
10	....	....	....	+	+	+

[a] Virus de Septicémie; Gas. Med., Jan. 10, 1874.
[b] Quoted in Sternberg, Bact., 1896.
[c] Bact., 1896.
[d] Zeit. für Hyg., 1893, p. 116, quoted by Rideal.
[e] Disinfection and Preservation of Food, 1903, p. 375.
[f] The English imperial gallon is equivalent to 10 pounds.
[g] Zeit. für Hyg., 1893, p. 86.
[h] Hyg., 1890, p. 357.

The largest amount used, 20 minims to the pint, or 1:384, about 2,600 parts per million, would take an hour to kill typhoid bacilli under conditions closely resembling the actual conditions.

The most important of all experiments of this kind, perhaps, and those which apply most closely to the problem under discussion, were those made by Rideal to determine the vitality of the typhoid organism. Typhoid-fever bacilli were introduced into impure water, which was kept at room temperature, with the following results:

Effect of sulphuric acid on typhoid fever bacilli.

Strength of solution.	Time of exposure.	Results.
Per cent.	*Hours.*	
0.025	20	Killed.
.030	½	Alive.
.030	20	Alive.
.030	½	Killed.
.035	½	Killed.

All these experiments show conclusively that sulphuric acid can and does kill organisms in water, but the question remains, How far are these facts applicable to the problem of the purification of the water in Youghiogheny River?

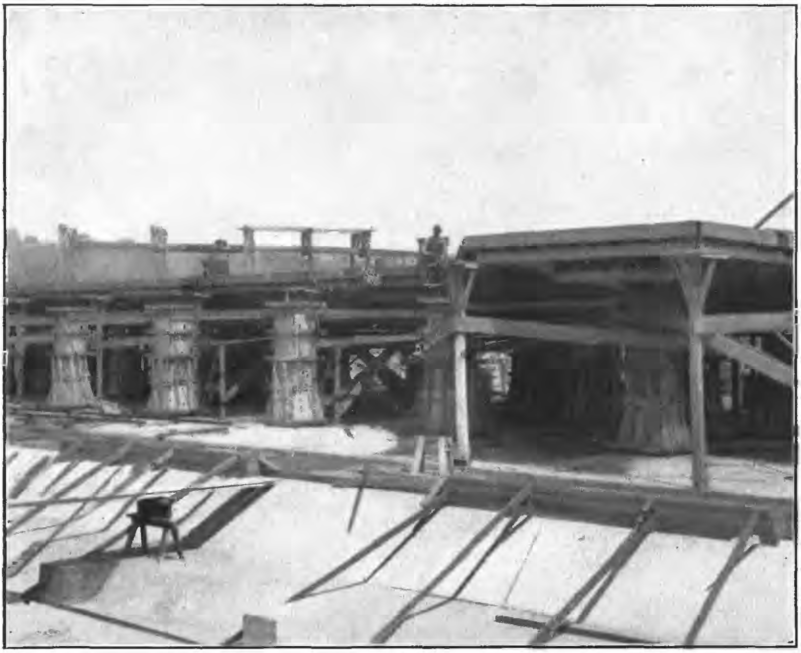
Certain conditions in the problem under discussion show that the action of the acid is valueless as a means of purification.

1. There is never sufficient acid to do the work.

2. It is impossible to apply the acid in constant quantity, owing to the wide variation in the flow both of the stream and the acid, the former being subject to wide and rapid variation, while the flow of acid may be as high as 30 or 40 parts per million at some periods and may cease altogether at others, as shown by the analyses.

Rideal's experiments show that a 0.025 per cent sulphuric-acid solution, equivalent to 250 parts per million, requires 20 hours exposure in impure water at room temperature to kill typhoid bacilli, while a solution of 350 parts per million (0.035 per cent) will kill the organisms in half an hour. There is never so much sulphuric acid in the water of Monongahela or Youghiogheny rivers. As shown above, at one time, in August, 1905, the amount was so small as to be undistinguishable by field-assay methods which readily distinguish a slight trace, amounting possibly to one-fiftieth part per million. The analyses made for the city of McKeesport, referred to above, show 44 parts per million of the acid uniformly distributed through the body of the stream and never as many as 100 parts per million, except possibly at isolated points immediately below the outflow of mines. It is clear, therefore, that although sulphuric acid is a germicidal agent under favorable conditions, such conditions do not and can not exist in the rivers under discussion, and the acid can not be counted on to purify them of sewage bacteria. Even if there were more acid present, it is to be remembered that its strength is not entirely available for the elimination of pathogenic bacteria. "A chemical disinfectant will frequently combine almost instantly with organic or other matters present in sewage, thereby becoming partially or entirely inert before it has time to attack the bacteria."[a] If 200 or 300 parts per million of sulphuric acid were being poured into the river, there is so much lime and other alkaline material present that the greater part of the acid would immediately combine with these to form merely a neutral sulphate instead of persisting as a free germicide. This difficulty has long been encountered in the various attempts made to chemically sterilize sewage. Sulphates are not germicidal at all, and only moderately antiseptic; the difference, be it

[a] Rideal, S. S., Disinfection and Preservation of Food. New York, J. Wiley & Sons, 1903.



A

B

PITTSBURG FILTER PLANT.

A, Collecting galleries; *B*, main conduit.

said, for nontechnical readers, being that an antiseptic will restrain or check the growth of bacteria while germicides kill them. Though the recent notable study of copper sulphate as a disinfectant of water supplies by Moore and Kellerman and others[a] has shown that under some conditions it is destructive to certain forms of bacteria, the sulphates of lime and magnesia actually encourage the growth of some organisms, while the sulphates of iron depend for their antiseptic power not on the acid but on the metallic base present; and this is probably the effective agent in the copper sulphate. Miquel classed iron sulphates as moderately antiseptic; finding that 11 grams per liter, which is equivalent to 1.1 per cent, were required to prevent the putrefaction of beef juice—that is, to prevent the growth of putrefactive bacteria in a food medium. Certainly no such enormous proportion of iron sulphate (11,000 parts per million) is ever present in the river water.

The people who have been using this water on the assumption that it is free from dangerous pollution have been relying principally on the statement, made by certain persons and repeated by others without investigation, that sulphuric acid is a germicide and that there is enough of it in the stream to purify the Youghiogheny River water. In depending on the antiseptic action of sulphuric acid to kill pathogenic organisms in Youghiogheny River water, the people of McKeesport and other cities drinking such water are making a mistake which has cost many lives and many thousands of dollars annually.

PUBLIC WATER SUPPLY AT PITTSBURG, PA.

The attention of sanitarians has for years been focussed on Pittsburg, on account of the notoriously high death rate from typhoid fever in that city. The Pittsburg Filtration Commission of 1897 so thoroughly investigated the questions of the pollution of the present sources of supply and of the possible sources of pure water as to make extended remark on this subject quite unnecessary here. The preceding discussion of the quality of water and drainage on both watersheds supplying this city should be sufficient to show the character of the supply. It is drawn directly from the running streams, without attempt at purification, to reservoirs too small to permit sedimentation for periods longer than a few days, after which the water enters the mains. The Filtration Commission showed the necessity for immediate and thorough filtration of the water if the typhoid death rate is to be in any great degree diminished, taking up the Allegheny River watershed in detail.

The filtration plant now in course of erection under the superintendence of Mr. Morris Knowles contemplates the use of Allegheny River water after sand filtration of the most thorough description. The plant is located on the river at Aspinwall, about 5 miles north of Pittsburg, nearly opposite the Brilliant pumping station. The new pumps on the Aspinwall side will pump the river water into sedimentation basins, two in number, at the upper edge of the site, whence the somewhat clarified water will enter the central chamber and proceed to the filter beds, of which there will be 50 or more, as the needs of the town may require. Although some difficulty is being encountered with soft ground, necessitating the driving of concrete piles, and with the building out of the river bank, for which gravel is being dredged from the river, the bank being faced with firmly anchored concrete blocks, the work is proceeding rapidly, a few of the filter units being already finished. Pl. IV shows sections of the work under way. The vaulting and floors of the filter beds are of standard construction in essential features. A noteworthy detail is the filter gallery between beds, a concrete passage where the purified water as it leaves the filters will be caught and carried toward the river, where it will be taken up by the Brilliant pumps and drawn across the stream. The line in the bed of the stream is in process of construction, a cofferdam being built out from the ends of the pure-water pipes to the Brilliant side. On the Aspinwall side the two pure-water pipes have been so constricted as to form two huge Venturi meters for the measurement of the pure water supplied from the filters. The view of the main conduit running along the upper side of the beds shows a small portion completed and the grade blocks set ready for further construction. When completed the plant

[a] Jour. New England W. W. Assoc., 1905.

should be one of the finest in America, and will probably add a very important chapter to the history of decrease in typhoid fever with filtration of a polluted supply.

The quality of these river waters at Pittsburg is shown by the field assays of the two streams and of Ohio River below their confluence:

Field assays of water at Pittsburg.

[Parts per million.]

Determination.	Allegheny River at Pittsburg.	Monongahela River at Pittsburg.	Monongahela River at Carnegie (tap).	Ohio River at Pittsburg.
Turbidity (SiO_2)	0	....	Cloudy.	55
Color	106	70	35	122
Iron (Fe)	1	1.5	1.5	2
Calcium (Ca)	42	65	90	56
Total hardness (as $CaCO_3$)	26.5	61	85	61
Alkalinity	51.4	23	22.6	47.4
Sulphates (SO_3)	[a]15	84	83	[a]20
Chlorides (Cl)	10.7	16	10.3	26

[a] Estimated.

It is notable that though the two Monongahela samples are practically identical in iron, sulphur trioxide, and alkalinity contents, the three factors which best show the effect of mine drainage, the Carnegie water has a little more calcium, with a consequent increase in total hardness. This is probably due in part to the absorption of calcium from the reservoir at Carnegie, in part to the possible admixture of limestone spring water. The South Pittsburg Water Company, which pumps from Monongahela River, supplies the South Side, several wards of the city proper, and many thousands of people along the line out to Carnegie.

The turbidities given in the Allegheny and Monongahela assays are only approximate, the water being slightly cloudy in both cases. The turbidity given for the Ohio River water, however, is the result of careful measurement with the turbidity rod, and shows a significant increase in suspended matter.

OHIO RIVER BASIN BETWEEN PITTSBURG, PA., AND BIG SANDY RIVER.[a]

GENERAL STATEMENT.

With the sewage of half a million people entering the stream, besides an enormous amount of drainage from mills and factories, as well as a great quantity of material dumped into the stream from the numerous craft plying in the three rivers at this point, Ohio River below Pittsburg is to all intents and purposes an open sewer. The increase in color downstream tends to strengthen this view, as does the increase in iron content, though the effect of the dilution by Allegheny River is to lessen the amount of sulphur trioxide in the water. The calcium content is practically an average of that of the two streams. The chlorides are so much higher than those of either the Allegheny or the Monongahela that they are undoubtedly traceable in part to the enormous sewage contamination. Bearing in mind the conclusions already reached with respect to the quick-spilling character of these watersheds and as to the massing of population near the mouth of the stream, we may say that the Allegheny above Pittsburg is as highly infected as if 100,000 people were massed at that point, and that the Monongahela is as badly contaminated as if there were a similar number located on its course immediately above Pittsburg. The population of Pittsburg being at

[a] Pollution on tributaries of Ohio River in Ohio is discussed in Water-Sup. and Irr. Paper No. 79, U. S. Geol. Survey, pp. 129-187.

least 300,000 it may safely be said that Ohio River below Pittsburg is contaminated by the sewage of at least 500,000 people, which enters the stream untreated, carrying with it contamination from thousands of typhoid-fever cases, of a virulence shown by the tables of death rate from this disease given above. Any water drawn from the Ohio at this point must be purified to a high degree in order to be safe for drinking. The only sense of safety in communities using this water is derived from the belief that there is a tendency in polluted waters toward the gradual death of the disease-producing organisms it contains—a belief that is firmly entrenched in the popular mind. The tendency is not always in this direction, the supposition that common water bacteria are more tenacious of life in infected water than the pathogenic organisms having been shown by some workers to be unfounded. Konradi[a] has shown that far from being unfavorable to their growth, water is an excellent medium for the culture of many disease-producing bacteria, and that in the long run it is they which survive over the water bacteria. The work of Mez[b] showed that these organisms live longer in sterilized than in dirty water, and that therefore pure drinking water once infected is more dangerous than foul water, a conclusion in line with the findings of Frankland and Klein, previously quoted. From this statement as a beginning, Konradi proceeded to experiment with the anthrax bacillus and its spores, *Staphylococcus pyogenes aureus*, the organism of pus, and the typhoid bacillus, all of the highest importance in this connection. He found that the ordinary water bacteria multiplied greatly for a time after the introduction of the pathogenic organisms, and then began to die out, and that after varying periods, the foul water, being kept at room temperature, was found to contain pure cultures of the disease-producing organisms, which retained full virulence up to complete evaporation. For the anthrax bacillus and its spores the period of life varied from 264 to 816 days, the water bacteria in the medium having completely disappeared after three or four weeks. The pus organism was found in pure culture after two months, and retained its virulence for 508 days. The bacillus of typhoid fever showed a similar power of conquering the water bacteria, which lived in the medium for four months, at the end of which time the bacillus typhosus was in pure culture, living in ordinary tap water at room temperature for 499 days. What more evidence is needed of the ability of the organisms of water-borne disease to poison a water as far as drinking purposes are concerned for a long time, admitting the pollution to cease, instead of continuing hourly as in the cases under consideration? Even sterilized water is found to allow the growth of anthrax and typhoid bacilli; though not of the pus micrococci.

It remains only to correlate these facts with the long-admitted disease-transmitting properties of water to make it clear that cities on the Ohio River immediately below Pittsburg might as well mix a well-known poison with pure water and drink it as use the river water without purification. "Among the carriers of virus, water is, according to the present state of our knowledge, by far the most important."[c] "Not only is typhoid one of the leading causes of death in America, but the greater part of it is conveyed directly or indirectly through water."[d] This fact has been so long established not only by scientific workers in the laboratory, but by long and costly epidemics, all traceable to the pollution of city supplies by typhoid-fever dejecta, that it is unnecessary to go further into that question. The fact is clear that the water of Ohio River below Pittsburg contains so large a number of pathogenic bacteria as absolutely to prohibit its use for drinking in the raw state.

CHARTIERS CREEK.

Washington, Pa.—The first important tributary stream below Pittsburg is Chartiers Creek, which receives the drainage of Washington, Pa. (population about 12,000). The water supply of this town is obtained from filter wells on the banks of Chartiers Creek, mixed at times with spring water from gravity sources. The position of the wells seems

[a] Centralblatt für Bakt., 36, May 28, 1904.
[b] Mikroskopische Wasser Analyse, 1898.
[c] Curschman, H., Typhoid Fever and Typhus Fever, Philadelphia, 1901.
[d] Baker, M. N., Municipal Engineering and Sanitation, New York, 1902.

to indicate that they are drawing largely on ground water on its way to the stream and not from the creek itself. That this is not sufficient protection is shown by the very high mortality rate for 1902.

Typhoid mortality at Washington, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1895	75	....	4
1900	110	42	3
1902	158	61	14

Without fuller data it is not possible to speak with certainty of this supply. It certainly is of doubtful quality. A field assay is given below.

Canonsburg, Pa.—Canonsburg (population 3,000), below Washington, on the same creek, has a gravity supply from a spring-filled reservoir, supplemented by raw water from Chartiers Creek when the water company deems necessary. The field assay shows the practical identity of the water with that at Washington, so that it seems likely that creek water is used much of the time. The presence of typhoid infection in Washington sewage is undoubted, and the likelihood of its occurrence in the water supply of Canonsburg follows naturally. The use of Chartiers Creek water raw is therefore ill-advised and dangerous. No figures showing typhoid mortality at Canonsburg are available.

OHIO RIVER FROM M'DONALD TO BEAVER RIVER.

McDonald, Pa.—At McDonald, Pa. (population 3,000), which drains into Ohio River above Sewickley, there is a mixed supply of a highly unsatisfactory character from Raccoon Creek and from deep wells. The water shed of Raccoon Creek is not, so far as known, guarded in any way, and the tap water is nearly always more or less turbid. The field assay shows a highly mineralized product, the carbonates being largely due to the well water, whereas the high turbidity and color show a surface origin from swampy drainage with inadequate sedimentation. It is not considered a good water for either domestic or industrial uses in its present condition.

Field assays of public supplies at Washington, Canonsburg, and McDonald.

[Parts per million.]

Determination.	Washington.	Canonsburg.	McDonald.
Turbidity	0	[a] 40	140
Color	96	180	140
Iron (Fe)	1.5	Trace.	0.5
Calcium (Ca)	107	110	142
Total hardness (as $CaCO_3$)	130+	130+	130+
Alkalinity	148	120	124
Sulphates (SO_3)	([a])	[a] 20	93
Chlorides (Cl)	7	36	59

[a] Estimated. [b] Slight trace.

Sewickley, Pa.—The greater portion of the population between Pittsburg and Sewickley (population 4,000) is supplied by the Monongahela Water Company, operating from Pittsburg. The Sewickley supply is derived partly by gravity from impounding reservoirs and partly from the Ohio River by pumping from cribs in the stream. The few analyses of the raw and the effluent water made in 1897 for the Pittsburg filtration commission show very little bacterial purification.

Analyses of public water at Sewickley.

[Parts per million.]

Date.	Water analyzed.	Turbidity.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Bacteria per c.c
1897.								
Nov. 3	Raw water........	Slight.....	0.110	0.016	None.	0.750	53.6	23,400
Nov. 3	Effluent...........	Clear.....	.325	.018	None.	1.500	37.4	910
Nov. 22	Raw water...	Slight.....	.210	.024	None.	.525	20.2	54,000
Nov. 22	Effluent...........	Slight.....	.080	.014	None.	.600	23.4	9,500
1898.								
June 27	Raw water........	Slight.....	.138	.046	None.	.525	24.0	15,500
June 27	Effluent...........	Slight.....	.140	.040	None.	.600	27.8	14,100

The figures for 1898 show that the degree of purification by this crib is uncertain and unreliable, and that the water supply from this source is not safe for domestic purposes. Typhoid-fever statistics confirm this view.

Typhoid-fever mortality at Sewickley, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1896	38	a 20	2
1897	33	a 20	2
1898	31	0	0
1899	47	7	3
1900	54	16	0
1901	53	11	3
1902	57	7	3
1903	49	10	2
1904	42	17	1

The percentages of deaths by typhoid fever are very high, as will be evident by reference to those of Olean and Salamanca, N. Y., and that of Bradford, Pa. The percentages of mortality from this disease at Allegheny, Pa., a notorious hotbed of typhoid fever, are as follows for certain years:

Typhoid mortality at Allegheny, Pa.

Year.	Total deaths.	Typhoid deaths.
1894	1,962	99
1896	1,995	74
1897	1,778	79
1898	2,036	73
1899	2,109	135

The two places are evidently in the same class, so far as the prevalence of typhoid fever is concerned. Certainly the water supply of Sewickley is not beyond suspicion. The experience of New Bethlehem, Pa. (see p. 26), a town of only half the size of Sewickley, shows that a filtration plant is not beyond the means of the latter if the citizens can be aroused to an appreciation of the loss annually suffered from this preventable disease.

Coraopolis, Freedom, and Monaca.—Besides Sewickley there are three or four other small towns between Pittsburg and Monaca, where Beaver River discharges into the Ohio. Coraopolis (population 3,000), a little above Sewickley, also pumps from a crib in the river. The quality of this supply is evident from the Sewickley figures. Freedom (population 2,000) also planned such a crib, but has succeeded in making arrangements with the filtration plant at Beaver Falls for a supply. Monaca (population 3,000) pumps its supply from deep wells in the gravel on the beach of the river. All these places sewer into the Ohio.

BEAVER RIVER BASIN.

SHENANGO RIVER.

Greenville, Pa.—Near the head of Shenango River, one of the tributaries of the Beaver, is the town of Greenville (population about 5,000). Its water supply is obtained by gravity from a spring-fed reservoir holding about 8,000,000 gallons. The daily consumption is about 1,000,000 gallons. In case of shortage the Little Shenango is pumped raw. This is a polluted stream and should not be used for drinking purposes without purification. The field assay (p. 83) shows that the water strikingly resembles those of French and Oil creeks. Arrangements should be made either for filtering the river water or for adding to the present storage capacity. Hardly any typhoid statistics are available for Greenville. In 1894 there were 7 cases and 1 death; in 1895 there were 15 cases and 1 death, enough to show that the cases were probably not isolated importations. The town sewage discharges into the creek.

Sharon, Pa.—About 20 miles down the Shenango is Sharon, with a population of about 10,000. The city water supply is derived from the river, the water being purified by mechanical filters, privately operated (see assay on p. 83). The plant consists of four large sedimentation tanks and eight filter units, the whole having a capacity of 1,700,000 gallons per day of fourteen hours. During the day the filtered water is pumped into the mains, whatever water is not used at the taps flowing into a 2,000,000-gallon storage reservoir. The field assay shows that the effluent from the filters is very similar to the raw water at Greenville.

The efficiency of mechanical filters is a matter of grave interest to many municipalities in this region, because of the very turbid condition of the stream waters. Although mechanical filtration has been practiced in this country for only a few years, it is very well understood that only by the coagulating processes in use as a preliminary to mechanical filtration can muddy waters be successfully handled day by day. Even if the small towns in this section could afford to install costly systems of slow sand filtration, it is probable that the high turbidities would soon so clog the filters as to make their operation very unsatisfactory. As the muddy stream waters are in this section the natural source of supply—at some places the only one—water purification has here developed largely along the lines of mechanical filtration.

When efficiently operated, with due study of the chemical nature of the water treated in each individual case, effluent water of satisfactory quality can be obtained from mechanical filters, the bacterial efficiency in many plants being nearly 100 per cent. When results are not satisfactory the cause of failure is usually found either in the inadequacy of the preliminary coagulation or in the grade of supervision provided. As the efficiency of the filters depends very largely on the complete combination of the suspended matters in the water with the chemicals added, failure may be expected unless each water is treated with the chemicals best suited to its composition and with a sufficient quantity of the chemicals. The majority of the processes devised for this purpose are in the experimental stage. The devices in most extensive use depend mainly on compounds of iron and aluminum. The processes depend upon the formation in the water of bulky precipitates through the combination of the aluminum or iron with the carbonates in solution. For this reason it is necessary to determine the alkalinity, and, if necessary, to increase an alkalinity naturally too low to allow the requisite chemical combinations. Ten or fifteen years ago, when the processes were not clearly understood, the coagulation basins were small and the amount of chemical added was frequently insufficient, so that a high degree of coagulation was seldom realized. In this respect the advance has been remarkable, the preliminary treatment receiving careful study, so that it is now very satisfactory. With the building of larger tanks, more complete chemical combinations are possible, so that a muddy water is very highly improved before going to the filters at all. Success depends so largely on the even uninterrupted flow of the chemical into the tanks that improvement in these filters has followed closely on improvement on the design of automatic devices for regulating the introduction of chemicals.

The second most common cause of failure of these filters is to be found in the grade of supervision provided. It would seem axiomatic that to install an expensive plant, designed to give certain results under carefully adjusted conditions, and then to hire an incompetent person to operate it is to make the machinery useless for the purpose for which is was designed. No business man would be guilty of such an absurdity with apparatus costing him the most trifling sum, yet such has been the course of action of many municipalities.

A most striking example of the efficiency of mechanical filtration of polluted surface waters is furnished by the decrease in the typhoid fever mortality of Lorain, Ohio, with the installation of filters. The town is located on the shore of Lake Erie, about midway between Cleveland on the east and Sandusky on the west, each about being 30 miles distant. The large amount of sewage that pours into the lake from these towns and others between them makes the raw water dangerous for a city supply unless taken out at a prohibitive distance from shore (cf. Erie, p. 104). The degree of healthfulness of this water supply before the introduction of the filter plant is clearly shown by the following figures showing mortality from typhoid fever:

Deaths per 100,000 from typhoid fever at Lorain, Ohio, before filtration.

Year.	Deaths.	Year.	Deaths.
1889	44	1893	183.3
1890	20	1894	48.8
1891	57	1895	131.6
1892	53	1896	83.3

These figures show that the supply ranked with the worst in the country at that time. In 1896 and 1897 mechanical filtration of this water by the Jewell system was resorted to. The figures showing typhoid fever mortality for the years following this installation are decisive as to the efficiency of the process in this instance:

Deaths per 100,000 from typhoid fever at Lorain, Ohio, after filtration.

Year.	Deaths.	Year.	Deaths.
1897	24.4	1900	11.5
1898	21.2	1901	5.5
1899	24.2	1902	26.3

The present mortality rate is as low as that of towns having carefully guarded surface supplies, and the filtration plant, judged by its practical results, is all that could be desired.

A chapter of important evidence is furnished by the rise in these figures when, in 1903, repairs to the plant made the use of raw lake water necessary for a brief period. For the first seven months of the year, the filter being then in use, there was not a single death from typhoid fever in the city; after the unfiltered water was turned in, although notices to the public had been printed in the local papers, the death rate from this disease from August to November, inclusive, rose to 180 per hundred thousand, dropping to 60 per hundred thousand in December and practically disappearing soon after the raw water was shut off.[a] It is hardly possible to get a clearer demonstration of the value of such a system in safeguarding the public health. It may be said positively that no public supply in this section should be taken from surface waters without filtration. The population is too dense to permit of the segregation of drainage areas except at a prohibitive cost, and some of the cities are too large to be supplied by spring waters without extensive segregation. Accordingly it is found that the largest towns have installed filtration systems similar to that at Sharon.

Typhoid-fever statistics for Sharon are too few to establish anything except the presence of the disease in the years given. In 1894 there were 13 cases and 3 deaths; in 1898, 16 cases and 2 deaths—that is, about the same as Sewickley, though Sharon has three times the latter's population.

NESHANNOCK CREEK.

Mercer, Pa.—At Newcastle Beaver River receives the waters of Neshannock Creek, carrying the drainage of a number of small towns. Chief of these is Mercer (population 2,000), about 25 miles above Newcastle. The public supply is pumped from Otter Creek to a mechanical filter. A field assay is given on page 83. The high color of this water may be due to drainage from the Half-moon Swamp at the head of the creek. The drainage area of the stream is sparsely inhabited, but there is sufficient pollution to make filtration necessary. There is little public interest in the question of water supply.

Newcastle, Pa.—Newcastle (population 35,000), a large manufacturing town, has a mechanical filter plant. The water is pumped from Neshannock Creek to large sedimentation tanks, thence to 8 filter units. The plant appears to be efficiently conducted. The following analyses of raw and filtered water at this place were made by Dr. F. E. Witherell for the American Waterworks and Guarantee Company, which controls this plant and numerous others. They are furnished through the kindness of that corporation.

Analyses of raw and filtered water from Newcastle, Pa.[b]

Date.	Bacteria per cubic centimeter.		Efficiency.	Colon bacillus.[c]	
	Raw water.	Filtered water.		Raw water.	Filtered water.
1902.			*Per cent.*		
May 1	760	36	95	....	....
May 2	740	38	95	....	....
May 3	670	30	95	....	....
May 4	710	19	97	....	....
May 5	720	41	94	....	....
May 6	980	43	96	....	....
May 7	770	38	95	....	....
May 8	530	35	93	....	....
May 9	420	28	93	....	....
May 10	630	30	95	....	....
May 11	420	24	94	....	....
May 12	370	22	94	....	....
May 13	610	32	95	....	....
May 14	560	40	93	....	....
May 15	550	33	94	....	....
May 16	600	33	94.5	....	....
May 17	610	34	95	....	....
May 18	530	37	93	....	....

[a] Engineering News, 1894. [b] All analyses made by Doctor Witherell. [c] +positive; −negative.

Analyses of raw and filtered water from Newcastle, Pa.—Continued.

Date.	Bacteria per cubic centimeter.		Efficiency.	Colon bacillus.	
	Raw water.	Filtered water.		Raw water.	Filtered water.
1902.			Per cent.		
May 19	470	23	95	....	....
May 20	770	48	94	....	....
May 21	730	41	94	....	....
May 22	550	21	96	....	....
June 1	2,000	70	96.5	+	–
Do	1,200	40	97	+	+
June 2	1,100	37	97	+	–
Do	1,400	80	94	+	+
Do	900	54	94	+	+
June 3	1,200	36	97	+	–
Do	600	68	89	+	+
Do	1,060	44	96	+	+?
Do	1,100	42	96	+	–
June 26	45,000	112	99.75	+	....
June 29	15,000	127	99.2	....	....
July 2	12,000	86	99.3	....	–
July 4	24,000	93	99.6	....	–
July 6	8,500	93	99.9	....	–
1903.					
Aug. 15	1,205	20	98.3	–	–
Aug. 22	2,500	74	97	+	–
Aug. 27	9,000	85	99.1	+	–
Sept. 1	2,300	35	98.5	+	–
Sept. 4	8,000	27	99.7	+	–
1904.					
Aug. 10	1,260	20	98.4	+	–
Aug. 11	780	23	97	+	–
Aug. 12	1,620	21	98.6	+	–
Aug. 13	2,800	10	99.6	+	–
Aug. 14	3,200	15	99.5	+	–
Aug. 15	4,200	18	99.6	+	–
Aug. 16	3,320	5	99.8	+	–
Aug. 17	4,800	25	99.5	+	–
Aug. 18	3,130	10	99.7	–	–
Aug. 19	6,200	38	99.4	+	–
Aug. 20	4,200	8	99.8	+	–
Aug. 21	3,720	29	99.2	+	–
Aug. 22	3,120	43	98.9	+	–
Aug. 23	3,010	55	98.2	+	–
Aug. 24	2,760	2	99.99	+	–
Aug. 25	5,100	3	99.94	+	–
Aug. 26	6,600	8	99.9	+	–
Aug. 27	6,400	3	99.95	+	–
Aug. 29	3,900	2	99.95	+	–
Aug. 30	3,000	3	99.9	+	–
Aug. 31	3,800	3	99.92	+	–
Sept. 10	2,500	5	99.8	+	–
Dec. 26	2,000	15	99.3	+	–
Dec. 28	15,000	71	99.5	+	–
Dec. 31	21,500	450	98	+	–

Analyses of raw and filtered water from Newcastle, Pa.—Continued.

Date.	Bacteria per cubic centimeter.		Effi-ciency.	Colon bacillus.	
	Raw water.	Filtered water.		Raw water.	Filtered water.
1905.			Per cent.		
Jan. 5	4,760	54	99	+	—
Jan. 6	4,250	35	99.2	+	—
Jan. 7	3,950	21	99.5	+	—
Jan. 9	7,210	12	99.8	+	—
Jan. 11	3,100	6	99.8	—	—
Jan. 12	2,800	2	99.93	+	—
Jan. 13	5,220	9	99.9	+	—
Jan. 17	12,000	72	99.4	+	—
Jan 19	15,200	12	99.92	+	—
Jan. 24	5,600	20	99.6	+	—

The percentages of efficiency are calculated from the figures given and show marked improvement since 1902. For May of that year the efficiencies are low, averaging 94.5 per cent. For a water so grossly polluted as the Neshannock such an efficiency is not high enough to assure a reasonable immunity from disease, and the condition is reflected in the high typhoid-fever death rate for 1902, shown in the table below. For June, 1902, the average efficiency was 95.9 per cent, also a low figure. The figures for July show improvement if they represent average conditions. For 1903 the few figures given show an average efficiency of 98.5 per cent, which is much more satisfactory. The typhoid mortality in that year was so high as to suggest that at other seasons of the year the filters were not working so well. For 1904 the figures are fuller and show a percentage efficiency averaging $99\frac{1}{3}$ per cent, reflected in the 50 per cent decrease in typhoid deaths for 1904. The figures for 1905, so far as they go, seem to show that this high standard is being kept up; altogether the plant at Newcastle may be considered to be doing very good work at the present time.

In the foregoing table it is noteworthy that the colon bacillus was positively identified in the raw water in nearly every case where the test was made, and in the filtered water during 1902. Since then the results have been negative. Doctor Witherell made the following statement in a letter dated November 17, 1905:

The tests made for *B. coli communis* were as follows: For the first inoculation a glucose neutral red bouillon is used, made up of—

1,000 cubic centimeters distilled or soft water.
5 grams beef extract (Liebig's).
20 grams Witte's peptone.
$\frac{1}{10}$ gram Grubler's neutral red.
20 grams grape glucose.
1 gram sodium taurocholate.

Reaction is +1, Fuller's scale. The broth is inoculated with $\frac{1}{100}$, $\frac{1}{10}$, 1, 5, and 10 cubic centimeter water samples and incubated 24 to 30 hours at 104° F. If the presumptive test is positive—that is, if 30 to 70 per cent of gas is formed, approximately one-third being carbon dioxide, with the medium strongly acid to litmus, andthe neutral red changed to canary yellow with green fluorescence—samples are plated into gelatin stab, agar streak, milk, potato, nitrates, Dunham's solution, and confirmatory results are looked for.

The typhoid statistics below are from the reports of the Pennsylvania State board of health, except for the years 1903, 1904, and 1905.

Typhoid mortality at Newcastle, Pa.

Year.	Population.	Deaths.	Rate per 100,000.
1895	19,600	16	....
1897	21,000	13	62
1898	24,000	6	25
1899	26,000	29	112
1900	28,350	36	127
1901	30,000	10	33
1902	32,000	39	122
1903 [a]	34,000	34	100
1904 [a]	35,000	18	51
1905 [a]	36,000	11	[b] 30.6

[a] Furnished by C. C. Honne, health officer of Newcastle.
[b] Up to Nov 11, 1905.

The figures showing population are roughly estimated from those for the census years 1890 and 1900. The estimates are only approximately correct, but are probably not far from the truth. As the number of cases is not obtainable for some years, the rate is calculated per 100,000 of population.

The field assays of this water show a very low alkalinity, probably due to acid drainage from manufacturing establishments on the stream. This is visible in the sulphate content also. The water is of fair quality for domestic purposes.

Field assays of public supplies in Shenango River and Neshannock Creek basins.

[Parts per million.]

Determination.	Greenville.	Sharon.	Mercer.	Newcastle.
Turbidity	0	0	0	0
Color	106	122	122	35
Iron (Fe)	1	.5	.5	Trace.
Calcium (Ca)	42	44	43	76
Total hardness (as $CaCO_3$)	47	47	42	61
Alkalinity	43	49	49	26
Sulphates (SO_3)	[a] 5	[a] 10	0	41
Chlorides (Cl)	5.6	11.2	9.7	9

[a] Estimated.

CONNOQUENESSING CREEK.

About 15 miles below Newcastle Connoquenessing Creek enters the Beaver near Ellwood City. The most important places in its drainage area are Butler, Grove City, Evans City, and Ellwood City.

Butler, Pa.—Butler (population 10,000), near the headwaters of Connoquenessing Creek, is well known to sanitarians for a noteworthy epidemic of typhoid fever occurring there a few years ago, caused by defects in the operation of the filters. The epidemic has been fully discussed by leading sanitarians, and in this place it is sufficient to remark that conclusive evidence was afforded by the costly experience of this period that the raw creek water was highly dangerous for drinking, and that constant vigilance in the operation of the filters is necessary to assure safety. The plant is now operated by the American Waterworks and Guarantee Company. Frequent bacterial analyses are made by Doctor Witherell, the coli tests being made as at Newcastle, except for the omission of the taurocholic acid control, The Butler supply (see assay below) is undoubtedly the best of those examined in the Connoquenessing Creek drainage, as it contains far less mineral impurity than any other.

Evans City, Pa.—Evans City (population 1,200) is situated on Breakneck Creek, a tributary of Connoquenessing Creek. Its supply is obtained by gravity from a hill reservoir impounding spring runs. The high chlorides and alkalinity suggest the presence of ground water. This water probably contains calcium chloride and would corrode boiler tubes.

Field assays of public supplies in Connoquenessing Creek basin.

[Parts per million.]

Determination.	Grove City.	Ellwood City.	Butler.	Evans City.
Turbidity	0	*a* 20	0	0
Color	35	140	45	44
Iron (Fe)	2.7	1	0	1
Calcium (Ca)	119	67	28	94
Total hardness (as $CaCO_3$)	130+	66	39	66
Alkalinity	201	40	40	191
Sulphates (SO_3)	*a* 5	*a* 20	*a* 3	Trace.
Chlorides (Cl)	23	27	19	78

a Estimated.

Grove City, Pa.—Grove City (population 1,600) is situated on Wolf Creek, one of the headwater streams of Slippery Rock Creek, the most important tributary of Connoquenessing Creek. Its water supply is pumped from a 200-foot driven well to a standpipe. The field assay (above) shows the water to be of a fair quality for a ground water, although it is hard and contains a little more iron than usual. It gives satisfaction for drinking purposes, but would be wasteful for laundry uses and is so high in incrusting carbonates that it would certainly incrust tubes.

Ellwood City, Pa.—Ellwood City (population 2,500) draws its water supply from Connoquenessing Creek. The water is said to be mechanically filtered. Before entering the Ellwood supply the creek receives the sewage of Butler (population 10,000), Evans City (population 1,200), and the two small towns of Harmony and Zelienople. The water is undoubtedly too grossly polluted to be safe in its raw state.

The traces of sulphur and iron, shown in the field assay (above), are probably due to a little mine drainage. The turbidity is higher than it should be for a filtered water and casts grave doubt upon the efficiency of the process. The color of the water is also high.

It will be clear from the foregoing data that Beaver River drains much sewage pollution from this section of western Pennsylvania. Filtration of this water is absolutely necessary before it can be safely used as a public supply.

BEAVER RIVER.

Beaver Falls, Pa.—The largest city on Beaver River is Beaver Falls (population 10,000). At this point the supply was until 1900 obtained directly from the river without purification. The result of the use of such water is indicated by the following figures showing the typhoid-fever mortality, which is among the highest in the country:

Typhoid mortality at Beaver Falls, Pa.

Year.	Total deaths.	Typhoid cases.	Typhoid deaths.
1896	124	28	8
1897	134	105	11
1898	128	80	15
1899	138	27	8
1900	169	22	15

Figures for later years are unobtainable.

In 1900 mechanical filters were installed, supplying Beaver Falls, New Brighton, Rochester, Freedom, and other places. Four of the filters are of the Jewell type, the remaining four of the old closed or oil-tank type. The plant seems to be efficiently operated, and local physicians speak well of the decrease in the number of typhoid fever cases since its installation. Bacterial analyses of 20 samples collected at the intake and at a tap in Beaver Falls show an average bacterial content as follows:

Bacterial analyses of water at Beaver Falls, Pa.[a]

[Bacteria per cubic centimeter.]

Raw water.		Filtered water.		
Total.	B. coli.	Total.	B. coli.	Efficiency.
				Per cent.
246,850	195	29,300	12	94

[a] Data furnished by water company.

This is a low efficiency both for total organisms and for bacillus coli, yet the filtrate is very much better than the raw water.

The field assay (p. 87) shows a water typical of the river waters of this section. It is soft enough to be suitable for any purpose.

OHIO RIVER BETWEEN BEAVER RIVER AND FISH CREEK.

Below the mouth of Beaver River the Ohio flows nearly southwest for about 10 miles through a rolling farming country. It crosses the State line a few miles above Chester, W. Va., a little town of about 1,000 population. From this point on, notwithstanding the enormous pollution in the river, the water is very commonly used as a public supply in its raw state. It is evident from the foregoing discussion that the inevitable effect of such a practice is the sacrifice of many lives annually, with the additional waste of thousands of dollars by the communities affected. Although West Virginia has laws on its statute books forbidding stream pollution under penalty of $5 fine for each offense, there is wanton and wholesale contamination of every stream in the State. As no typhoid-fever statistics are obtainable for towns in this State, except for Wheeling, it is impossible to supply that concrete evidence of the disease-producing quality of the water which is furnished by such figures. The quality of these supplies will be evident, however, from the following descriptions of conditions in this section and from the typhoid-fever records of those towns in Ohio which take their supply from the river unpurified and which have collected figures concerning this disease:

Chester, W. Va.—At Chester the public supply is pumped from a filter well that is sunk in the fine sand of the river bank. The well is about 8 feet in diameter and is covered with a brick and concrete dome. The pumping machinery is mounted in a larger well close by, a gallery connecting the two. The effluent from this plant is beautifully clear and sparkling at all times, although the river is usually muddy. There can be no question, however, that so far as organic contamination is concerned no change of importance occurs during the natural filtration of this water. It can not be regarded as a safe supply for this municipality, and if typhoid-fever statistics were available the town would probably be found to suffer heavily from the disease. That this is not mere conjecture is evident from the high typhoid-fever percentages for East Liverpool, Ohio, directly across the river. This town pumps its water supply from the Ohio River raw, and is seen to be suffering constantly and heavily from typhoid fever.

Typhoid mortality at East Liverpool, Ohio.

Year.	Total deaths.	Typhoid deaths.
1897	154	9
1900	196	17
1901	187	26
1902	226	15
1903	337	13

The field assay (p. 87) shows the increased mineral content resulting from the passage of the water through the river sand, the mineral contents being appreciably higher than those of the river water at Pittsburg. This water is too hard to be considered excellent for boiler uses, and its muddy condition in the raw state makes it very poor for other industrial purposes. It is, however, of better quality than the ground waters in this section, as will be evident from the field assay of the wells at Wellsburg and Wheeling, given below.

New Cumberland, W. Va.—At New Cumberland, about 15 miles below East Liverpool, the city supply is also raw Ohio River water. The town has about 1,200 inhabitants, and is partially sewered. Above it on both banks of the river are visible evidences of pollution, besides the accumulated filth coming down in the river from Pittsburg. The supply of Steubenville, Ohio (population, 14,000), is of the same kind. The officials of this town have for years made no report of typhoid mortality.

Wellsburg, W. Va.—Wellsburg (population, 2,500), about 10 miles below Steubenville, also uses raw Ohio River water. The field assay of water from a 60-foot well much used for drinking purposes on one of the main streets of Wellsburg is given on page 87. There are are numerous drilled wells on the the streets, to which resort is had for drinking water to some extent. This water is very hard and not suitable for any use except drinking.

Wheeling, W. Va.—Wheeling (population, 40,000), on Ohio River about 14 miles below Wellsburg, has probably one of the worst typhoid-fever records for a town of its size and wealth in this or any other country. Like the towns just mentioned, it pumps its supply raw from Ohio River, without any attempt even at adequate sedimentation. Wheeling Creek, which flows through most of the town, is an open sewer. The intake of the waterworks is located a very short distance above the town. The works are owned by the city, and considerable thought has been devoted to the regulation of rates, but none to the quality of the water supply. In view of the conditions above described, under which town after town turns its disease-polluted sewage into the river, the strange thing is not that Wheeling should lose many lives and thousands of dollars through the use of polluted water for drinking, but that any American community should tolerate such a state of affairs. The figures shown below are available from the reports of the United States Public Health and Marine-Hospital Service. Although for but a portion of the years shown, they indicate closely the character of the supply:

Typhoid mortality at Wheeling, W. Va.

Quarter ending—	Total deaths.	Deaths from typhoid fever.
March 31, 1904	200	8
June 30, 1904	187	18
March 31, 1905	182	7
June 30. 1905	141	8

The significance of these percentages may be better understood when they are compared to the figures previously given as to Sewickley, Allegheny, Pittsburg, McKeesport, and other places. The condition here is almost incredibly bad.

The field assays below shows that the river water is considerably softer than the naturally filtered water at Chester. The well of the Acme Box Company is used for all purposes, both steam making and drinking, in the factory of the concern. It is unfit for any of them, being so excessively high in sulphates and iron as to corrode boiler tubes very rapidly. The use of this water represents a heavy annual expense for needless repairs. It is not very palatable, and its high color is not reassuring as to the safety of the well from contamination by surface water.

Moundsville, W. Va.—At Moundsville (population, 6,000) the water supply is obtained from wells on an island in Ohio River of the rather rare type in use at Gallipolis, Ohio, described on page 64. The typhoid-fever statistics of the latter town may very well be applied to the consideration of Moundsville's supply, the conditions being practically identical at the two places. The wells are four in number and 16 feet deep. The borings are carefully cased, admitting water only through strainers at the bottom. They are connected near the top so as to be pumped together. The effluent is beautifully clear and pleasant to the taste. The field assay shows considerable diminution of the sulphates in the river water, with entire absence of suspended matter and color, though at this period the raw water is a muddy brown.

Field assays of water from towns along Ohio River.

[Parts per million.]

Determination.	Beaver Falls, Pa., public supply.	Chester, W. Va., public supply.	Wellsburg, W. Va., 60-foot well.	Wheeling, W. Va., well of Acme Box Co.	Wheeling, W. Va., city supply.	Moundsville, W. Va., city supply.
Turbidity	0	0	0	0	0	0
Color	83	90	5	123	45	0
Iron (Fe)	(a)	Trace.	.5	20	(b)	0
Calcium (Ca)	45	102	200	274	55	96
Total hardness (as $CaCO_3$)	51	128	....	....	77	111
Alkalinity	29	88	267	380	22	63
Sulphates (SO_3)	c 20	40	54	+522	41	15
Chlorides (Cl)	12	27	15	99	19	24

a Slight trace. b Very slight trace. c Estimated.

FISH CREEK.

Fish Creek, which enters the Ohio about 8 miles below Moundsville, drains a country very deficient in water resources. Along the West Virginia Short Line of the Baltimore and Ohio Railroad the small communities have to get their supplies from individual wells, the deep-well water not being of very good quality.

Hundred, W. Va.—At Hundred (population, 300) there is a 118-foot well, which, as shown by the field assay, is of very good quality for water drawn from such a depth. The high alkalinity may indicate the presence of magnesium. Although somewhat hard, this water would make a good public supply.

Littleton, W. Va.—Littleton (population, 700), a few miles farther west, has a public supply very similar in quality to the well at Hundred. It is drawn from 2 wells 145 feet deep recently drilled to replace the public supply from Fish Creek, a little stream which is probably as highly polluted for its size as any stream could be. The springs in this section are not very numerous nor very large, most of them drying up in the summer. The Farrell Spring at Littleton, a limestone spring of unusual hardness, is piped into a few dwellings for domestic purposes. Its water is strikingly similar in mineral content to that of the deep well.

Board Tree and Cameron, W. Va.—The Bill Spring at Board Tree (population, 50), a few miles west of Littleton, is also very hard, the water seeming to come from a limestone formation. It is much used for domestic purposes. The 66-foot well at Board Tree is the only bored well in this section. Its water is so high in incrusting solids as to be of no use except for drinking. Fish Creek itself is a small stream that flows over the naked rock in most of its course and practically dries up in the summer. The field assay shows that its water is considerably harder than the river waters of the Monongahela basin, but still comparatively soft and available for industrial purposes. The railroad leaves the stream soon after passing Board Tree, going north to the terminus at Moundsville. The only important town in this section is Cameron, which has about 1,000 population. It has a city water supply pumped to reservoirs from 5 driven wells 100 feet deep. The field assay shows this water to be far too hard for any use except drinking, the sulphates being so high as to incrust boiler tubes. The railroad uses the waters of Graves Creek, a small stream emptying into Fish Creek, for steaming purposes. A large brick filter well has been constructed in the bank of the stream, in which the water is collected. The field assay shows it to be but little better than the well water.

Field assays of waters in Fish Creek basin.

[Parts per million.]

Determination.	Hundred.		Board Tree.		Littleton.		Cameron.	
	118-foot well.	Fish Creek.	Bill Spring.	66-foot well.	Farrell Spring.	145-foot well.	100-foot wells.	Graves Creek.
Turbidity	0	0	0	0	0	0	0	[a] 4
Color	5	37	35	96	35	90	17	10
Iron (Fe)	.75	0	0	1.75	0	.8	.5	0
Calcium (Ca)	70	32	87	156	110	119	137	102
Total hardness (as $CaCO_3$)	118	63	118	....	130+	132	130+	132
Alkalinity	187	35	61	171	78	71	216	47
Sulphates (SO_3)	20	5	30	58	35	42	83	52
Chlorides (Cl)	19	14	14	80	24	19	49	19

[a] Estimated.

FISHING CREEK.

At New Martinsville another small stream, Fishing Creek, enters the Ohio, draining also a poor and sparsely populated country. The industry of this section has always been dependent on the oil wells, and the decline or failure of these has caused the abandonment of many habitations.

Smithfield, W. Va.—Smithfield, near the crest of the divide between the Monongahela and the Ohio, is a typical oil town of a few hundred population, without any public water supply. The 160-foot well assayed is one of three 8-inch wells bored by the South Penn Oil Company for boiler uses and also for town supply. It yields a surprisingly soft water, the total hardness not being much higher than that of Fish Creek. The chlorides, however, are so enormously high as to make the water very corrodant in boilers (see assay below). It is probably best used for drinking only. A sample from a 46-foot well showed a total hardness of 91 as compared with the 42 parts per million of the last supply, so that in this instance it is not necessarily the deep-well water that is harder. There are very few permanent springs in this section. The water of Carlin Spring (see assay below), which is 80 feet above the house into which it is piped, is of fair quality, the total hardness, it is noted, being exactly the same as that of the shallow well.

Pine Grove, W. Va.—At Pine Grove, about 10 miles west of Smithfield, a once prosperous oil town, having at present about 500 population, there is no public supply, the townspeople using individual wells and small springs. The 50-foot well shown in the assay is probably high in magnesium carbonate and the alkalies. It is of fair quality for domestic purposes. The Newman Spring is much better in every respect, but is not large enough to supply more than a few families.

Field assays of water at Smithfield and Pine Grove, W. Va

[Parts per million.]

Determination.	Smithfield.			Pine Grove.	
	46-foot well.	160-foot well.	Carlin Spring.	50-foot well.	Newman Spring.
Turbidity	....	0	0	0	0
Color	....	35	96	17	37
Iron (Fe)	....	Trace.	0	0	0
Calcium (Ca)	....	(a)	46	32	35
Total hardness ($CaCO_3$)	91	42	91	77	63
Alkalinity	....	236	49	229	47
Sulphates (SO_3)	....	0	(a)	0	0
Chlorides (Cl)	....	393	19	90	9

a Very slight trace.

OHIO RIVER FROM FISHING CREEK TO MIDDLE ISLAND CREEK.

New Martinsville, W. Va.—New Martinsville (population, 2,000) has expended much money in experimenting with water-supply methods without adequate return. Its supply is now pumped raw from Ohio River. An attempt was made to get water from filter wells similar to those at Moundsville, but unsuccessfully. Recently it has been planned to dig large brick wells in the shore of the river and pump the public supply therefrom. This would give a very clear water satisfactory for industrial purposes, but it would be no safer from a sanitary standpoint than the raw water itself. The condition of Ohio River is well recognized in this town, which has gone to the length of providing a number of drilled wells scattered over the city, from which pure drinking water is obtainable. The field assay shows this water to be extremely hard, but it should be excellent for drinking.

Sisterville, W. Va.—The only important town between New Martinsville and St. Marys, about 35 miles down the river, is Sisterville, a manufacturing town which had a population of 3,000 in 1900 and which is growing with great rapidity. Its supply is pumped directly from Ohio River to tanks.

St. Marys, W. Va.—The public supply at St. Marys (population, 1,000) is also pumped raw from Ohio River. The high turbidity of the sample indicates that the inhabitants of this town are practically drinking diluted mud for a large part of the year. The water of the 60-foot well at this point seems to be of good quality for drinking, although somewhat hard. The high hardness as compared to the calcium content would seem to indicate that the alkalinity is due mostly to magnesium carbonate. The town is built directly on the river and contributes liberally to its pollution.

Field assays of water at New Martinsville and St. Marys, W. Va.

[Parts per million.]

Determination.	New Martinsville.		St. Marys.	
	Ohio River.	53-foot well.	Ohio River.	60-foot well.
Turbidity	140	0	240	0
Color	88	22	35	35
Iron (Fe)	1	5	0	(a)
Calcium (Ca)	64	200	47	60
Total hardness ($CaCO_3$)	76	....	97	130+
Alkalinity	35	203	32	42
Sulphates (SO_3)	b 20	b 10	b 20	0
Chlorides Cl)	19	40	29	29

a Slight trace. b Estimated.

MIDDLE ISLAND CREEK.

Middle Island Creek, which discharges into the Ohio a little above this point, drains a sparsely populated farming country. As far as contamination goes, however, the scattering nature of the population is more than counterbalanced by the directness of the pollution. In nearly every case where it was possible and convenient to build a privy on or close to the creek it has been built there instead of where it would not pollute the water.

West Union, W. Va.—The only important town on this drainage area is West Union, on the Parkersburg division of the Baltimore and Ohio Railroad, about 30 miles west of Clarksburg. The assay below shows the water of the creek to be of very fair quality for industrial purposes. The high color is due mostly to organic pollution. West Union (population, 1,200) has no public supply, the inhabitants getting their water from wells varying in depth from 20 to 150 feet. The 128-foot well assayed (below) is in very general use, being on the public street. The water is of poor quality for any purpose except drinking. That of the 38-foot well is strikingly similar in its mineral contents.

OHIO RIVER FROM MIDDLE ISLAND CREEK TO THE LITTLE KANAWHA.

Williamstown, W. Va.—Williamstown (population, 400), on Ohio River, about 15 miles below St Marys has no public supply. The field assay shows that the water from a 60-foot well at this place is of fair quality though somewhat hard. It is noteworthy that the field assay of Ohio River at this point shows exactly the same chlorine content. The well is about 300 feet from the river.

Field assays of water from West Union and Williamstown, W. Va.

[Parts per million.]

Determination.	West Union.			Williamstown.	
	Middle Island Creek.	128-foot well.	38-foot well.	60-foot well.	Ohio River.
Turbidity	0	0	0	0	0
Color	160	0	17	22	22
Iron (Fe)	0	(a)	.5	0	0
Calcium (Ca)	Trace.	126	133	87	46
Total hardness ($CaCO_3$)	63	130+	....	139+	139+
Alkalinity	36	116	0	42	29
Sulphates (SO_3)	(b)	[c] 20	[c] 20	44	[c] 20
Chlorine (Cl)	9	90	70	40	40

[a] Slight trace. [b] Very slight trace. [c] Estimated.

Marietta, Ohio.—Opposite Williamstown is Marietta, with about 15,000 population, discharging its sewage into the river. Three streams in Ohio—Little Muskingum River, Duck Creek, and Muskingum River—enter Ohio River within a mile or two of each other at Marietta. Each drains an area comprising considerable population, so that the sewage entering at Marietta alone would be sufficient to make the raw river water unsafe, even if the pollution entering above were eliminated.

Parkersburg, W. Va.—In spite of the pollution at Marietta, which is evident from a cursory inspection of the river, Parkersburg, otherwise a growing and progressive town (population, about 17,000) takes its water supply unpurified from Ohio River. The supply is extremely bad, being almost always very turbid and unsatisfactory for any domestic uses. The claim is made in the city that this water is used only for fire purposes, spring water being largely bottled and sold for drinking. The value of this claim has already been estimated. There is no doubt that if typhoid-fever statistics were obtainable for this city a very serious condition of the public health would be manifest. It may be very well estimated from the typhoid-fever statistics of Marietta, Ohio, except that conditions at Parkersburg would be much worse.

Typhoid mortality at Marietta, Ohio.

Year.	Total deaths.	Typhoid deaths.	Year.	Total deaths.	Typhoid deaths.
1897	115	7	1901	256	21
1898	123	6	1902	174	13
1899	163	5	1903	194	8
1900	192	10			

These percentages are so high as to need no comment. Both Marietta and Parkersburg have the distinction of being in the same class with Wheeling as to water supply.

Of great interest in this connection are the filters of the Parkersburg Steel and Iron Company a few miles above the city These wells are about 13 feet in diameter, 34 feet deep, and about 75 feet from shore. They are bricked up from the bottom, the pumping machinery being incased in one of the wells, which is connected with the other. Six hundred thousand gallons of clear water are pumped from these wells every day, although the Ohio River water is usually muddy. It is found quite satisfactory in the boilers of the company, but it is hardly necessary to say that in spite of its brilliancy and inviting appearance it would not be safe for drinking. The well on the public street in Parkersburg is one of two or three that are much drawn on for drinking purposes. The water is utterly unfit for anything else, being very high in sulphates and chlorides (see assays below).

Field assays of water from Ohio River and well at Parkersburg.

[Parts per million.]

Determination.	Raw water.	Filtered water.	Well water.	Determination.	Raw water.	Filtered water.	Well water.
Turbidity	180	0	0	Total hardness $CaCO_3$	76	139+	....
Color	90	45	5	Alkalinity	27	100	42
Iron (Fe)	([a])	0	.5	Sulphates (SO_3)	[b] 20	[b] 20	144
Calcium (Ca)	50	142	137	Chlorides (Cl)	19	19	101

[a] Slight trace. [b] Estimated.

LITTLE KANAWHA RIVER BASIN.

A great deal of drainage enters the river at Parkersburg by way of Little Kanawha River, which flows nearly west across the State from Upshur County. The principal tributary of the Little Kanawha is Hughes River, which enters at Newark station.

LITTLE KANAWHA RIVER.

There are several small towns on this stream, the largest being Clenville (population, 400), Grantsville (population, 300), Spencer (population, 900), Reedy (population, 400), and Elizabeth (population, 800), comprising a total urban population of 2,500, all of which contribute privy pollution to the stream. The water of Little Kanawha River is one of the purest in the State so far as inorganic content goes, being so soft as to rank with the Pennsylvania spring waters. The field assay at Burnsville, not far from its source, shows a very excellent water. The field assay of water from Little Kanawha River at Parkersburg shows a complete change in its character. The turbidity at the mouth of the stream is very high at all times on account of the character of the soil through which it flows in the lower half of its course. It gains very much in hardness also, and is altogether undesirable in its raw state for domestic use at Parkersburg, although soft enough to be of fair quality for boilers.

HUGHES RIVER.

Pennsboro, W. Va.—Pennsboro (population, 800) has no public supply, the inhabitants using individual wells, which are few and yield water of poor quality. The 207-foot well assayed below is too high in mineral content to be of use for any purpose, there being too much calcium to be correctly estimated by field methods and a qualitative test showing the presence of much magnesium. The water of the 46-foot well is somewhat better in quality, but only by comparison. Both these wells are subject to shortage in dry times. The town is built on steep slopes, draining into the North Fork of Hughes River, privy contamination being conspicuous, and the same is true of the other small stations along the stream.

Cairo, W. Va.—The most conspicuous carelessness in public supply in this section is at Cairo (population 800). This town pumps its supply from Hughes River, the claim being made that it is only for fire protection, and that drinking water is taken entirely from individual wells. About 100 feet above the pumping station on the creek are a privy and barn right on the banks of the stream, so that at high water filth from both places goes directly into the river and heavy rains at all times wash pollution into the stream. This is a representative condition in this section. Field assay below shows the creek water to be of fair quality for industrial purposes, the well water not so good. It seems probable that the calcium is present almost entirely as calcium chloride, the alkalinity being extremely low. The color of this well water is so high as to create a suspicion as to its freedom from contamination.

Field assays of water from Little Kanawha River basin.

[Parts per million.]

Determination.	Pennsboro.		Cairo.		Burnsville.	Parkersburg.
	207-foot well.	46-foot well.	40-foot well.	Hughes Creek.		
Turbidity	0	0	0	Cloudy.	0	150
Color	35	17	44	244	70	35
Iron (Fe)	(a)	0	2	(b)	Trace.	(a)
Calcium (Ca)	High.	130	130	61	0	15
Total hardness (as $CaCO_3$)	139+	139+	132	76	28	104
Alkalinity	424	185	26	41	23	34
Sulphates (SO_3)	[c] 10	0	0	0	0	(a)
Chlorides (Cl)	60	40	172	40	9	40

a Slight trace. b Very slight trace. c Estimated.

OHIO RIVER FROM LITTLE KANAWHA RIVER TO KANAWHA RIVER.

Between Parkersburg and Point Pleasant there is no important city on the Ohio River. Little places having a hundred or more inhabitants are dotted along the stream, the largest being Ravenswood and Millwood, which are the termini of short branch lines of railroads. Neither have public supplies.

Point Pleasant, W. Va.—Point Pleasant (population 2,500) has a water supply of the natural filtration type in use at Gallipolis, Ohio, and Moundsville, W. Va. It is derived from two wells drilled in the Ohio River sand, the water seeping through the sand and entering the wells through strainers at the bottom. It is pumped into the city reservoir by compressed air. The water is of crystal clearness and low temperature in summer, so that it is very inviting and much used. The experience of Gallipolis would indicate that for a year or two this will be an ideal supply, but it is doubtful whether it will be safe for drinking a few years hence. Comparison with the raw river water shows high turbidity eliminated by the natural filtration and some gain in mineral content by the passage through sand. Except for its muddiness the raw water is much more desirable for industrial purposes.

Field assays of Ohio River water from Point Pleasant, W. Va.

[Parts per million.]

Determination.	Filtered.	Raw.	Determination.	Filtered.	Raw.
Turbidity	0	429	Total hardness (as $CaCO_3$)	118	83
Color	17	....	Alkalinity	124	47
Iron (Fe)	0	....	Sulphates (SO_3)	a 20	a 20
Calcium (Ca)	98	82	Chlorides (Cl)	15	....

a Estimated.

KANAWHA RIVER BASIN.

Kanawha River has a drainage area about as large, roughly, as that of the Monongahela. It drains nearly all the southern half of West Virginia. The principal industries of the country through which it flows are coal mining and lumbering, but the latter is rapidly disappearing. Typhoid-fever statistics are hardly necessary in this drainage area. Ocular evidence of the pollution of the surface waters is so plentiful on all sides that the mere description of conditions is enough to condemn nearly every supply in the section.

The principal tributaries of the Kanawha are Gauley, Greenbrier, and New rivers, the last being really the Kanawha under a different name.

NEW RIVER BASIN.

New River has its rise in North Carolina and enters West Virginia at its southern boundary. It flows through a beautiful mountain country, sparsely inhabited, and is comparatively unpolluted until it receives the waters of Bluestone River.

BLUESTONE RIVER.

Bluestone River is a very small stream, draining a number of mining camps and flowing into New River about 5 miles above Hinton. Field assays at Pocahontas, Va., and Graham, Va., (p. 93), show the presence of a great deal of free acid in the mine effluent waters, probably not, however, in sufficient quantities to be germicidal, even if the flow of both were constant. It is noteworthy that all along this stream algæ flourish, apparently unharmed by the acid. The disgusting pollution by privies in this section is therefore carried down practically unchanged, except for the worse, into New River. Pl. V, *B* gives a fair idea of sanitary conditions at the head of this stream at low water. The place pictured is by no means the worst on the course of the stream. It is evident that rain at all times washes privy droppings into the stream, and that at high water the contents of the privies find their way directly into the current. The population of this town is largely composed of colored coal miners, who live herded together along the banks in squalid huts, under the most unsanitary conditions. Typhoid-fever dejecta poisoning this water from these people would have ample time to be carried down for many miles before the case would even be brought to a physician for treatment.

Graham, Va.—Good water is scarce in this section. The 52-foot well at Graham, Va. (population 1,500), shows very hard water, unsuitable for domestic use, yet it is considered one of the best in the town. The water stratum from which this well draws has apparently been contaminated by a cesspool sunk a few hundred feet above the well. A sample recently sent to the State University at Morgantown, W. Va., for analysis is said to have shown the presence of intestinal pollution.

Pocahontas, Va.—The public supply of Pocahontas (population 2,800) is obtained from Bluestone River, which is also pumped by the Norfolk and Western Railroad to supply its shops at Bluefield and its station at Graham. The partial field assays show results of qualitative tests for sulphuric acid in Baby mine drainage at Pocahontas, Va., and quantitative determinations of iron and sulphates.

Field assay of water of Bluestone River at Pocahontas, Va.

[Parts per million.]

Determination.	Laurel Creek above mine waste.	Outfall at mouth.	1,000 feet below mine outfall.	3,000 feet below outfall.
Iron (Fe)	2	4	3	3
Alkalinity	(a)	(b)	(c)	Acid.
Sulphates (SO_3)	122	+522	338	410

[a] Water acid. [b] More acid. [c] Much more acid.

Bluefield, W. Va.—The public water supply of Bluefield (population 7,000), on Brushy Fork, forms an exception to the general filthy character of the water supplies in this section. The supply is derived from two large springs a few miles above town, which are carefully walled up and protected against pollution, accidental or otherwise. The supply is always abundant and seems to be of good quality, though a little hard for laundry uses. The high color is a little disquieting, but may be due to marshy drainage or a foul condition of the pipes. It is undoubtedly the best water in this section. The water of the deep wells at the brewery, one of which was assayed, is very much harder and contains an appreciable amount of sulphates. It is used for steam making at this establishment and causes considerable trouble in the boilers, as might be expected.

Field assays of water from Graham, Va., and Bluefield, W. Va.

[Parts per million.]

Determination.	Graham, Va., 52-foot well.	Bluefield, W. Va.	
		Public supply.	700-foot well.
Turbidity	0	0	0
Color	10	122	....
Iron (Fe)	.5	0	(a)
Calcium (Ca)	130	113	146
Total hardness (as $CaCO_3$)	....	111	....
Alkalinity	147	121	269
Sulphates (SO_3)	[b] 10	[b] 5	42
Chlorides (Cl)	24	9	21

[a] Very slight trace. [b] Estimated.

GREENBRIER RIVER.

At Hinton, New River receives an enormous amount of pollution from Greenbrier River, an important tributary, on which the conditions are very unfortunate. It is one of the most beautiful streams in the State, the water almost always being very clear, but it is poisoned at its very source by privy contamination.

Durbin, W. Va.—Above Durbin, on the headwaters of the stream, there are a great many sawmills. Sanitation in these mill camps consists in building the privies directly over the river and in throwing all waste and refuse either into the stream or on the ground near by, so that they can be washed into the water. At Durbin fecal pollution is nauseatingly abundant on the banks. The railroad privy is so located as to discharge into the river, and a number of the houses drain almost directly into a small run that enters the river at this point. More heedless contamination of a pure and beautiful river could hardly be imagined. The field assay (p. 95) shows a water of almost perfect purity, its high color being the only objec-

A. CHARACTERISTIC VIEW ON NEW RIVER, WEST VIRGINIA.

Showing rapid flow.

B. HEAD OF BLUESTONE RIVER, WEST VIRGINIA.

Showing existing conditions.

tionable feature. The water of the 84-foot well at this place is of fair quality, not too hard for laundry use.

Marlinton, W. Va.—Between Durbin and Marlinton the contamination from mill camps is as bad as above Durbin. Marlinton, the largest hamlet in this section, is a pretty and rapidly growing lumber town of about 500 population. It has no public water supply. Greenbrier River at this point shows an increase in hardness, but is still a very soft water (see table below). The pollution at Marlinton from outhouses is considerable. A quasi public supply is piped into the railroad tank, and thence into a few buildings, from Knapp Creek, a little trout stream, comparatively clean and pure. The field assay shows the Knapp Creek water to be of excellent quality for any purpose. Still better is the water of the large spring that is piped to two banks and a boarding house in the town. There is practically no mineral impurity in this water except the iron. The high color is probably due to the nature of the drainage. It is the best supply in this section.

Ronceverte, W. Va.—Between Marlinton and Ronceverte (population about 1,000) there is a scanty population and but little drainage from houses. It is unfortunate, however, that at almost every place where there is a house a privy either overhangs the stream or stands close to it. The Ronceverte water supply is pumped directly from Greenbrier River into a reservoir, whence it flows by gravity into the mains. It is used unpurified for all purposes, and the townspeople regard it as pure water, because there are no houses directly above the intake. In the light of the above discussion of Allegheny and Monongahela rivers it is plain that self-purification in this stream is a negligible factor. While by no means an unusually rapid stream, it is too small for navigation, and its occasional pools are separated by numerous stretches of swift water. It is so grossly polluted from its very source to a point a mile or two above the pumping station as to leave no doubt of its unhealthfulness when used raw as a public supply. Ronceverte is not sewered, and its drainage and that of the railroad shops at this point form an important contribution to the river.

Alderson, W. Va.—At Alderson, about 8 miles below Ronceverte (population 800), there is no public supply. The water of the 80-foot well (assay below) is a typical ground water of this locality. Although very hard, it is a good water for drinking, the well being carefully cased into the rock. There is much defilement of the river at this point from outhouses.

Talcott, W. Va.—At Talcott, a hamlet of a few families, 10 miles above Hinton, some privies overhang the river. Dejecta from these drop directly into the river, and could certainly infect supplies below in a few hours.

Field assays of water from Greenbrier River basin.

[Parts per million.]

Determination.	Durbin. 84-foot well.	Durbin. Greenbrier River.	Marlinton. Greenbrier River.	Marlinton. Knapp Creek.	Marlinton spring.	Ronceverte, Greenbrier River.	Alderson, 80-foot well.	Hinton, Greenbrier River.
Turbidity	0	0	0	0	0	0	0	0
Color	22	40	35	35	40	40	5	45
Iron (Fe)	.5	0	0	2	2	(a)	(b)	(a)
Calcium (Ca)	40	0	....	34	0	31	151	40
Total hardness (as $CaCO_3$)	66	14	28	35	11	37	....	49
Alkalinity	58	11	30	24	8	34	183	39
Sulphates (SO_3)	0	0	0	0	0	0	45	0
Chlorides (Cl)	9	5	9	9	9	9	22	14

[a] Very slight trace. [b] Slight trace.

NEW RIVER FROM GREENBRIER RIVER TO GAULEY RIVER.

Hinton, W. Va.—Hinton (population 4,500) is an important town commercially and a railroad division headquarters. Sanitary conditions are unfortunate here. The water supply of the town is pumped raw from Greenbrier River, about a mile above Hinton. In view of the above-described conditions in that stream the quality of this supply needs no comment.

At the junction of Greenbrier and New rivers there is in the stream a sharply marked dividing line between the clear Greenbrier water and the muddy brown current of New River. The drainage area of New River yields to that stream a great deal of silt and clay, besides ore washings from mines, so that a summer shower will make its water very turbid for several days, yet will not appreciably cloud the Greenbrier. Field assay shows that the water of New River is of fair quality except for this feature. Sedimentation in properly constructed basins would make it very good for industrial purposes. The accumulated pollution of Greenbrier and Bluestone rivers should bar it from use as a source of domestic supply, yet it is so used at some places.

Between Hinton and Thurmond, on New River, there is no town of more than about 1,000 population. The hamlets are massed along the river bank, house after house having its privy located on the river, so that no one would be inclined to drink the raw water at Thurmond (population 450) after inspecting the contamination. It is nevertheless pumped for domestic purposes, though not for drinking by guests, at the large hotel at that town below the mouth of Thurmond Creek.

Field assays show the turbidity of Thurmond Creek, a rapid mountain stream draining a coal region, to be somewhat less than that of the main stream and its quality to be fair in other respects. It is polluted by drainage from a cluster of houses about 100 feet above the mouth.

Pl. V, *A* gives some idea of the rapidity of the current of New River at this point and makes unnecessary the discussion of its profile. It is evident that a stream so rapid will show very little self-purification, so that pollution entering at any point will be carried downstream practically unchanged, except, perhaps, as to the coarser matters, for many miles below. The domestic use of this water raw at Thurmond is very dangerous.

Field assays of water from New River and Thurmond Creek.

[Parts per million.]

Determination.	New River at Hinton.	Thurmond Creek at Thurmond.	New River at Thurmond.
Turbidity	700	90	148
Color	35	17	61
Iron (Fe)	0	(a)	(a)
Calcium (Ca)	46	28	40
Total hardness (as $CaCO_3$)	63	49	59
Alkalinity	54	22	53
Sulphates (SO_3)	[b] 10	33	[b] 5
Chlorides (Cl)	....	9	9

[a] Very slight trace. [b] Estimated.

Below Thurmond the banks of the river are thickly dotted on both sides with little hamlets inhabited by coal miners. The Chesapeake and Ohio Railroad runs along the west bank and the Kanawha and Michigan Railroad along the east bank. At every station privies overhang the banks, sometimes half a dozen within a few feet. Although the total population as far down as Montgomery is not over a few thousand, it is unfortunately true that nearly all its excrement discharges into the stream.

GAULEY RIVER.

What has been said of New River is also true of Gauley River, a beautiful stream entering New River at Gauley Bridge, a village of a few hundred population. At Camden, near the source of the Gauley, the water is very clear and as pure as any found in a state of nature so far as dissolved mineral solids are concerned. With proper sanitation along its course the stream would be an asset of great value in the wealth of the State. The privy of the railroad station at Camden on the Gauley is located on the bank of the stream, so that excreta may seep from it into the water at all times and ordinary rains may wash much pollution into the stream. As the population of this section is very small the sum total of the pollution as far down as Gauley Bridge is not great. The field assay at Gauley Bridge shows that the Gauley at this point is still a very pure and clear stream, its waters being sharply defined against the yellow current of New River. A sample of Cherry River, the principal branch of Gauley, taken at Richwood, shows water of the same character, although somewhat highly colored. Much lumbering is carried on in this section and there is some pollution of the stream by the floating population of the lumber camps, so that at Richwood the water of Cherry River is not used for drinking. This follows the rule observed in other sections—that the small towns at the head of a polluted stream are the first to abandon its use as a water supply. The water supply of Richwood is derived from drilled wells that range in depth from 200 to 300 feet. The water is of very good quality for a water drawn from this depth. It is fairly soft and should be quite satisfactory for general use, although it is by no means equal to the water of Cherry or Gauley rivers if they are kept clean.

Richwood is the principal town drained by the Gauley. There are a number of small communities besides, but it is probable that the total population of the area drained is not over 3,000. It would require only the most ordinary care to keep this stream pure and undefiled.

Field assays of waters of Gauley River basin.

[Parts per million.]

Determination.	Camden, Gauley River.	Richwood.		
		Gauley River.	Cherry River.	Public supply.
Turbidity	0	0	0	0
Color	40	44	70	17
Iron (Fe)	1	5	Trace.	1
Calcium (Ca)	0	0	0	40
Total hardness (as $CaCO_3$)	7	21	14	90
Alkalinity	11	17	15	85
Sulphates (SO_3)	0	0	0	0
Chlorides (Cl)	9	9	9	19

There are very few springs in this section and most of these fail during the latter part of the summer. The spring at Fayette, which comes out of the rock beside the railroad track, a hundred yards or so below the railroad station, is much used for drinking. Its water is very soft, but the high chlorides are disquieting. The spring at Kanawha Falls is much larger and is piped down from the rock for the use of the village, which has a population of about 100. It is a typical soft water.

KANAWHA RIVER FROM GAULEY BRIDGE TO ELK RIVER.

Below Gauley Bridge, New River becomes the Kanawha and is lined on both banks with coal-mining hamlets, all contributing privy droppings to the stream.

The field assay of Kanawha River at Gauley shows a poor water in comparison with that of the Gauley or of Cherry River. The stream was fairly clear at the time of the assay—a rare condition. The channel is very rocky and rough, the river in many places flowing over bare ledges of rock. Although many coal mines discharge into the stream with more or less regularity, the traces of iron and sulphates are so slight as to show that so far as the disinfecting influence of mine drainage is concerned the consumers of this water have no protection.

Montgomery, W. Va.—In spite of pollution the raw water is used as a public supply at Montgomery. At this place the belief is entertained, as at other places in the Monongahela basin, that the mine drainage entering the river exercises sufficient germicidal influence in the water to make it safe for drinking. The field assays of water from New and Kanawha rivers fail to disclose a single instance where there was free acid in the water or where the sulphate and iron contents indicated the presence of mine drainage to more than a slight degree. Inspection of both shores of the river from its source down to the mouth at Point Pleasant reveals no considerable outfall of mine drainage. While there are a large number of mines, there seems to be very little acid water coming out of them, certainly not enough to be of any sanitary importance.

The quality of ground water obtainable at this point is shown by the field assay of water from the 145-foot well at Montgomery. It is too hard to be very satisfactory for domestic uses and its slight cloudiness casts some doubt on the safety of the well from contamination.

Field assays of waters from upper Kanawha basin.

[Parts per million.]

Determination.	Kanawha at Gauley.	Spring at Fayette.	Spring at Kanawha Falls.	145-foot well at Montgomery.	Kanawha River at Montgomery.
Turbidity	0	0	0	0	0
Color	70	17	45	62	70
Iron (Fe)	.5	(a)	(a)	9	1
Calcium (Ca)	96	(a)	0	100	40
Total hardness (as $CaCO_3$)	59	45	31	139+	45
Alkilinity	44	b 4	26	133	55
Sulphates (SO_3)	b 5	0	0	b 5	b 5
Chlorides (Cl)	9	20	7	65	9

a Slight trace. b Estimated.

ELK RIVER.

Sutton and Clay, W. Va.—Elk River is used raw for public supply at Sutton (population, 1,200), about 40 miles below its source at Webster Springs. Previous to the use of the stream water as a public supply at Sutton (assay on p. 99) there was much typhoid fever, traceable to the use of contaminated wells. The local physicians claim that there has been a great falling off in the number of typhoid-fever cases since the introduction of the river water. Sutton drains into the stream, and below it a number of small hamlets contribute their pollution, especially in the neighborhood of Clay (population, 1,000), the county seat of Clay County. A large mining population drains into the stream from this town down to Charleston, so that the raw water can not be considered safe for domestic use at any point below Sutton.

KANAWHA RIVER AT AND BELOW CHARLESTON, W. VA.

Charleston, W. Va.—The largest town in the southern half of the State is Charleston (population, 15,000), which has gained amazingly in wealth and population within the last few years. It is in advance of other places in this section in recognizing the fact that the water of Kanawha River is unfit for use. Its public supply is drawn from Elk River, a stream of great natural beauty, similar to Cherry River and Gauley River.

The intake of the Charleston waterworks is about a mile and a half above the mouth of Elk River; at this point the current of both Kanawha and Elk rivers is very sluggish, forming a stagnant pool, polluted by the city sewage outfalls. The water company is planning to move the intake upstream, so as to guard against this pollution being backed up to the intake by wind. The company is also considering the installation of a crib in the bed of Elk River. The present plant is excellent so far as it goes, there being eight modern filter units in use. This plant, however, is sufficient to purify only about one-third of the daily consumption, so that the present procedure consists of filtering one-third of the supply and then mixing the pure water with the polluted water from Elk River. The installation of a crib for Charleston water supply would be of no value whatever, as it would only clarify the water and would not purify it from organic contamination. In view of the large investment already made in mechanical filters at this point, it would seem best to buy a sufficient number of additional filters and provide for their economical operation, insuring a safe water supply from one of the purest streams in the State so far as mineral contents are concerned. Public opinion will probably compel some such plan in the near future.

The quality of ground water obtainable at Charleston is not very good for domestic uses· Field assays (below) of the two deep wells here show that the water of one is fairly soft for water drawn from so great a depth. It is, however, extremely high in iron, which leaves a heavy yellow deposit on the tanks through which it passes. The other well is so high in chlorides that it would probably give trouble in boilers. Both waters are allowed to pour out of pipes into wooden tanks so arranged as to allow free oxidation. The water is then used in the manufacture of ice.

St. Albans, W. Va.—St. Albans (population, 1,200), about 15 miles below, is located at the point where Coal River enters the main stream. The field assay of Coal River (below) shows it to be of good quality except for high turbidity and color, both due to the nature of the drainage area, which is mostly a heavy red soil in a forest country, rapidly being denuded. There is no public supply at St. Albans. The 70-foot well assayed is typical and shows a rather hard water for domestic purposes. From this point the river flows through a rolling farming country, with scattering hamlets along the banks, the largest town being Winfield (population, 500). The stream is not used for public supply below Montgomery.

Field assays of water, Kanawha basin.

[Parts per million.]

Determination.	Charleston.				St. Albans.		Sutton.
	125-foot well.	200-foot well.	Kanawha River.	Elk River.	70-foot well.	Coal River.	Elk River.
Turbidity	0	0	97	0	0	315	0
Color	78	17	90	70	22	140	96
Iron (Fe)	28	16	1	0	(a)	0	2
Calcium (Ca)	41	81	46	....	49	0	....
Total hardness (as $CaCO_3$)	....	....	49	31	118	21	28
Alkalinity	82	103	44	27	52	20	27
Sulphates (SO_3)	0	(b)	c 5	0	0	0	9
Chlorides (Cl)	55	280	11	14	39	14	9

a Minute trace. b Slight trace. c Estimated.

OHIO RIVER FROM KANAWHA RIVER TO BIG SANDY RIVER.

GUYANDOT AND MUD RIVERS.

Below the confluence of the Ohio and the Kanawha there are no important towns above Huntington, where two small streams enter, both muddy and sluggish. Guyandot River drains a rather flat valley in southwestern West Virginia, and there are no large towns on its drainage area. It is much used to raft lumber down to Ohio River and is much polluted The field assay (p. 100) of the stream at its mouth at Guyandot (population, 1,800) shows very high turbidity; otherwise the water is of fair quality for industrial purposes. Mud

River, a tributary of the Guyandot, joining it at Barboursville, drains a well-populated section along the line of the Chesapeake and Ohio Railroad. The largest town on this stream is Milton (population, 100). At this point a somewhat interesting experiment was made by the railroad in the attempt to get boiler water free from high turbidity. A pool, 8 by 8 feet and 18 feet deep, was dug about 100 yards from the river bank, the water seeping through the bank from the stream into the pool. This water was pumped to a tank for locomotive use, but has been for sometime abandoned. Comparison of field assays show that the water gained about 50 per cent in hardness by its filtration through the ground and lost only about one-third of its turbidity, the particles of soil probably being too fine to be caught by the filtration. Both Mud River and the Guyandot would be suitable for industrial use if properly sedimented with coagulant so as to remove the suspended matter.

OHIO RIVER AT HUNTINGTON, W. VA.

The water supply of Huntington (population,12,000) is drawn from Ohio River, filtered. As the river receives the drainage of Kanawha and Guyandot rivers in West Virginia and Raccoon Creek, Guyandot Creek, and Symes Creek, Ohio, near Huntington, the water must be purified to a high degree to be safe for drinking. For this reason the completeness of the equipment of the Huntington waterworks should be a matter of local pride and general congratulation. Huntington has the best filtration plant in West Virginia—perhaps the only one employing a bacteriologist. It is controlled by the American Waterworks and Guarantee Company, which employs Doctor Witherell to make serial analyses here as at Newcastle and Butler, Pa. The plant pumps from Ohio River by means of five large mains, separately controlled by gate valves and opening at varying distances from the shore so that the disturbance of the water resulting from variations in the height of the river can, to some extent, be counteracted by pumping from different levels. The sedimentation basins are very large and discharge the clarified water into six modern steel filter tanks designed by the company, differing slightly from the Jewell type in the form of cleaning apparatus and in minor details. The pure water is caught in a large tank below the filters and pumped into the mains. The plant is kept in fine condition within and without and is in every way a credit to the town.

The field assay shows the effluent from the mechanical filters to be of very good quality, the mineral content being not appreciably higher than that of the raw water at Pittsburg. The incrusting solids are not high enough to cause trouble in boilers. A fair quality of ground water is obtained in this section, the field assay below being of water from a 57-foot well at the machine shop. The wells in this section range from 50 to 70 feet deep, the one given being typical.

Field assays of water from Milton, Guyandot, and Huntington, W. Va.

[Parts per million.]

Determination.	Milton.		Guyandot.	Huntington.	
	8 by 8 foot well.	Mud River.	Guyandot River.	57-foot well.	Ohio River, filtered.
Turbidity	180	300	667	0	0
Color	80	35	45	22	....
Iron (Fe)	0	0	(a)	1.25	(b)
Calcium (Ca)	107	....	Some.	179	61
Total hardness (as $CaCO_3$)	118	76	55	....	76
Alkalinity	96	48	13	159	30
Sulphates (SO_3)	....	....	0	c 20	c 20
Chlorides (Cl)	39	....	10	29	11

a Very slight trace. b Slight trace. c Estimated.

TWELVEPOLE CREEK.

Twelvepole Creek, which enters the Ohio at Kenova, drains a long, narrow valley containing a scattering farming population.

Dunlow, W. Va.—Dunlow, near the head of the stream, is a small village without either public water-supply or sewerage. The well assayed (below) is at the railroad station and is disused. The high color of the water is due to débris thrown into the well. Evidently a fair quality of water could be obtained here. The spring water is much softer but is liable to high turbidity after excessive rain, as at the time the assay was made. The supply is too small to be of value except for private uses. The field assay of the creek (below) shows excellent water except for the high suspended matter. The hardness is very low, probably being mostly magnesium carbonate. For any industrial purposes this water could be made available by plain sedimentation. It is somewhat used for drinking purposes in the raw state and evidences of privy contamination are plentiful.

Wayne, W. Va.—The stream follows the course of the railroad and receives dejecta from outhouses at every station, so that at Wayne (population 400) the most considerable town on its drainage area, it is altogether unfit for use. There is a deplorable scarcity of water at Wayne, the well assayed (a dug well) being the only important source of supply. Although this water is of good quality so far as mineral matter is concerned, the well is liable to surface contamination, being partly supplied from the roofs of the court-house, which are guttered to lead into it. There are no drilled or bored wells in the town. In summer all the ground water fails, when water is drawn from Twelvepole Creek and used raw. Conditions here are very bad.

Field assays of water from Dunlow and Wayne, W. Va.

[Parts per million.]

Determination.	Dunlow.			Wayne.
	Twelvepole Creek.	Spring.	66-foot well.	60-foot well.
Turbidity	350	250	0	0
Color	35	35	+200	17
Iron (Fe)	0	Trace.	12	.75
Calcium (Ca)	....	....	36	Trace.
Total hardness (as $CaCO_3$)	28	48	....	42
Alkalinity	26	36	75	23
Sulphates (SO_3)	....	0	0	[a] 5
Chlorides (Cl)	9	9	4	9

[a] Estimated.

BIG SANDY RIVER BASIN.

TUG FORK OF BIG SANDY RIVER.

Tug Fork of the Big Sandy, which forms part of the boundary line between West Virginia and Kentucky, probably carries more offensive pollution than any stream in West Virginia, which is saying a great deal. It has its rise near the Virginia line and flows through a densely populated coal region, its tributaries and its own banks being lined at every possible opportunity with privies and other sources of pollution.

North Fork, W. Va.—North Fork, a typical coal camp of this section, has a public supply from a 90-foot well, said to be carefully cased (see assay on p. 103). The only safe water in this section is that drawn from such sources. The Norfolk and Western Railway has put down wells at approximately this depth all along its line. A few of these are not in use, but the majority of them furnish fair water. The field assay shows this well water to be somewhat hard, the high sulphates making it undesirable for use in steam making. Tug Fork is incredibly polluted in its course through this town. A large negro population lives in squalid huts along its banks and discharges excreta continually into its waters, the privies being thickly clustered together in places. The stream is very small at this point, running probably not more than a few second-feet in dry times, so that the state of affairs can be readily imagined.

Welch, W. Va.—At Welch (population 600), the largest town at the head of the creek, the extent of the pollution going into the stream is probably greater, but the public supply is rather carefully guarded. It is derived from 200-foot wells, which are pumped to reservoirs. The field assay (p. 103) shows this to be very hard water, undesirable for any purpose except drinking. The assay of the Norfolk and Western well at this point is interesting for comparison with that at North Fork, which shows a somewhat better water. The chief impurities are calcium carbonate and chloride. For industrial uses the water of Tug Fork is far better than either.

Panther, W. Va.—A characteristic case of water-supply pollution in this State may be seen at Panther, a small lumber hamlet (population 100) situated at the confluence of Panther Creek with Tug Fork. Pl. VI gives two views showing the character of the pollution at this point. The upper picture shows a number of houses located on the creek about a mile above its mouth.

It is evident that drainage from these privies and from the houses must continually find its way into the creek. About 100 feet above the mouth of this creek is the intake pipe by which its water is pumped into a large tank for supplying the mill and the town. The milldam crosses Tug Fork at a point a short distance below the mouth of Panther Creek. The lower picture shows the greater part of the mill, with a large privy close to the boiler house and another across Panther Creek on the left bank of the Tug Fork. It is evident that heavy rains may at any time cause a sufficient rise in Tug Fork to carry contamination from either or both these privies into the intake pipe on the creek. This supply is filthy. Typhoid-fever statistics are unobtainable, but a practicing physician in this neighborhood informed the writer that he had more cases of typhoid fever than of anything else.

The field assay (p. 103) shows the water of Panther Creek to be very excellent as to inorganic content.

Williamson, W. Va.—Between Panther and Williamson, a distance of about 35 miles, numerous thriving little hamlets scattered along the river, each having a population of a few hundred, add a large amount of privy pollution to its water. Notwithstanding this state of affairs, which is well known to all who travel on the Norfolk and Western Railroad, the raw water is used as a source of public supply at Williamson (population 1,800). A number of the citizens realize the danger of using this polluted water and efforts are being made to raise enough money to provide a pure supply. It has been planned to build a filter well in the bed of Tug Fork for this purpose. This would free the supply from the high turbidity which is at present one of its drawbacks and would make the tap water clear and inviting, but would not assure safety to the consumers from water-borne disease. No really satisfactory supply can be gotten for Williamson by this means. Either a complete ground-water system should be installed or steps should be taken to provide a mechanical filter. The quality of the ground water obtainable here is shown by the field assay of the Norfolk and Western Railroad well at the station. Although somewhat hard it is good water, quite satisfactory for general use, and if the well were properly cased would be free from danger of pollution.

A

B

TUG FORK OF BIG SANDY RIVER, NEAR PANTHER, W. VA., PUBLIC-SUPPLY INTAKE.

A, One-half mile above intake; *B*, 50 feet below intake.

Field assays of water from basin of Big Sandy River.

[Parts per million.]

Determination.	North-fork, W. Va.	Welch, W. Va.		Panther.	Williamson. W. Va.	
	90-foot well.	Well.	200-foot well.	Panther Creek.	93-foot well.	Tug Fork.
Turbidity	0	0	0	0	0	0
Color	22	10	34	78	70	44
Iron (Fe)	2.5	1	1.25	1	4	0
Calcium (Ca)	96	56	110	0	96	27
Total hardness (as $CaCO_3$)	....	132	....	21	....	62
Alkalinity	77	58	43	32	120	28
Sulphates (SO_3)	106	[a]5	115	0	[a]5	[a]20
Chlorides (Cl)	20	62	....	7	9	14

[a] Estimated.

BIG SANDY RIVER BELOW TUG FORK.

Kenova, W. Va.—Kenova (population 1,000), a few miles below Huntington, formerly took its water from driven wells. The supply is now drawn from Big Sandy River without purification. The field assays show this to be a much better water for any purpose than that of the Ohio River, the extremely high turbidity of the Ohio putting it out of the question for industrial uses before filtration.

Field assays of water from Big Sandy and Ohio rivers at Kenova, W. Va.

[Parts per million.]

Determination.	Big Sandy River.	Ohio River.
Turbidity	0	422
Color	70	44
Iron (Fe)	0	0
Calcium (Ca)	51	50
Total hardness (as $CaCO_3$)	49	69
Alkalinity	78	52
Sulphates (SO_3)	[a]10	[a]10
Chlorides (Cl)	19	24

[a] Estimated.

SUMMARY OF CONDITIONS BELOW PITTSBURG.

The water-supply problems before municipalities on Ohio River and on the Kanawha are not fundamentally different from those confronting towns on Allegheny and Monongahela rivers. In the case of the Ohio we have seen that although the water is heavily contaminated by sewage from over half a million people, it is extensively used for drinking in its raw state. The only possible plea for such use is that there is self-purification going on in the river. No elaborate argument is needed to show the fallacy of this plea after the discussion already presented. It is sufficient here to say that conditions on the Ohio are less favorable to purification by detention than on the Monongahela, where purification has been shown to be imperfect or inefficient. For this inefficiency there are two reasons: First, although the Ohio is well canalized, its greater slope and greater quantity of water make its velocity considerably higher than that of the Monongahela; second, enormous freshets, which occur in the Monongahela in the spring, happen much more frequently in the Ohio, every heavy rain causing a sharp rise, and as the difference between high and low water in this river is 50 feet or more, it is perfectly clear that pathogenic material deposited at the bottom by sedimentation could be scoured out at frequent intervals, poisoning the water for use as a source of public supply. The only way to obtain pure water from the Ohio is to resort to filtration, and the experience of numerous towns in the valley and on the Mississippi River has shown that for this turbid water mechanical filtration is more practicable than slow sand filtration. This is partly because of the ability of small towns to purchase and operate a small filter plant, the cost of the English system being prohibitive, and partly because waters of such high turbidity clog sand filters very rapidly, causing a greatly increased operating expense.

In spite of these conditions, on the whole stretch of stream between Pittsburg, Pa., and Catlettsburg, Ky., there is but one town—Huntington, with about 12,000 inhabitants—efficiently operating a filtration plant, and but three towns where natural filtration of any importance has been attempted—Moundsville and Point Pleasant, in West Virginia, and Gallipolis, in Ohio. The typhoid fever statistics obtainable for Gallipolis condemn all three supplies, and it is altogether likely that a heavy percentage of unreported cases should be added to the official figures. Altogether there is urgent need in this section for education along sanitary lines.

The tributary streams seem worse than the Ohio, because they are so much smaller and the contamination is so much more apparent. The cases noted where privies are located but a few hundred feet or a few miles above the intake of a public supply are not cited as unusual or extreme cases. On the contrary, in describing these conditions, an effort has been made to speak as moderately as possible. The facts themselves are sufficiently startling. It is a practically universal custom in West Virginia to build privies on running streams if it is possible to do so without going too far from the house. This was found to be the case to a greater or less degree on every stream, of whatever size, in the State. As a result every stream in West Virginia is grossly polluted and at the same time used without purification for domestic water supply.

On New and Kanawha rivers the conditions are even worse than on the Ohio, on account of the closely collected coal-mining population along the banks of the streams. The velocity of the water in these streams is so high that detention is a negligible factor although the Kanawha is to some extent canalized, and the only influence toward self-purification that need be considered is the germicidal effect of mine drainage and ore washings. It has been shown above that neither sulphuric acid nor the sulphates are present in this water in sufficient quantity to make them at all comparable with the waters of the Monongahela and Youghiogheny. It has been shown such influences are ineffective in purifying the Youghiogheny. On Kanawha and New rivers they are practically negligible, being just sufficient to impart unpleasant qualities to the water without having any germicidal effects.

ERIE, PA.

The city of Erie (population, 60,000) is located on the south shore of Lake Erie and of Presque Isle Bay, a small body of water about 4 miles long and 1½ miles wide, with an average depth of 15 feet, although a portion of the bay is 22 feet deep. The bay is landlocked save at the eastern end, where a 300-foot channel connects it with Lake Erie.

The first city supply was derived by gravity from a spring-fed reservoir. On the abandonment of this system, many years ago, the supply was drawn from the bay at a point 975 feet north of the southern shore. As the city grew in population and the sewers of many thousands of people poured their daily pollution into the bay, the supply speedily became unfit for use, and in 1896 the present intake was built. It is 60 inches in diameter and extends for 8,000 feet out into the bay.

The present supply is therefore taken from what is practically a large sedimentation basin of the dimensions above given, the detention in which, though somewhat disturbed by the wind and the rising and falling of the lake level, would yet cause great improvement in the quality of the water if the pollution were not of the grossest character. The fact is, however, that the contamination is so offensive in kind and so great in amount as to make the water utterly unfit for drinking or domestic use in its raw state. The conditions were very well summarized by Judge Walling in his recent decision of the suit brought by certain persons to restrain the commissioners of the city of Erie from proceeding with the improvement of the supply.

The city is situated on land descending to the bay, into which the contents of 62 miles of sewers are emptied, and which also receives the washings from 31 miles of paved streets and much filth from barns and other buildings. Nearly 10,000 water-closets are in daily use in the city, the discharge from which is carried into the bay. A large amount of garbage and offal is also thrown into the bay from ships in the harbor and from fish houses and other buildings on the shores. The creeks that run through the city into the bay are practically open sewers from the county farms and other places west of the city. The city of Erie is thus using the bay both as a cesspool and as a source of water supply. With the sewage from all these sources daily going into the bay, there to be circulated by the movements of the water till the whole is simply somewhat diluted sewage, and the city at the same time pumping its water out of the pollution, the figures showing typhoid mortality seem surprisingly low. The following table, taken from statistics by the board of health of the city of Erie, given in its annual report for 1904, shows the number of deaths in this city from typhoid fever as well as the rate per 100,000 of inhabitants, from 1876 to 1904, inclusive:

Typhoid mortality at Erie, Pa.

Year.	Deaths.	Rate per 100,000.	Year.	Deaths.	Rate per 100,000.
1876	13	20	1891	30	71
1877	10	40	1892	24	55
1878	6	23	1893	15	34
1879	7	22	1894	17	37
1880	4	14	1895	21	45
1881	17	58	1896	18	37
1882	19	62	1897	13	26
1883	6	19	1898	8	16
1884	6	18	1899	18	35
1885	10	29	1900	18	34
1886	11	31	1901	8	15
1887	7	19	1902	13	25
1888	9	23	1903	17	29
1889	19	48	1904	27	46
1890	29	71			

That the figures show no uniformity of increase during the earlier years is probably due in part to incomplete returns and in part to the more accurate methods of diagnosis of the present day, which distinguish as typhoid fever some diseases that were formerly classified otherwise. For the years 1887 to 1895 the tendency is seen to be quite clearly upward. The extension of the intake pipe in 1896 had its effect in lowering the mortality rate for a time, as is shown by the steady decrease for three years, 1896 to 1898, inclusive. That this improvement could continue long with the rapid growth of population and coincident increase in pollution was not to be expected. With the exception of the year 1901 the figures have climbed steadily upward until in 1904 there were in the city 46 deaths from typhoid fever to the hundred thousand—certainly too many.

The dangerous character of this water should be obvious to anyone who sees the sewage going into the bay and then sees it pumped out as drinking water. Sanitary inspection is to-day considered more trustworthy, in the absence of conditions allowing perfect control, than sanitary analysis. In this instance there are no factors modifying the character of the supply that can not be accurately estimated, as the water is not subject to great fluctuations in quality or quantity. The evidence at hand may therefore be well supplemented by sanitary analyses of this water made by Dr. W. P. Mason, covering the period from 1892 to 1901, which show the gradual increase in sewage pollution by the steady rise of the chlorine content. As the quantities considered in water analysis are very small, a change of a small fraction of a part per million may be significant, in the absence of adequate cause for it. No sanitary analysis of water is valuable except when it is considered in conjunction with the exact conditions. In this case the conditions exclude any factor but the increase in sewage pollution to account for the increase of chlorine.

Sanitary analyses of water at Erie, Pa.

[Analyses by W. P. Mason, in parts per million.]

Sample No.	Place and date.	Total solids.	Albuminoid ammonia.	Free ammonia.	Nitrates.	Chlorine.
1	Intake June, 1892	132	0.175	0.100	Trace.	6
2	Pittsburg dock, June, 1892	128	.200	.130	Trace.	6
3	Big Bend, June, 1892	138	.145	.065	Trace.	7
4	Faucet in residence, June, 1892	141	.190	.050	Trace.	6
5	New intake, June, 1900	115	.146	.155	0.137	2
6	New intake, September, 1900	105	.133	.073	.063	9.5
7	New intake, November, 1900	171	.048	.081	.087	8.0
8	New intake, February, 1901	135	.112	.080	.200	8.5

Aside from the remarkably low figure for June, 1900, the rise in the chlorine content of this water is too steady and too uniform to be mistaken. The low figure mentioned may have been due to the fact that the sample was taken just before the seasonal change in the water strata, due about August at Erie. The summer's accumulation of sewage was probably stirred up from the bottom, making the chlorine content in the next sample higher and the figure for the June sample very low. This, however, would only partially explain the difference. The final figures, 8.5 parts per million, acquire further significance when compared with those of December, 1889, when at the inlet of the water works, then much closer to the shore, the chlorine content as determined by Doctor Cresson was but 3.188 parts per million.

The columns headed free ammonia, albuminoid ammonia, and nitrates give the quantity of nitrogen in this water expressed in the three forms in which it was determined. So expressed, the amount of nitrogen found in water is an index, under proper conditions, of the amount of organic matter present. Taken by itself, any one of these factors is meaningless; taken in conjunction with a number of others in cases where it is impossible to control the factors of impurity, as in the Mississippi River, they may be misleading; but in the case of Presque Isle Bay there is no possibility that much organic matter gets into the water except through sewage contamination. This being admitted, the figures show that there was much organic pollution at the time of the analyses.

Nor is bacteriological evidence wanting of the contamination of the basin. The following figures, summarizing analyses made by Doctor Mason from April, 1901, to February, 1903, shows the presence of bacteria which are invariably associated with wastes from animal intestines:

Bacteriological analyses of water at new intake, Erie, Pa.

Date.	Taste.	Odor.	Color.	Turbidity.	Alkalinity.	Bacteria per c. c.	Bacillus coli communis.
Apr. 1, 1901	0	0	0.1	6	47.5	5,500	Present.
June 10, 1901	0	0	0	0	50	....	Present.
Oct. 1, 1901	0	0	Trace.	Slight.	50	119	None.
Jan. 22, 1902	0	0	.22	(a)	50	637	Present.
Apr., 1902	0	0	.2	Slight.	90	402	Present.
Feb. 20, 1903	0	0	10	....	....	....	

[a] Very slight.

All but one of these samples contained bacillus coli, which could only have entered the water by fœcal contamination. The evidence seems conclusive that Presque Isle Bay is, as was said by Mr. George Y. Wisner in his report to the commissioners upon the advisability of getting a new supply, "little less than a diluted cesspool."

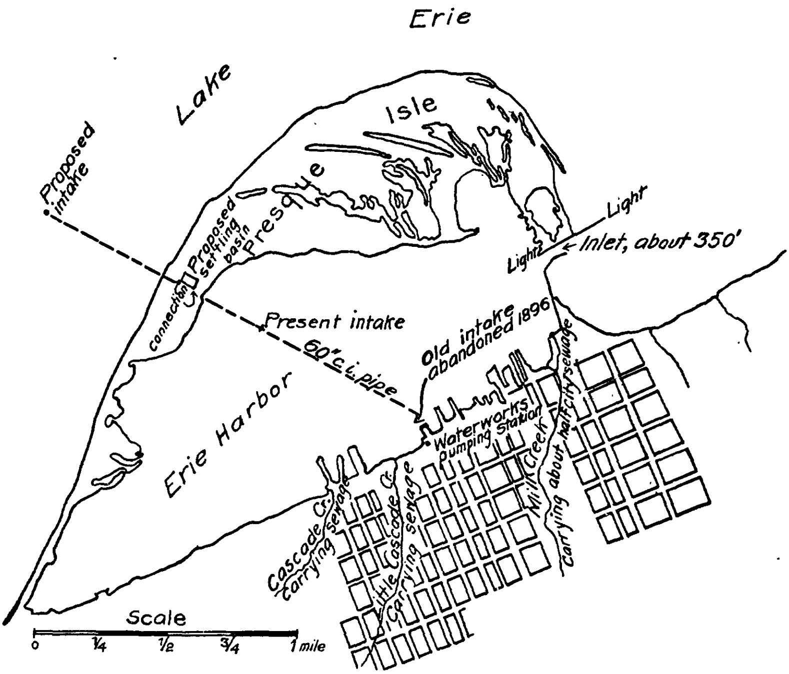


FIG. 3.—Map of Erie, Pa., and Erie Harbor, showing proposed improvement in water supply.

It became necessary either to filter this water or to get a new supply from Lake Erie. The former course would involve a very large first cost, both for the filtering plant itself and for the intercepting sewer that would be necessary to convey all contamination out into the lake, as otherwise the imperfections of practical operation would make the effluent highly suspicious. The most economical solution of the problem, as well as the best in the long run, is certainly the plan adopted—that of extending the present intake pipe out into Lake Erie to a sufficient distance to insure a pure supply for some time to come.

The following analyses of Lake Erie water show that it is greatly superior to the water of the bay, and that it contains no bacteria that point to sewage contamination:[a]

Analyses of Lake Erie water.

[Parts per million.]

Date.	Color.	Turbidity.	Free ammonia.	Alb. ammonia.	Chlorine.	Nitrates.	Alkalinity.	Total solid.	Bacteria.
Apr. 1, 1901	0.1	12	0.039	0.075	6.5	0.15	42.5	140	3,000
June 10, 1901	0	0	.02	.095	6	.075	50	126	....
Oct. 10, 1901	0	Slight.	.071	.093	6	.037	50	134	70
Jan. 22, 1902	.1	Slight.	.053	.109	7	.125	55	172	126
Apr. 19, 1902	.025	....	.056	.159	8	.025	100	142	80
Feb. 20, 1903	5	25	.039	.105	5	.1	97.5	147	2,490

Although this water is far superior to the present supply, the increase in alkalinity, probably due to sewage contamination, would seem to indicate that in time filtration will be necessary. The direction of the prevailing winds on the lake, together with the eastward current, causes the sewage from Toledo, Sandusky, Cleveland, and Ashtabula to be drifted eastward. The great distance of Toledo and Sandusky from Erie make it probable that their sewage is completely oxidized before it reaches the Erie intake. Ashtabula, a city of 13,000 population, lies about 48 miles west of Erie, and Cleveland, with 381,000 people, about 90 miles west. The currents set along the south shore and such sewage from these places as does not sink to the bottom within the first few miles after leaving the towns is swept eastward, steadily decreasing in quantity and becoming less dangerous in quality until near Presque Isle it begins to take a more northeasterly direction. Yet at no time can it probably dangerously affect the quality of the new supply, as there seems to be every favorable condition in this immense body of water to insure perfect oxidation of the contaminating influents before the Erie intake is reached. The contingency of increasing pollution of the lake water is of less present importance than the turbidity occurring at certain seasons of the year, which, as may be seen from the foregoing analyses, may be high enough to give the water an objectionable appearance. This difficulty can certainly be overcome by the construction of sedimentation basins on Presque Isle, as provided in the plans.

The projected improvements, designed by Mr. George H. Fenkell, and now going rapidly forward under his direction, contemplate the extension of the 60-inch steel intake pipe about 10,000 feet northward beyond the present intake, across Presque Isle Peninsula and into Lake Erie, with 5-foot gate valves for connections with the settling basins, etc., and a timber crib, weighted with stone, protecting the end of the intake pipe, which terminates in a special opening about 25 feet below mean lake level. The work shows a number of construction features of interest, in particular the submarine joint designed for this work. This has a gasket of lead pipe snugly fitting the steel intake pipe, and when the joint is made the 16-inch bolts are screwed up so as to bring the flanges together, compressing the lead between them and insuring a tight joint.

[a] Rept. Dept. Health, 1902 and 1904.

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CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 161.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports; (2) Monographs; (3) Professional Papers; (4) Bulletins; (5) Mineral Resources; (6) Water-Supply and Irrigation Papers; (7) Topographic Atlas of United States—folios and separate sheets thereof; (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

Most of the above publications may be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they may be obtained, free of charge (except classes 2, 7, and 8), on application.
2. A certain number are delivered to Senators and Representatives in Congress, for distribution.
3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they may be had at practically cost.
4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they may be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the thirteenth in Series L, the complete list of which follows (PP= Professional Paper, B=Bulletin, WS=Water-Supply Paper):

SERIES L, QUALITY OF WATER.

WS 3. Sewage irrigation, by G. W. Rafter. 1897. 100 pp., 4 pls. (Out of stock.)

WS 22. Sewage irrigation, Pt. II, by G. W. Rafter. 1899. 100 pp., 7 pls. (Out of stock.)

WS 72. Sewage pollution near New York City, by M. O. Leighton. 1902. 75 pp., 8 pls.

WS 76. Flow of rivers near New York City, by H. A. Pressey. 1903. 108 pp., 13 pls.

WS 79. Normal and polluted waters in northeastern United States, by M. O. Leighton. 1903. 192 pp., 15 pls.

WS 103. Review of the laws forbidding pollution of inland waters in the United States, by E. B. Goodell. 1904. 120 pp.

WS 108. Quality of water in the Susquehanna River drainage basin, by M. O. Leighton, with an introductory chapter on physiographic features, by G. B. Hollister. 1904. 76 pp., 4 pls.

WS 113. Strawboard and oil wastes, by R. L. Sacket and Isaiah Bowman. 1905. 52 pp., 4 pls.

WS 121. Preliminary report on the pollution of Lake Champlain, by M. O. Leighton. 1905. 119 pp., 13 pls.

WS 144. The normal distribution of chlorine in the natural waters of New York and New England, by D. D. Jackson. 1905. 31 pp., 5 pls.

WS 151. Field assay of water, by M. O. Leighton. 1905. 77 pp., 4 pls.

WS 152. A review of the laws forbidding pollution of inland waters in the United States, second edition, by E. B. Goodell. 1905. 149 pp.

WS 161. Quality of water in upper Ohio River basin and at Erie, Pa., by S. J. Lewis. 1906. — pp., 6 pls.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

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