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CHEMICAL AND BIOLOGICAL SURVEY OF THE WATERS OF ILLINOIS

REPORT FOR YEAR ENDING DECEMBER 31, 1911

EDWARD BARTOW

DIRECTOR

WATER SURVEY SERIES No. 9

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SAMUEL WILSON PARR, M.S. . . . . Consulting Chemist
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†To May, 1911.
*After September, 1911.

LETTER OF TRANSMITTAL

STATE WATER SURVEY.

UNIVERSITY OF ILLINOIS,
Urbana, Illinois, February 1, 1912.

EDMUND JANES JAMES, PH.D., LL.D.,
President University of Illinois.

SIR: Herewith I submit a report of the work of the State Water Survey for two years ending December 31, 1911, and request that it be printed as a bulletin of the University of Illinois, State Water Survey Series No. 9.

The report contains a statement concerning the expansion of the Survey during the latter half of the year, made possible by increased appropriations, a summary showing the analytical work done in each year since the foundation of the Survey, and a summary showing the analytical work done in each month during 1911, and a brief review of work being done with reference to the quality of water in the state by other organizations. Abstracts of reports of the engineering division are given. There are several special articles which describe the expermental work and investigations carried on during the year.

Thanks are due to the regular laboratory staff for their interest in the work of the Survey and to Prof. A. N. Talbot, Dr. R. H. Jesse, Mr. C. E. Millar, M. S., and Mr. B. H. Harrison, B.S., for assistance rendered in the preparation of special articles, and to Messrs. Alvord and Burdick for permission to publish the report on the pollution of Fox River at Geneva. Credit is given in appropriate places for the part each has taken.

Respectfully submitted,
EDWARD BARTOW,
Director.

GENERAL REPORT

GENERAL STATEMENT FOR THE YEAR ENDING DECEMBER 31, 1911.

The year 1911 has seen a notable advance in the work of the State Water Survey. The 47th General Assembly passed a law which permitted considerable expansion. Because of its vital influence on the work of the Survey, the law is quoted in full.*

EDUCATIONAL—UNIVERSITY OF ILLINOIS, WATER SURVEY.

1. Authorizes employment of field men.
2. Appropriates $15,000 per annum.
3. Annual and special reports.
4. How drawn.

AN ACT imposing new and additional duties upon the State Water Survey and making an appropriation therefor.

SECTION 1. Be it enacted by the People of the State of Illinois, represented in the General Assembly: That the State Water Survey, heretofore established at the University of Illinois, shall, in addition to the duties heretofore imposed upon it, be authorized and instructed to employ such field men as may be necessary to visit municipal water supplies and inspect watersheds, to make such field studies and to collect such samples as are necessary, to analyze and test samples and to make any investigations to the end that a pure and adequate public water supply for domestic and manufacturing purposes may be maintained in each municipality, to make sanitary analyses free of charge of samples of water from municipal water supplies or from private wells collected according to the directions of the State Water Survey, and to report the result of such examination to the Board of Health, Superintendent of Water Works, other officer or officers of the Water Department of the city, village or incorporated town or to citizens by whom the samples, respectively, were collected.

Sec. 2. That the sum of fifteen thousand dollars ($15,000) per annum, or so much thereof as may be necessary, is hereby appropriated out of any money in the State treasury not otherwise appropriated, to be used for the payment of salaries or other compensation of the assistants and employees and for such other expenses as may be necessary for visiting municipal water supplies; inspecting watersheds, making field studies, and collecting and testing samples of water, and for making

*Laws of Illinois, 47th General Assembly, 1911, 43.

any investigations that will show how to best obtain or conserve an adequate supply of pure water for domestic and manufacturing purposes in every section of the State.

Sec. 3. That an annual report of the work of the State Water Survey and such special reports as may be necessary shall be published.

Sec. 4. That the Auditor of Public Accounts is hereby authorized and directed to draw his warrant on the treasurer for the amounts herein appropriated, payable out of any money in the treasury not otherwise appropriated, upon the order of the Board of Trustees of the University of Illinois, attested by its secretary and with the corporate seal of the university; and no installment subsequent to the first shall be paid by the treasurer, nor warrant drawn therefor, until detailed accounts showing expenditures of the preceding installments have been filed with the Auditor of Public Accounts; and, provided, further, that vouchers shall be taken in duplicate, and the original of duplicate vouchers shall be forwarded to the Auditor of Public Accounts for the expenditure of sums appropriated in this Act.

The above bill originated in the Senate, was passed by the House without amendment, and on May 25, 1911, was approved by the Governor, and became a law. The passage of this bill was brought about largely through the influence of the members of the Illinois Water Supply Association with the assistance of the Illinois Society of Engineers and Surveyors. Without the efforts of the committee of this Association, consisting of Mr. F. C. Amsbary, Mr. H. B. Morgan, and Mr. W. J. Spaulding, the legislation would not have been obtained.

The original bill authorizing the formation of a Water Survey has never been published in any of the Survey Bulletins. For the sake of those who may be interested, it is published here.*

CHEMICAL SURVEY OF THE WATERS OF ILLINOIS.

§1. Trustees of the University of Illinois to establish a chemical survey of the waters of Illinois.

§2. Duty of the University.

§3. Appropriates $3,000 per annum for making survey.

§4. How drawn.

AN ACT to establish a chemical survey of the waters of the State of Illinois.

SECTION 1. Be it enacted by the People of the State of Illinois, represented in the General Assembly: That the trustees of the University of Illinois, are hereby authorized and directed to establish a chemical and biological survey of the waters of the State in connection with said university.

§ 2. It shall be the duty of the university to collect facts and data concerning the water supplies of the State; to collect samples of waters from wells, streams and other sources of supply, to subject these samples to such chemical and biological examination and analyses as shall serve to demonstrate their sanitary condition, and to determine standards of purity of drinking waters for the various sections of the State, to publish the results of these investigations in a series of reports to be issued annually, or oftener, to the end that the condition of the potable waters of the State may be better known, and that the welfare of the people of the various communities of the State may thereby be conserved.

§ 3. For the installation and support of said survey there is hereby appropriated the sum of three thousand ($3,000) dollars per annum.

§ 4. The Auditor of State is hereby authorized and directed to draw his warrants quarterly, in advance, on the Treasurer for the sums hereby appropriated,

*Laws of Illinois, 40th General Assembly, 1897, 12.

upon the order of the chairman of the Board of Trustees of the University of Illinois, attested by the secretary, and with the corporate seal of the university: PROVIDED, that no part of said sums shall be due and payable to said institution until satisfactory vouchers, in detail, approved by the Governor, shall be filed with the Auditor, for the expenditure of the last quarterly installment of appropriations herein made.

APPROVED June 7, 1897.

The Water Survey has been carrying on a scientific study of water conditions in the State for 15 years, and this study has shown the need of funds for the employment of field men to visit all parts of the State. As soon as sufficient funds were available, a field division or engineering division of the State Water Survey was organized with the following Staff:

Engineer, Mr. Paul Hansen, Massachusetts Institute of Technology, B.S., 1903; Engineering Assistant with the Massachusetts State Board of Health, 1903; Draftsman on designs for improved Water Supply and Sewerage, Columbus, Ohio; Engineer with the Pittsburg Filter Company, 1905; Assistant Engineer, Ohio State Board of Health, 1906; Acting Chief Engineer, Ohio State Board of Health, 1909; State Sanitary Engineer of Kentucky, 1910.

Assistant Engineer, Mr. Ralph Hilscher, Beloit College, B.S., Beloit, Wis., 1908; Massachusetts Institute of Technology, 1909–1910; Asst. Engineer, Massachusetts State Board of Health, 1910.

Assistant Engineer, Mr. Walter G. Stromquist, Bethany College, Lindsborg, Kansas, B.A., 1905; University of Kansas, 1906; University of Illinois, B.S., 1910; Assistant Engineer, Excelsior Springs, Missouri, 1910.

Inspector, Mr. W. F. Langelier, B.S., New Hampshire College, 1909; Chemist State Water Survey, 1909–11.

Chemist, Mr. H. P. Corson, B.S., New Hampshire College, 1910; Assistant in Chemistry, University of Illinois, 1910–11.

Bacteriologist, Mr. W. Bernreuter, B.S., University of Illinois, 1910; Bacteriologist State Water Survey, 1910–11.

Chemist, Mr. F. C. Gephart, B.A., University of Kansas, 1906; Research Assistant Northwestern University Medical School, 1907–11.

The laboratory staff is practically the same as before, excepting the addition of another chemist.

It is not the purpose of the Engineering Division of the State Water Survey to do the work ordinarily done by municipal engineers or by consulting engineers. It is not the plan to do engineering work, but to see that water companies and municipalities proceed along proper lines in making additions or in the construction of new work.

To indicate the character of the work that may be done, we need but say that there are 115 municipalities of 1,000 inhabitants or more without general water supplies. Our investigation has shown that in that part of the State where the greater proportion of the towns are without water supplies, the typhoid fever rate is the greater; whereas, in that section of the State where most of the towns have general supplies, the typhoid fever rate is lower. We have already had requests for assistance from several towns which are contemplating the installation of supplies, or the improvement of existing supplies: Anna, Benton, Breese, Carlyle, Casey, Chester, DeKalb, Eldorado, Fairfield, Georgetown, Harrisburg, Mounds, Peoria Heights and Rankin.

As shown in a report prepared for the Illinois Society of Engineers and Surveyors,* the majority of the water supplies which obtain water from streams are furnishing an unfiltered water. In many cases the claim is made that the water is not used for drinking purposes. This situation may be criticized, because it is difficult to prevent people from drinking an easily obtainable impure water, and if the general supply is admittedly bad, the residents will use water from shallow wells which may be worse. Several towns are considering the installation of filter plants, some of which we have been able to assist, namely: Mt. Carmel, Effingham, Pana and Harrisburg.

We are also taking up again the regular control of the water furnished by filter plants already installed and are urging the installation of small laboratories for chemical and bacteriological control. Such laboratories have been established at Kankakee, Rock Island, Streator, Pontiac and Danville. The authorities at Alton, Elgin and Lake Forest are considering the installation of such laboratories. It is sometimes possible to make arrangements with local chemists to do the analytical work, as at Macomb, where the necessary tests are made by the Professor of Chemistry in the State Normal School, and at Evanston, where the work is done by a Professor of Chemistry in the Northwestern University.

Studies have been made of the watersheds of the Fox River and the Vermilion River, and of the shore of Lake Michigan from Chicago to the State line. These surveys have been made at the request of municipalities or citizens in the respective areas. In fact, the Survey prefers to do work in response to requests from the citizens of a community, for then it is assured of local co-operation. The number and character of the requests which have come to us have been very gratifying. and the members of the Survey staff feel very hopeful for the future.

We propose to carry on what might be called a "Campaign of Education." We are prepared to give illustrated lectures to assist in influencing public opinion in favor of the introduction of general water supplies, the filtration of surface supplies, or in methods of sewage disposal.

REPORT OF LABORATORY DIVISION.

From the time of its foundation, September, 1895, to December 31st, 1911, the State Water Survey has received 22,789 samples of water (see Table I). Of these, 13,252 were sent by private citizens, health

*Report 26, 161.

TABLE I. SHOWING THE NUMBER OF WATER SAMPLES EXAMINED AT THE DIRECT REQUEST OF PRIVATE CITIZENS OR LOCAL HEALTH OFFICERS, ARRANGED BY YEARS AND ACCORDING TO THE NATURE OF THE SOURCE.

SOURCES.	Oct. 1895, to Dec 31, 1896	YEARS.															Total for each source.
		1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	
Surface waters, rivers, lakes and ponds	69	72	102	54	59	61	97	75	80	107	304	336	356	372	428	196	2768
Springs	16	21	34	23	22	35	28	18	28	41	63	52	68	62	41	29	581
Cisterns	12	19	17	7	7	3	10	6	7	5	13	29	28	31	21	25	240
Natural ice	4	12	1	11	9	4	9	3	12	6	....	1	5	1	12	9	99
Artificial ice	....	1	....	2	1	....	1	1	....	4	....	....	0	0	0	1	12
Water for artificial ice	3	....	....	3	....	1	1	....	5	2	1	....	1	2	0	2	21
Water for natural ice	....	2	....	....	....	3	1	1	2	....	6	....	....	3	0	3	21
Shallow wells in rock	28	16	8	22	12	22	10	17	25	25	19	45	32	53	43	29	406
Deep wells in rock	58	48	34	26	36	56	59	23	28	66	170	159	258	345	207	119	1492
Flowing wells in rock	45	8	16	12	13	14	3	8	9	11	22	17	43	3	2	2	228
Shallow wells in drift	500	245	168	243	274	209	243	245	270	292	142	514	683	614	344	256	5542
Deep wells in drift	64	68	43	30	24	36	63	54	51	40	114	154	160	159	95	103	1258
Flowing wells in drift	63	5	4	9	4	....	3	5	5	12	19	25	2	1	7	....	164
Sewage	37	....	21	25	10	....	1	7	2	6	6	5	33	46	5	1	200
Unknown	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	20
Total samples from citizens	899	517	448	467	471	444	529	463	525	613	1182	1365	1682	1651	1201	795	13052
Other Samples	888	811	988	1579	1866	778	147	419	555	466	445	55	87	73	101	279	9537
Total for year	1787	1328	1436	2046	2337	1222	676	882	1080	1079	1627	1420	1769	1724	1302	1074	22589

officers, or water works officials. The remaining samples, with the exception of 2,800, collected in connection with the investigation of the Chicago Drainage Canal, have been collected by the members of the staff, or under their direction for the study of special problems.

During the year 1911, 1,074 were received (see table II), 795 having been sent to the Laboratory by health officers or private citizens. The number received from outside parties was less in 1911 than in any year since 1905 (see Table I). This was due to the fact that the 46th General Assembly decreased the appropriation for the work of the State Water Survey, and it was impossible to make, free of charge, analyses for all who desired such work. Beginning with July, 1910, a small fee was charged to cover the cost of analyses. The effect of this charge was seen in the decrease of the number of analyses to 410 during the latter half of 1910 compared with 1,022 during the latter half of 1909. Two hundred and forty-one samples were received during the first half of 1911, whereas 554 were sent in during the second half of 1911 after analyses were again made free of charge. When the additional funds became available, a new letter of information was prepared in accordance with the provisions of the law as follows:

Dear Sir:

By an act of the 47th General Assembly, the State Water Survey "is authorized and instructed to employ such field men as may be necessary to visit municipal water supplies and inspect watersheds, to make such field studies and to collect such samples as are necessary, to analyze and test samples and to make any investigations to the end that a pure and adequate public water supply for domestic and manufacturing purposes may be maintained in each municipality, to make sanitary analyses free of charge of samples of water from municipal water supplies or from private wells collected according to the directions of the State Water Survey, and to report the result of such examination to the Board of Health, Superintendent of Water Works, other officer or officers of the Water Department of the city, village, or incorporated town, or to citizen by whom the samples, respectively, were collected."

In accordance with the above Act the State Water Survey will make sanitary analyses of samples of water collected according to its directions. The Survey will consent to make sanitary analyses free of charge whenever a request is endorsed by a Health Officer or there is a possibility of injury to health because of the character of a water supply, either public or private.

A representative of the Survey is available for consultation with respect to water supplies, water purification and sewage disposal.

Analyses to determine the mineral content of a water, to determine the medicinal value, or to determine the character of a water with reference to its use in boilers or for manufacturing purposes, may be made, but a fee (except for municipal supplies collected by a representative of the Survey) will be charged to cover the cost of the analysis.

TABLE II. SHOWING THE NUMBER OF WATER SAMPLES EXAMINED DURING THE YEAR ENDING DECEMBER 31, 1911. ARRANGED BY MONTHS ACCORDING TO THE NATURE OF THE SOURCE.

SAMPLES BY REQUEST.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Surface waters, rivers, lakes, ponds	22	15	22	8	14	7	17	15	14	28	17	17	196
Springs	2	4	1	1	1	1	5	2	1	3	3	5	29
Cisterns	......	......	1	......	......	......	......	......	6	3	6	9	25
Natural ice	2	4	1	......	......	2	......	......	......	......	......	......	9
Artificial ice	......	......	......	1	......	......	......	......	......	......	......	......	1
Water for nature ice	2	1	......	......	......	......	......	......	......	......	......	......	3
Water for artificial ice	......	......	......	2	......	......	......	......	......	......	......	......	2
Shallow wells in rock	2	......	......	1	......	1	1	4	2	7	5	6	29
Deep wells in rock	4	7	3	9	7	5	7	20	15	10	12	20	119
Flowing wells in rock	......	......	......	......	......	......	......	1	......	1	......	......	2
Shallow wells in drift	6	9	15	3	9	12	45	37	36	32	32	20	256
Deep wells in drift	5	1	4	9	3	5	8	16	16	15	16	5	103
Flowing wells in drift	......	......	......	......	......	......	......	......	......	......	......	......	......
Sewage	......	......	......	......	......	......	1	......	......	......	......	......	1
Unknown	4	......	......	1	......	2	......	6	1	1	1	4	20
Total samples by request	49	41	47	35	34	35	84	101	91	100	92	86	795
ANALYSES MADE ON THE INITIATIVE OF THE STATE WATER SURVEY.													
Surface, rivers, lakes, ponds	10	......	3	4	8	1	20	17	9	10	18	10	110
Springs	......	......	......	13	......	1	1	......	......	......	......	......	15
Deep wells in rock	......	7	......	......	......	6	2	......	4	......	1	3	23
Flowing wells in rock	......	......	......	......	......	2	......	......	......	......	......	......	2
Shallow wells in drift	2	......	......	......	......	2	11	6	......	......	......	10	31
Deep wells in drift	2	7	3	......	......	7	1	......	......	......	4	3	27
Sewage	......	......	......	......	......	......	......	......	2	......	......	......	2
Trade wastes	......	......	......	......	......	......	11	......	8	......	......	......	19
Swimming pool	......	......	......	......	50	......	......	......	......	......	......	......	50
Total on initiative of State water survey	14	14	6	17	58	19	46	23	23	10	23	26	279
Total	63	55	53	52	92	54	130	124	114	110	115	112	1074

The Survey requires that samples be collected in specially cleaned, glass-stoppered bottles, which the Survey furnishes, and that all transportation charges be paid. Whenever possible, samples of water, especially of water from municipal supplies, will be collected by a representative of the Survey.

If work is desired as outlined above, kindly indicate as fully as possible on the inclosed card your reasons for desiring it. Should the reasons warrant, containers will be forwarded and, if necessary, a representative of the Survey sent as soon as possible.

Address all communications,

DIRECTOR STATE WATER SURVEY, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS.

Very truly yours,

EDWARD BARTOW,
Director State Water Survey.

The card mentioned in the information letter, reduced one-third, is shown below.

(Name)	(Address)
Desires*.......analyses of water from †	Reason for desiring the analysis†
Well .... Pond	Typhoid fever............. Sediment ....
Spring .... Sewer	Other diseases..............Odors ....
Cistern.....................Drain	Medicinal properties...... .Taste ....
River..................... Trade Waste.........	Value for boiler use........... Color.................
Lake	Water treatment...........Irrigation ....
Remarks:	Manufacturing ....

Signed...
Request for sanitary
examination endorsed by.................................
(Health Officer.)

*Indicate number
†Mark with cross.

REPORT OF ENGINEERING DIVISION.

ALTON: INSPECTION OF THE EXISTING WATER WORKS PLANT. Visited by W. F. Langelier, December 4, 1911. The present laboratory equipment is incomplete and does not permit of all the tests necessary for the proper control of a water supply. Arrangements will be made to obtain the necessary additional materials and the attendant will learn to make control tests. A more complete inspection of the existing plant will be made and a report submitted at a later date.

ANNA: PROPOSED WATER SUPPLY AND SEWERAGE. Visited by Paul Hansen, on November 13, and again by W. G. Stromquist, December 8, 1911, with reference to the proposed public water supply and system of sewerage for the city. These visits formed the basis of preliminary reports, and complete reports will be submitted when samples of the proposed water supply have been secured for analysis. The water supply project involves drilling of deep wells in limestone rock near and just east of the Illinois Central Railroad. The proposed sewerage project involves a system of sanitary sewers which will discharge crude sewage into a small creek flowing to the eastward. This stream also receives the sewage from the Anna State Insane Hospital, and is rather badly contaminated. Purification works for both the Institution and the city will be a necessity in the near future.

ANNA STATE INSANE HOSPITAL: PROPOSED NEW WATER SUPPLY. Projects for a proposed new public water supply for the Anna Insane Hospital were investigated by Paul Hansen. This investigation involved two visits—on November 13, 1911, and on January 8, 1912. The existing water supply of the Anna State Hospital is derived from deep wells in the limestone rock, which have become contaminated, due to the cavernous character of the rock. They also yield a water that is very hard and at times turbid. Owing to prevalence of typhoid fever, apparently water borne, a new supply was desired. The first project contemplated securing water from the American bottoms of the Mississippi River near the village of Ware, some eleven miles distant. A number of objections to this project resulted in a recommendation to the Board of Administration that further studies be made and that a competent consulting engineer be employed for this purpose. Acting upon the above recommendation, the Board of Administration employed Mr. Dabney H. Maury, consulting engineer of Peoria, Illinois, to act in co-operation with the State Water Survey to search for a new water supply. This resulted in a recommendation to the Board of Administration that a water supply be obtained from a small creek about four miles to the westward of the Institution and adjacent to the Mobile and Ohio Railroad. The new installation involves the construction of an impounding reservoir of about 80,000,000 gallons capacity, the installation of a pumping station and a filter plant, the laying of a rising main to the Institution and the erection of an elevated storage reservoir connected with the rising main.

AURORA: EXAMINATION OF EXISTING WATER SUPPLY. Visited by Ralph Hilscher, on October 20, 1911, in connection with a sanitary survey of the Fox River. A general description of the public water supply was obtained, which has been embodied in a report sent to the local authorities. The supply is obtained from five wells somewhat over 2,000 feet deep which flow small streams under artesian pressure when not being pumped. With pumping, the wells yield an abundant supply of water for the present needs of the city. The water is not highly mineralized and is of exceptionally good quality from a sanitary point of view.

BATAVIA: EXAMINATION OF EXISTING WATER SUPPLY. Visited by Ralph Hilscher, on October 20, 1911, in connection with a sanitary survey of the Fox River. A general description of the public water supply was obtained, which has been embodied in a report sent to the local authorities. The supply is derived from a single 10-inch well 1,270 feet in depth in which the water rises to within 16 to 40 feet of the surface of the ground, depending upon the rate at which the pumps are operated. The water is rather soft and of excellent quality from a sanitary point of view.

BENTON: EXISTING PUBLIC WATER SUPPLY AND A PROPOSED NEW WATER SUPPLY. An investigation of the existing water supply and proposed new water supply was made by W. G. Stromquist, on December 7, 1911. It was learned that the existing water supply is derived from a pond adjacent to the C. & E. I. Railroad in the northern part of the town. The supply is of poor quality and inadequate in quantity. A new source of supply is being developed about four miles to the northward of the city. It will be a large impounding reservoir having a capacity of 200,000,000 gallons. Purification of the new supply is not contemplated, because it is not believed to be a paying proposition by the water company, and, moreover, it is claimed that the water will not be used for domestic purposes. The State Water Survey now has the situation at Benton under advisement, and analyses of the new supply will be made from time to time with a view to determining the suitability of the water in the raw state for a public supply.

BREESE: PROPOSED NEW PUBLIC WATER SUPPLY. Visited by W. G. Stromquist, December 4, 1911. It was found that Breese was using an unpurified surface water obtained from Shoal Creek, about four miles to the eastward. This water is of poor quality and is not used for domestic purposes by the residents of Breese. An improved water supply is under contemplation involving the purification of the water from Shoal Creek by means of sedimentation, assisted by coagulation with lime and iron. Plans have not as yet been prepared, but when ready they will be reviewed by the State Water Survey.

BUSHNELL: DISPOSAL OF SEWAGE. Was visited by Edward Bartow, on May 3, 1911, to inspect the proposed sewer outfalls. Treatment of the sewage would be advisable to prevent a local nuisance rather than because of any possible effect on the water supply of Macomb. It was suggested that a competent consulting engineer be retained in order that the most modern methods of sewage disposal might be used.

CANTON: SEWAGE DISPOSAL NUISANCE. Visited by Mr. W. F. Langelier, September 21 and 22, 1911, in connection with an investigation of a sewage disposal nuisance, the object being to determine the quality of the effluent from a septic tank treating a part of the city sewage. Samples of raw sewage and the effluent were collected and sent to the laboratory. A report was prepared and sent to Dr. Kirby of Canton. The tank referred to has a capacity of 75,000 gallons and receives the sewage from about 100 people only. Practically no sediment was visible in the effluent, and it was found to be non-putrescible. Under these conditons it was felt that the nuisance complained of, namely, the loss of several hogs having access to the creek water, could hardly be due to this cause. The Survey has not been advised of any further proceedings.

CARLYLE: EXISTING PUBLIC WATER SUPPLY AND PROPOSED WATER PURIFICATION. Visited by W. G. Stromquist, on October 23, 1911. A report was prepared descriptive of the existing water supply. The water is taken from the Kaskaskia River and used without purification. It is claimed, however, that the water is not used for general domestic purposes. At the time of the investigation, the installation of a filtration plant was being considered, but up to date plans and specifications have not been prepared.

CHATSWORTH: EXISTING PUBLIC WATER SUPPLY. Visited by W. F. Langelier, November 11, 1911, in connection with a survey of the Vermilion River. A satisfactory supply is obtained from a 1,400 foot well pumped into two horizontal tanks placed in the pump house. The water is distributed by air pressure. A small branch of the Vermilion River about five miles from town is the nearest stream. The town is without a sewerage system.

CHENOA: EXISTING PUBLIC WATER SUPPLY. Visited by W. F. Langelier, November 11, 1911, when an inspection of the existing public water supply was made. At the time of this visit, the town was obtaining its water supply from wells owned by a canning establishment located there. The quality was not satisfactory, and the municipality was having a new well drilled. The indications were that an abundant supply could be obtained at a depth of 2,000 feet. A large well to hold an emergency supply was being built. The scheme of distribution was to pump direct, using electric power. There is no sewerage system except a few tile lines to a nearby creek carrying only small amounts of sewage.

CHESTER: PROPOSED PURIFICATION OF PUBLIC WATER SUPPLY. DISPOSAL OF WASTE FROM KNITTING MILL, COMPARATIVE TEST OF WATER FROM MISSISSIPPI RIVER. Visited by Edward Bartow, on July 5, 1911, with reference to a nuisance resulting from the waste from a knitting mill. It was found that a waste from one department containing sodium sulphide was frequently discharged into the sewer at the same time that waste containing sulphuric acid was discharged by another department. It was recommended that the sulphuric acid be neutralized before the waste was discharged. Samples of the wastes were collected and analyzed. Experiments in the removal of color and odor by treatment with alum and iron sulphate, showed that the coloring matter could be easily removed and a clear effluent obtained. The neutralization of the acid with sodium carbonate prevented odors but did not remove the color. We were informed that after the acid was neutralized, no further complaint was made.

Visited on August 2, 1911, to collect samples of water from different parts of the river, in an attempt to determine differences in the character of the water at various points. Samples were taken from the reef between Menard and Chester, from near the waterworks intake, from the channel just below intake, from the channel above the prison, from the bank of the river above the prison, and from below the sewer at the prison. There was a slight variation in the turbidity and total residue. The sample taken near the waterworks intake was better than the others, probably because the water above the intake had less current than in other places. There was but little variation in the dissolved matter, the total nitrogen as albuminoid ammonia and the number of bacteria vary with the turbidity. There was, however, nothing to indicate that the water obtained from any particular point would be more difficult to treat than that obtained from any other point. At no point would the water be satisfactory for a municipal supply without treatment. Water of worse character has been successfully treated at East St. Louis, Quincy and other cities. The conclusion was reached that at any stages of the river higher than the stage at the time the samples were taken (about 4 ft.) no differences could be found in the samples of water, and the sewage from the prison would not prevent the successful operation of a purification plant. It was recommended that further samples be taken at a period of very low water.

Visited by Paul Hansen, on September 20, 1911, and again on February 13, 1912, with reference to a proposed improvement in the existing public supply. The present supply is drawn directly from the Mississippi River, at a point where it is subjected to possible pollution by sewage from the State Prison and Insane Hospital at Menard, a few miles in an up-stream direction. The water is also excessively turbid at most times and is not much used for domestic purposes. It is proposed to improve the quality of the supply by filtration, and at a meeting of city officials, representatives of the water company and interested citizens, Mr. Hansen described the various processes of filtration and recommended mechanical filtration as best adapted to conditions at Chester.

CHILLICOTHE: POLLUTION OF ILLINOIS RIVER BY CHICAGO DRAINAGE CANAL. On November 8, 1911, a number of dissolved oxygen determinations were made at this point by W. G. Stromquist, as a part of an investigation to determine the extent to which pollution results from the discharge of sewage into the Chicago Drainage Canal.

CRYSTAL LAKE: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, on October 27, 1911, for the purpose of making inquiry into the cause of a typhoid fever epidemic which began about August 25, 1911. It was found that contaminated milk was the probable cause of the epidemic. An examination was made of the water supply, which is derived from an 8-inch tubular well having a depth of 290 feet and from a dug well having a depth of 64 feet. Both of these wells are in a built-up part of the town and not far removed from ditches, cesspools and other possible sources of contamination. No reliable analyses are available showing the quality of the water owing to the fact that bacterial samples shipped to the laboratories of the State Water Survey were not iced. The dug well at any rate should be regarded with suspicion.

DANVILLE: EXISTING PUBLIC WATER SUPPLY. Visited by W. F. Langelier, November 22, 1911, in order to advise upon the construction of an improved hypochlorite plant for disinfecting the supply. Laboratory equipment necessary for carrying on filter control tests was outlined. Danville was visited prior to this, on October 6, 1911, by Ralph Hilscher, relative to an examination of the existing water supply. A Descriptive report was prepared and submitted to the local authorities. The supply is obtained from the Vermilion River, treated with lime and iron, settled, sterilized with calcium hypochlorite and filtered through mechanical filters. A laboratory is being installed and bacterial control will be established.

DUQUOIN: EXISTING PUBLIC WATER SUPPLY. A brief visit was made by W. G. Stromquist, on December 7, 1911, with reference to the existing public water supply. The matter was partially reported upon, and the Survey will make a more complete examination of the water supply at DuQuoin as soon as opportunity permits.

EARLVILLE: EXISTING PUBLIC WATER SUPPLY. Visited by Mr. Ralph Hilscher, on October 25, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply, and a report giving a general description thereof was prepared and submitted to the local authorities. The supply is obtained from two 10-inch tubular wells 150 feet deep, located near the center of the city. The wells seem to yield a sufficient quantity of water to meet local needs and the quality is good from a sanitary point of view, notwithstanding the rather unfavorable location.

EAST DUNDEE: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, on October 18, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply, and a report giving a general description of same was prepared and submitted to the local authorities. The supply is obtained from a dug well 15 feet in diameter, and 25 feet deep, located near the center of the village. There are no sources of contamination within the immediate vicinity. No analyses have been made in the laboratories of the State Water Survey.

EFFINGHAM: LIQUID WASTE FROM A CATSUP FACTORY. Visited by Edward Bartow, on November 1, 1911, in connection with an alleged nuisance caused by waste from the catsup factory of the Mullen-Blackledge-Nellis Company, complaint having been made by Mr. J. D. Terstegge. Mr. Terstegge had sued the company for damages. The court, in a suit started October 16, acquitted the defendant. Some cause for complaint was found. It was recommended that settling tanks be installed, that, if necessary, the effluent be sterilized, and that a sewer be constructed between the factory and Salt Creek in order that the waste might be more highly diluted by the water from Salt Creek. Since the season was over, no experiments could be made until the next canning season, at which time arrangements would be made for further investigations.

ELDORADO: PROPOSED PUBLIC WATER SUPPLY AND SEWERAGE SYSTEM. Visited by W. G. Stromquist, December 5, 1911, for the purpose of obtaining data relative to proposed new sewerage system and public water supply. A partial report embodying the results of this visit was prepared. The project has not yet been completed and the matter is now under consideration by the State Water Survey.

ELGIN: INSTALLATION OF CONTROL LABORATORY. EXISTING PUBLIC WATER SUPPLY. Visited by Edward Bartow, on October 12, 1911, for a conference with the authorities concerning the installation of a control laboratory. Owing to smaller consumption, because of installation of meters, and because of the increased production due to an additional well, it had been possible to almost entirely dispense with the use of the filtered river water. When the filtered river water is used, filtration is supplemented with the use of hypochlorite. It, therefore, seemed unnecessary to install a laboratory for daily control at that time.

Visited by Ralph Hilscher, on October 14, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply and a report giving a general description of same was prepared and submitted to the local authorities. The supply is principally obtained from four deep wells, one of which is 2,000 feet in depth, while the other three are 1,300 feet in depth. At times, the wells are not capable of yielding the entire supply, then water is pumped from the Fox River and passed through Jewell filters of the pressure type. As the filters are inefficient in removing bacteria, filtration is supplemented by treatment with bleach.

EUREKA: LIQUID WASTES FROM CORN CANNING FACTORY. Visited by Edward Bartow, September 7, 1911, at the request of Dickinson & Company, Canners. During the summer, the wastes from the factory which were allowed to flow into the dry bed of a small stream caused a nuisance by their putrefaction. Unfortunately, at the time of the visit the stream had been washed out by recent rains and the conditions which would warrant complaint could not be determined. Samples of the effluents from the various departments of the factory were taken. Later analyses in the laboratory showed that the wastes contained six times as much organic matter as the ordinary sanitary sewage.

A settling tank installed by the company had not been able to prevent a nuisance. By disinfection with calcium hypochlorite, and by keeping the flow in the stream bed as free as possible, the nuisance had been lessened. It was suggested that some method of treatment might be satisfactory, or the nuisance might be prevented by constructing a sewer to a larger stream and adding sufficient amounts of chemicals to prevent putrefaction until natural processes have decomposed the waste without odors. Since the season was practically over, arrangements were made for further tests during the season of 1912.

EVANSTON: PROPOSED PURIFICATION OF EXISTING WATER SUPPLY. Was visited by Edward Bartow and Paul Hansen, on November 23, 1911, for the purpose of addressing the local authorities relative to the necessity for purification of the public water supply. A later visit was made by Ralph Hilscher, on December 8, 1911, for the purpose of obtaining a description of the public water supply. This description has been embodied in the form of a report. Evanston obtains its water supply from Lake Michigan at a point about 3,000 feet from shore. The water is more or less subject to sewage contamination, as is evidenced by a number of analyses and the prevalence of typhoid fever in the city. The typhoid fever reached epidemic proportions in the latter part of 1911, which greatly alarmed the residents. This gave rise to a vigorous movement looking toward the purification of the supply. Largely through the agency of the State Water Survey, the authorities were induced to install a chlorination plant, as a temporary means for rendering the water safe. The chlorination plant has been in successful use since the early part of January, 1912. The water will be more completely treated at a later date by means of filtration. Mr. Langdon Pearse, consulting engineer of Chicago, has been engaged to prepare plans.

FAIRBURY: EXAMINATION OF THE PUBLIC WATER SUPPLY. This city was visited by W. F. Langelier, on November 10, 1911, in connection with a survey of the Vermilion River. Examination of the city water was made in connection with the construction of a water tower which is to be built in the near future. A mineral analysis of the water was made. It was determined that the water, although containing H_2S, was not of such a character to corrode a metal tank. No sanitary sewage enters any branch of the Vermilion River at this point.

FAIRFIELD: PROPOSED NEW WATER SUPPLY. Visited by Paul Hansen, on November 16, 1911, with reference to a proposed new water supply. It was found that the existing water supply was being drawn from several small impounding reservoirs subject to more or less contamination. This supply, besides being contaminated, is also inadequate to serve the needs of the city. A new supply which it is hoped to obtain from drilled wells near the center of the city is being contemplated. There are also other possibilities of securing an adequate water supply from surface sources, but such will require purification. The city officials were advised to drill test wells before deciding definitely upon the location of the pumping station or the expenditure of any money for permanent development. The Survey is now awaiting the results of test wells.

FLORA: PROPOSED PUBLIC WATER SUPPLY. Visited by Paul Hansen, on November 17, 1911, with reference to proposed new water supply, and later on the city was again visited by W. G. Stromquist, who obtained further data upon which there was based a descriptive report. The city obtains its water supply from drilled wells in the southern part of the town, which yield a water rather hard and somewhat impregnated with iron, but apparently of good quality from a sanitary point of view.

FORT SHERIDAN: PUBLIC WATER SUPPLY AND SEWERAGE. This reservation was visited by Ralph Hilscher, on December 15, 1911, at which time, data were obtained for a descriptive report relative to water supply and sewerage. The visit to Fort Sheridan was made in connection with a general investigation of the water supply and sewerage conditions along the Lake Michigan north shore.

GALESBURG: EXISTING PUBLIC WATER SUPPLY. This city was visited on December 2 and 3, 1911, by Paul Hansen, with reference to the existing water supply. Data were obtained to serve as a basis for a descriptive report. Special attention was given to the adequacy of the supply, which is obtained from eight wells in the southwestern part of the city. The installation, during the past year, of improved pumping machinery in the wells has increased the yield so that they may be counted upon to furnish the city an ample supply of water for a few years. The Water Survey, however, is urging systematic tests of the water-bearing formation with a view to ascertaining the maximum quantity of water that may be derived from this locality. Such data will prove valuable in guiding future extensions of the waterworks of the city, which is now having a rapid growth.

The sewage of Galesburg is very inadequately disposed of. Most of it enters a small creek passing through the heart of the city, and within a few hundred feet of the waterworks wells. Studies concerning the removal of sewage from this stream have been made by Mr. W. S. Shields, of Chicago. As yet, his recommendations have not been acted upon. In the southwestern part of the town is a new sewer district which discharges into a small stream passing through farm and pasture land. At present the city is enjoined from making any additional connections to this sewage system, owing to the pollution of this stream below the outlet.

The State Water Survey has offered to co-operate with the engineers of the City of Galesburg in connection with further investigations of the water supply, and the more satisfactory disposal of sewage.

GENEVA: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, on October 19, 1911, in connection with a sanitary survey of the Fox River watershed, and in co-operation with Alvord and Burdick to study the pollution of the Fox River. Advantage was taken of the opportunity to make an examination of the existing public water supply, and a report giving a general description of same was prepared. The supply is obtained from an artesian well 1,000 feet in depth and located near the center of the city. The supply seems to be ample to meet all present needs of the community. No analyses of the supply have been made in the laboratories of the State Water Survey, but the quality is undoubtedly very good from a sanitary point of view.

GEORGETOWN: PROPOSED PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, on November 28, 1911, at which time several possible sources of water supply were investigated. Results of this investigation were embodied in a descriptive report. The State Water Survey is now co-operating with the city and its engineers in further investigations of possible sources of water supply.

GLENCOE: EXISTING PUBLIC WATER SUPPLY AND SEWERAGE. Visited by Ralph Hilscher, on December 13, 1911, in connection with an investigation of the water supply and sewerage conditions of Lake Michigan North Shore towns. Results of this investigation were embodied in a report. The supply is obtained from the Village of Winnetka, which in turn draws water directly from Lake Michigan without purification.

The sewage purification plants at Glencoe were examined and found to be in a very neglected condition. Filters comprising a portion of one plant in the east part of town are not used at all. The effluent from two septic tanks is permitted to go directly into the North Branch of the Chicago River, on the west side of town.

HARRISBURG: PROPOSED PURIFICATION OF EXISTING SUPPLY. Visited by W. G. Stromquist, on October 24 and 25, and again on November 15, 1911, by Paul Hansen. A description of existing water supply has formed the basis of a report. Plans for water purification works are now in preparation and will soon be submitted to the State Water Survey for review.

HENNEPIN: POLLUTION OF ILLINOIS RIVER BY CHICAGO DRAINAGE CANAL. W. G. Stromquist, on November 7, 1911, made a number of dissolved oxygen determinations as a part of an investigation to determine the extent to which pollution results from the discharge of sewage into the Chicago Drainage Canal.

HIGH LAKE: PROPOSED PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, on September 19, 1911, for the purpose of collecting samples of water from wells from which it was proposed to obtain a public supply. High Lake is a new town which is being promoted by a real estate company, and at that time contained only a few houses, none of which were occupied.

HIGHLAND PARK: EXISTING PUBLIC WATER SUPPLY AND SEWERAGE. Visited by Ralph Hilscher, on December 17, 1911, in connection with an investigation of water supply and sewerage conditions in Lake Michigan North Shore communities. Results of this investigation were embodied in a report.

KENILWORTH: EXISTING PUBLIC WATER SUPPLY AND SEWERAGE. Visited by Ralph Hilscher, on December 11, 1911, in connection with an investigation of water supply and sewerage conditions in Lake Michigan North Shore communities. Results of this investigation were embodied in a report. The supply is obtained from Lake Michigan, and is filtered by means of pressure mechanical filters. Owing to the liberal filtration area, fairly high efficiencies are obtained. The process could be improved by utilization of the pump well as a coagulating basin and by the addition of hypochlorite treatment.

KNOXVILLE: EXISTING PUBLIC WATER SUPPLY. Visited by W. G. Stromquist, on December 27, 1911. This visit was made on account of discoloration of water. The results of this investigation were embodied in a preliminary report. The cause of complaint, while undoubtedly due to the presence of iron in the water, involves complications that have not been completely developed. Another investigation will be made at the first opportune time.

LAKE BLUFF: EXISTING PUBLIC WATER SUPPLY AND SEWERAGE. Visited by Ralph Hilscher, on December 19, 1911, in connection with an investigation of water supply and sewerage conditions in Lake Michigan North Shore communities. Results of this investigation were embodied in a report. The supply is obtained from two wells, one about 300 feet in depth and the other about 700 feet in depth. The water is highly mineralized and moreover is scarcely adequate to meet the present needs of the village. The State Water Survey is at present co-operating with the village authorities in the effort to secure a more satisfactory supply.

LAKE FOREST: EXISTING PUBLIC WATER SUPPLY AND SEWERAGE. Visited by Ralph Hilscher, on December 18, 1911, in connection with an investigation of water supplies and sewerage conditions in Lake Michigan North Shore communities. Results of this investigation were embodied in a report. The Lake Forest Water supply will be studied in detail by the State Water Survey with a view to securing an assured good quality of water at all times.

LA SALLE: INVESTIGATION OF THE POLLUTION OF TWO DEEP WELLS. Visited by W. F. Langelier, on November 14, 1911, on account of the pollution of two deep wells. The wells were recently sunk at a considerable distance from any visible source of pollution. Sterilization of the inside of the casings caused a decided improvement, as was shown by subsequent bacterial analyses.

LAWRENCEVILLE: EXISTING PUBLIC WATER SUPPLY. Visited by Paul Hansen, on November 17, 1911. An examination was made of the existing water supply with special reference to purification. A later visit on December 2, 1911, was made by W. F. Langelier, with reference to the installation of a control laboratory and the installation of a chlorination plant. The latter has been installed, but as yet nothing has been done about the laboratory.

LITCHFIELD: EXISTING PUBLIC WATER SUPPLY. Visited by W. G. Stromquist, on December 2, 1911. An examination was made of the existing water supply with special reference to the necessity for improvement in the quality of the supply. This investigation formed the basis of a descriptive report. The waterworks is owned by the city, but operated by a private company. The supply is obtained from two sources, namely, an impounding reservoir on a small water-course to the south of the city and from the west branch of Shoal Creek, several miles to the eastward of the city. The water supply, being untreated, is turbid and more or less contaminated; and is generally considered unsatisfactory for domestic purposes. The State Water Survey is endeavoring to interest the community in an improved water supply, including purification works.

LOCKPORT: POLLUTION OF ILLINOIS RIVER BY CHICAGO DRAINAGE CANAL. W. G. Stromquist, on November 1 and 2, 1911, made a number of dissolved oxygen determinations as a part of an investigation to determine the extent to which pollution results from the discharge of sewage into the Chicago Drainage Canal.

MACOMB: EXISTING PUBLIC WATER SUPPLY. Visited by Edward Bartow, May 3, 1911, to inspect the new filter plant and to collect samples of water for analysis to determine its efficiency. It was recommended that sterilization with calcium hypochlorite be used as an adjunct to filtration and that bacterial and chemical control be established. Prof. J. P. Drake, Professor of Chemistry at the Western Illinois State Normal School, was engaged to make the necessary tests. Crooked Creek was inspected above the intake, near Macomb, and also at Bushnell. It would not seem as if sewage from Bushnell would seriously affect the water at Macomb.

Visited by Paul Hansen, on December 3, 1911. An examination was made of the newly installed public water supply obtained from Crooked Creek, and then purified in a mechanical filter plant. Limited time did not permit the obtaining of a complete description of the waterworks. The filter plant is built entirely of reinforced concrete and represents the best practice in design and construction for the smaller installations. A description of the new waterworks may be found in the annual report of the Illinois Water Supply Association for 1912.

MARSEILLES: POLLUTION OF ILLINOIS RIVER BY CHICAGO DRAINAGE CANAL. W. G. Stromquist, on November 4-6, 1911, made a number of dissolved oxygen determinations as a part of an investigation to determine the extent to which pollution results from the discharge of Chicago sewage into the Chicago Drainage Canal.

McHENRY: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, on October 16, 1911, in connection with a sanitary survey of the Fox River. A general description of the public water supply was obtained, which has been embodied in a report sent to the local authorities.

METROPOLIS: EXISTING WATER SUPPLY. Visited by Paul Hansen, on September 23, 1911. Limited time did not permit the securing of adequate information to serve as a basis for a descriptive report. The water supply is obtained from wells in drift bordering the Ohio River. In all probability, the water is of a very good sanitary quality.

MOLINE: SANITARY SURVEY OF MISSISSIPPI RIVER. Visited by Edward Bartow, July 9, August 15, September 12, October 16 and November 14, 1911, to collect samples of water from the Mississippi River to determine the advisability of constructing a new intake for the waterworks. The report of this investigation is published elsewhere in this Bulletin under the title, "Sanitary Survey of the Mississippi River at Moline."

MORRIS: POLLUTION OF ILLINOIS RIVER BY CHICAGO DRAINAGE CANAL. W. G. Stromquist, on October 30 to November 3, 1911, made a number of dissolved oxygen determinations as a part of an investigation to determine the extent to which pollution results from the discharge of sewage into the Chicago Drainage Canal.

MOUNDS: PROPOSED NEW PUBLIC WATER SUPPLY. Visited by Paul Hansen, on November 14, 1911, and by W. G. Stromquist, on December 8, 1911. The city is about to install a water supply to be obtained to the southward of the city from deep wells in the rock. The wells are now being drilled and the State Water Survey is awaiting an opportune time for obtaining samples of the water.

MT. CARMEL: EXISTING PUBLIC WATER SUPPLY AND FILTRATION PLANT UNDER CONSTRUCTION. Visited by Edward Bartow, April 1, 1911, for a conference concerning a purification plant. Sedimentation with coagulation, and sedimentation with coagulation and filtration, were under consideration. The latter was recommended as the most desirable. If sedimentation and coagulation were adopted arrangements should be made so that filters could be installed at a later date. Mr. W. F. Monfort of St. Louis was later engaged as Consulting Engineer, and it was decided that sedimentation with coagulation and filtration be adopted. A second visit was made on August 11th, for a conference with Mr. Monfort concerning plans for the purification plant.

Visited November 16, 1911, by Paul Hansen, with special reference to water purification plant now under construction. The plant is of good design, built entirely of reinforced concrete, and represents best practice in connection with this class of work. Owing to inadequate funds, however, the coagulating basins and clear water reservoir have not been made as large as is desirable. It is expected that additions to these will be made in the future, as increase in the water consumption demands.

NORTH CHICAGO: EXISTING PUBLIC WATER SUPPLY AND SEWERAGE. Visited by Ralph Hilscher, December 22, 1911, in connection with an investigation of water supply and sewerage conditions in Lake Michigan North Shore communities. Results of this investigation were embodied in a report. The supply is obtained from Lake Michigan about 400 feet from the shore, and is subject to contamination by sewage from Waukegan. The State Water Survey is negotiating with the local authorities in an effort to induce them to improve the water supply.

North Chicago is installing a sewerage system involving purification works. These purification works appear to be inadequate for the needs of the city, and, moreover, they are constructed upon a site which does not readily permit of future extensions.

UNITED STATES NAVAL TRAINING STATION: EXISTING PUBLIC WATER SUPPLY AND SEWERAGE. Visited by Ralph Hilscher, December 19, 1911, in connection with an investigation of water supply and sewerage conditions in Lake Michigan North Shore communities. Results of this investigation were embodied in a report. The supply is obtained from Lake Michigan about one-half mile from the shore. The water is passed through slow sand filters. These operate very effectively, excepting when the raw water becomes turbid due to inshore winds, at which time they become rapidly clogged.

Sewage from the Naval Training Station is treated in a sewage purification plant comprising sedimentation tank, upward roughing filters and percolating filters. The design of this plant is apparently defective and it is proposed by the State Water Survey to make a test of its efficiency with a view to recommending modifications.

OTTAWA: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, October 25, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply, and a report giving a general description was prepared. The supply is derived from 4 tubular wells ranging in depth from 115 feet to 155 feet. All have 6-inch casings. The wells are under artesian pressure, but do not flow enough water to furnish the entire supply at all times. By pumping the wells, however, an ample supply can be obtained for all needs of the city. Six samples of the water supply of Ottawa have been analyzed in the laboratories of the State Water Survey, and found to be of excellent quality from a sanitary point of view, and moderately soft for a deep ground water.

PANA: PROPOSED NEW PUBLIC WATER SUPPLY. Visited by W. G. Stromquist, December 1, 1911. An examination was made of the existing water supply and inquiry was made relative to a proposed new water supply. Results of this visit were embodied in a report. The new supply is to be obtained from an impounding reservoir located on a small creek to the eastward of the town. The reservoir will have a storage capacity of about 70,000,000 gallons. The water will be pumped to the city, where it will be passed through a filtration plant of the mechanical gravity type. In designing this filtration plant, coagulating basins were omitted, and because the water will undoubtedly be subject to high turbidities, it is doubtful whether the filters can be operated successfully. The State Water Survey has the matter under consideration, and will make an investigation of the filter plant as soon as it is placed in operation.

PEORIA: SUPPOSED CONTAMINATION OF WATER SUPPLY, ODORS AND TASTES IN WATER AND ADDITIONAL WELLS. Visited by Edward Bartow, on August 10, 1911. It was feared that sewage, from a few houses, emptying into an open ditch some 500 feet from the wells, might affect the water in the wells. Determinations of the chlorine in the sewage and in the water showed a much greater quantity in the water from the deep wells than in the sewage. This fact, together with the fact that no intestinal bacteria and very few bacteria of any kind were found in the water, led to the conclusion that contamination could not result from this source.

The odors and tastes were found to be due to a growth of aigæ in the water. The bacteriological tests showed that the water was perfectly safe for use for drinking purposes and the odors and tastes soon disappeared. Treatment with a small amount of copper sulphate assisted in removing the odor and tastes.

New wells about three miles from the pumping station were under construction. Kamples of water taken from these wells and analyzed in the laboratory showed water of a good quality.

PEORIA HEIGHTS: PROPOSED NEW PUBLIC WATER SUPPLY. Visited by W. G. Stromquist, December 26, 1911. An investigation was made relative to a proposed new water supply, and the results of the investigation were embodied in a report. The State Water Survey is co-operating with the local authorities in the development of the new supply and will review plans and specifications and make tests of the water at the proper time.

PLANO: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, October 24, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply, and a report giving a general description thereof was prepared.

PONTIAC: EXISTING PUBLIC WATER SUPPLY. Visited by W. F. Langelier on November 1, 10 and 11, 1911, in connection with a sanitary survey of the Vermilion River. The laboratory technique was improved, and the failure of the hypochlorite plant to work was remedied.

QUINCY: EXISTING PUBLIC WATER SUPPLY. Visited by Edward Bartow and Paul Hansen, on September 18, 1911. A brief examination was made of existing water supply with special reference to proposed modifications in methods of purifying the water. The State Water Survey still has this matter under consideration.

ROBINSON: EXISTING PUBLIC WATER SUPPLY. Visited by W. F. Langelier, December 2, 1911, to examine the existing public water supply. The supply is obtained from a large open well. It is outside the city limits and is a satisfactory supply in every way. The water is especially soft compared with other waters in this locality.

ROCK ISLAND: TYPHOID FEVER EPIDEMIC, EXISTING WATER SUPPLY AND NEW FILTER PLANT. Visited by Edward Bartow, March 26, 1911, to investigate a typhoid fever epidemic. The results of the visit are reported elsewhere in this Bulletin. Visits were also made by Edward Bartow on May 4, July 11, September 13, October 18 and November 14, 1911, to inspect the new filter plant which was put into operation during the spring, and to collect samples of water for analysis to determine the efficiency of the plant.

RUSHVILLE: PROPOSED CHANGE IN PUBLIC WATER SUPPLY. Visited by W. G. Stromquist, December 28, 1911. An investigation was made of a proposed change in the public water supply and a report was prepared. The new supply will be derived from a large dug well 5 miles south of the city. It was not practicable at the time to obtain samples of water from the proposed new water supply, and the Survey is now awaiting a favorable opportunity to obtain such samples.

ST. CHARLES: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, October 19, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply and a report giving a general description thereof was prepared. The water supply is derived from two tubular wells, one of which is 200 feet in depth and the other 850 feet in depth. The supply seems to be ample in quantity and is of good quality from a sanitary point of view. The total residue is comparatively low, and the supply meets with general popular approval.

SANDWICH: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, October 24, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply and a report giving a general description thereof was prepared. The supply is derived from two 8-inch tubular wells, 120 feet deep, and located near the center of the city. The wells are only $2\frac{1}{2}$ feet apart, thus acting virtually as a single well. The supply seems to be adequate in quantity, and is of very good quality from a sanitary point of view.

SPRINGFIELD: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, on September 13, 1911. Data obtained during this visit were embodied in a report descriptive of the Springfield public water supply. It is proposed in the near future to increase the supply by sinking additional wells. The State Water Survey will co-operate in the investigations about to be made.

STREATOR: INSTALLATION OF CONTROL LABORATORY. Visited by Edward Bartow, on March 1 and October 15, and by W. F. Langelier, on October 15 to November 15, 1911, on leave of absence from the Water Survey, with reference to the installation of the control laboratory. This laboratory was placed in operation about the first of November, and has been continued since under the supervision of Mr. R. D. Huggans.

TISKILWA: EXTENSION OF CITY SUPPLY. Was visited by Edward Bartow, July 10, 1911. Samples of water were collected from the present city supply and from springs. The analyses showed the possibility of obtaining a water of good quality. Several schemes were under consideration for the extension and improvement of the supply. It was impossible without obtaining considerable engineering data to decide which was the better. The necessary information was obtained later in the summer by the W. S. Shields Company of Chicago, who made recommendations concerning the improvement of the distribution system.

WAUKEGAN: EXISTING PUBLIC WATER SUPPLY AND SEWERAGE. Visited by Ralph Hilscher, December 21, 1911, in connection with an investigation of water supplies and sewerage conditions in Lake Michigan North Shore communities. Results of this investigation were embodied in a report. The supply is obtained from Lake Michigan about 4,000 feet from shore. The water is subject to pollution by sewage from Waukegan. The State Water Survey is urging purification of the supply by filtration, but recommends the immediate installation of a hypochlorite treatment plant. Waukegan has had a great deal of typhoid fever which is undoubtedly water-borne.

WILMETTE: EXISTING PUBLIC WATER SUPPLY AND SEWERAGE. Visited by Ralph Hilscher, December 11, 1911, in connection with an investigation of water supplies and sewerage conditions in Lake Michigan North Shore communities. Results of this investigation were embodied in a report. The supply is obtained from Evanston, which in turn takes its supply from Lake Michigan. The water has hitherto been of unsatisfactory quality from a sanitary point of view, but the authorities at Evanston have recently installed a hypochlorite treatment plant which in all probability will be followed by the installation of a filtration plant.

WEST DUNDEE: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, October 18, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply and a report giving a general description of same was submitted. The supply is obtained from a series of springs in East Dundee on the opposite side of the Fox River. Analyses made in the laboratories of the State Water Survey show the sanitary quality of the water to be good. The water is not highly mineralized. There are possibilities of contamination, however, and the continued good quality of the water rests entirely upon careful protection of the springs, which is being done at the present time.

WOODSTOCK: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, October 16, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply and a report giving a general description of same was prepared. The supply is obtained from three deep tubular wells, respectively 2,000 feet, 1,200 feet and 1,000 feet in depth. The water is of good sanitary quality and is but moderately mineralized. The quantity seems to be ample to meet the present needs of the community.

YORKVILLE: EXISTING PUBLIC WATER SUPPLY. Visited by Ralph Hilscher, October 23, 1911, in connection with a sanitary survey of the Fox River watershed. Advantage was taken of the opportunity to make an examination of the existing public water supply, and a report giving a general description thereof was prepared. The supply is obtained from a number of springs on a site about one-half mile east of town. The water is pumped to a reservoir of about 175,000 gallons capacity, and thence it flows to the city. No analyses have been made in the laboratories of the State Water Survey.

ZION CITY: WATER SUPPLY AND SEWERAGE CONDITIONS. Visited by Ralph Hilscher, December 21, 1911, in connection with an investigation of water supplies and sewerage conditions in Lake Michigan North Shore communities. Results of this investigation were embodied in a report. Zion City has no public water supply, but one is in contemplation. No active steps have yet, however, been taken towards its installation. The private wells in general use are not above suspicion. The absence of a public water supply results in seriously objectionable conditions because it is difficult to dispose of the sewage properly.

ASSOCIATIONS AND COMMISSIONS.

Various Associations and Commissions are interested in some phases of water problems. These Associations and Commissions in Illinois have been co-operating in an endeavor to prevent useless duplication in the investigation of any water problems.

State Laboratory of Natural History. (1884) Professor S. A. Forbes, University of Illinois, Urbana, Director. The State Laboratory of Natural History is interested in the character of the streams of the state with respect to their effect on stream life. A special study is being made to determine the effect of the Chicago sewage on the plankton and food fishes in the Illinois River. The chemical work has been done under the direction of the State Water Survey.

Illinois Society of Engineers and Surveyors. (1885) J. A. Harman, Consulting Engineer, Peoria, President; E. E. R. Tratman, Wheaton, Secretary-Treasurer. Water supply and sewage disposal problems form an important part of the work of the members of this organization. The 1911 proceedings contained six papers relating to water and sewage problems. A brief review of these is given elsewhere.

Sanitary District of Chicago. (1890) Thomas A. Smyth, President; George M. Wisner, Chief Engineer, American Trust Bldg., Chicago. The Sanitary District of Chicago has continued its investigations of sewage disposal for the City of Chicago during 1911. The officials of the District were especially interested in an attempt to obtain assurance that they could take from the lake the maximum amount of water allowed by the international agreement. The State Water Survey and the Sanitary District are co-operating in making determinations of dissolved oxygen in the Illinois River. An abstract of a report on Sewage Disposal is given elsewhere.

Illinois State Geological Survey. (1905) F. W. DeWolf, University of Illinois, Urbana, Director. The State Geological Survey has charge of drainage investigations and is interested in the character of the water obtained from deep wells and the horizons from which the water can be obtained.

Lake Michigan Water Commission. (1908) Dr. G. B. Young, Health Commissioner, Chicago, President; Dr. Edward Bartow, Director State Water Survey, University of Illinois, Urbana, Secretary. The Lake Michigan Water Commission, which was established in 1908, has for its object the investigation of the sanitary conditions of Lake Michigan, with a view to conserving a supply of pure water for those cities and towns which depend on Lake Michigan for their source of supply. The members of the Commission are appointed by the governors of the states, and the mayors of several cities which border the lake. There are also representatives from the United States Army and the United States Public Health Service. No special appropriations are made for this commission. The members are, for the most part, officials connected with state, federal, or municipal bureaus. Papers are presented at the various meetings which have been published in the report of the commission. The second report is reviewed elsewhere in this Bulletin.

Illinois Water Supply Association. (1909) R. R. Parkin, Chief Engineer, Elgin Water Dept., Elgin, President; Dr. Edward Bartow, Director State Water Survey, University of Illinois, Urbana, Secretary-Treasurer. The Illinois Water Supply Association is composed of persons interested in the waterworks and water supplies of Illinois. The annual meetings are held at the University of Illinois in February or March. Papers dealing with topics of interest to waterworks men are read. The program of the third meeting is published elsewhere in this report.

Rivers and Lakes Commission. (1909) R. R. McCormick, First National Bank Bldg., Chicago, Chairman; Robert Isham Randolph, First National Bank Bldg., Chicago, Secretary. An abstract of the law passed by the Forty-seventh General Assembly is given elsewhere in this report.

Great Lakes International Pure Water Association. (1911) Dr. C. E. Ford, Cleveland, Ohio, President; Dr. Edward Bartow, University of Illinois, Urbana, Secretary. At a meeting of representatives from various municipalities throughout the country held in Chicago, September 29, 1911, an association was formed of those interested in the character of the water of the Great Lakes. It is supposed that the second meeting will be held during the latter part of 1912, to effect a permanent organization and to outline a method of procedure.

National Association for the Prevention of Streams Pollution. (1911) Calvin W. Hendrick, American Bldg., Baltimore, Md., Chairman; H. de B. Parsons, 22 William St., New York City, Secretary. This association has for its object the prevention of excessive pollution of streams. A committee has been appointed to determine the feasibility of establishing standards for the rivers and waterways of the United States. It is expected that this committee will report at the meeting in the latter part of 1912.

Co-operation with State Board of Health. Co-operation with the State Board of Health was continued through the year 1911. Water analyses for the State Board of Health have been made when requested. Samples of water were analyzed free of charge during the first half of the year, when application was made to the State Board of Health, otherwise a charge has been made. After July 1, analyses were made free of charge of samples collected according to the directions of the State Water Survey. This was in accordance with the provisions of the bill "imposing new and additional duties on the State Water Survey." Reports summarizing the work done have been published in the monthly bulletins of the State Board of Health.

EXPERIMENTAL INVESTIGATIONS

In connection with the routine analytical work, the members of the laboratory staff are engaged constantly on special problems relating to water and water supplies. In nearly every case, the problem is suggested by difficulties arising in various waterworks or sewage disposal works throughout the State. The staff is assisted in this work by instructors and students in the University. During 1911, such assistance was given by Dr. R. H. Jesse and Dr. L. L. Burgess, instructors in Chemistry, Mr. C. E. Miller, Assistant in Chemistry and Mr. L. T. Fairhall, Mr. B. H. Harrison and Mr. H. P. McGregor, students in the College of Science. The work done by Dr. Burgess and Mr. Fairhall will be described in a later bulletin. The experimental work of the instructors, students and the laboratory staff is fully described elsewhere in this bulletin. Following is a brief outline of each experiment or investigation:

Composition of Insoluble Gases Formed by the Decomposition of Organic Matter. This study was primarily undertaken to determine the cause of an explosion in a septic tank at Highland Park. It has lead to a study of the comparative composition of gases obtained in sewage purification works with gases found in pure and polluted streams. Striking similarity is found to exist between the composition of gases from septic tanks and gases obtained from the sludge at the bottom of the Illinois River. On the other hand, gases formed in an unpolluted stream differ widely in composition from the gases mentioned.

Opinions Relative to Principles Governing Streams Pollution. Because of agitation concerning the disposal of sewage by allowing it to flow into streams, a questionaire was prepared and sent to a number of leading sanitarians. The replies received have been analyzed and the conclusion is reached that the disposal of sewage by dilution should not be prohibited but that it should be allowed only under competent central control.

Determination of Ammonia Nitrogen in Water. This investigation was suggested because of difficulties experienced in determining ammonia in waters containing hydrogen sulphide. Two schemes for the analysis were tried. One, the addition of a substance to hold the hydrogen sulphide and allow the ammonia to distill over, and another to hold the ammonia while the hydrogen sulphide was removed. The latter method using sulphuric acid to hold back the hydrogen sulphide was found to be very satisfactory.

Extent and Composition of Incrustation on Some Filter Sands. This investigation was suggested because of the incrustation formed on the sand grains at several filter plants in the state. The incrustation varied in amount from 15% to 633% of the original sand. It consisted principally of calcium carbonate. Its formation could be prevented by increased sedimentation capacity, or possibly by the use of carbon dioxide or flue gases instead of air, in washing the filters.

Sanitary Survey of the Mississippi River at Moline. This investigation was undertaken to determine the relative purity of the water of the Mississippi River in three places: The so-called "pool" from which one intake draws its water, the channel opposite the city and a point six miles up the river. A series of monthly comparative examinations show that no advantage would be gained by taking the water from the point up the river.

Sanitary Survey of the Lake Michigan Watershed in Illinois. This survey was made because of the known bad conditions of the water supply and sewage disposal. The survey furnished the Water Survey a basis for further investigations.

Sanitary Survey of the Vermilion River Valley. This investigation was undertaken first because of complaints concerning nuisances in the Vermilion River at Streator, and second, in order to determine the possibility of obtaining a satisfactory water supply from deep wells. The nuisance was found to exist during periods of low water. Partial purification of the sewage will probably be sufficient for a number of years to come. Existing deep wells in the neighborhood of Streator are found to furnish a much harder water than is furnished by the present city supply.

Sanitary Survey of the Fox River Valley. This investigation was undertaken because of complaints concerning the pollution of the Fox River at Geneva.

Composition of Sediment in Deep Well Waters Containing Iron. The investigation was undertaken because of difficulties with sediment in the water supplies of central Illinois. On exposure to the air a reddish-brown precipitate, accompanied by the iron-bearing algæ, crenothrix, is formed. The analyses show that the sediment consists of about one-third iron oxide, one-third organic matter and the remainder silica and alumina.

Experiments in the Removal of Iron from the Water Supply of the University of Illinois. The investigation was undertaken because of the presence of iron in the water supply, which causes the water, on exposure to the air, to become yellow and turbid and to lose its attractive appearance. The conclusions were, that aëration and filtration can remove the iron, and that sedimentation is of little advantage. The work was continued on a larger scale at the Champaign and Urbana Water Works Pumping Station, as described in a paper by Prof. A. N. Talbot, *"Removal of Iron from a Drift Well Water."* As a result of the experiments on the larger scale, it was concluded that a combination of aëration and filtration through gravel and sand without chemicals was a satisfactory method of treatment. The tests show 80 to 90% iron reduction.

REPORTS OF ASSOCIATIONS AND COMMISSIONS.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.

The Twenty-sixth Annual Report (1911) contains several papers somewhat related to the water problems of Illinois. Their titles with a brief abstract are given below.

The Waterworks of East St. Louis. H. H. Horner. The water taken from the Mississippi River is treated by sedimentation, aëration, coagulation and filtration. The filters have a nominal capacity of 17 mil. gal. per 24 hours. The daily consumption averages 15,000,000 gallons.

The Outlet Sewer Plant, East St. Louis. W. A. Thompson. Enginneering construction details.

Levee and Drainage Project of the East Side Levee and Sanitary District. T. N. Jacob. The district includes the cities of East St. Louis, Granite City, Madison and Venice, having an area of 96 sq. miles. It is planned to provide a system of canals to control the discharge of water falling on the catchment area tributary to the district which will prevent the overflowing of the smaller streams; to drain off the water that accumulates and becomes stagnant on the low areas; and to provide a system of levees that will prevent overflows from the Mississippi River. The work, it is expected, will be completed within three years.

Sewage Disposal. W. S. Shields. A discussion of the Imhoff claims, together with brief descriptions of some of the newer sewage treatment plants in the state, is given.

The Calumet Sag Channel. L. K. Sherman. The Calumet Territory is that part of the Sanitary District of Chicago south of 87th Street. It has an area of 95 sq. miles, and includes South Chicago, Riverdale, Harvey, Blue Island, Morgan Park, etc. It is the only part of the Sanitary District in which provision has not been made for the removal of sewage. The rapid growth of this territory has developed conditions that are growing intolerable.

The plan adopted for the disposal of the sewage from the Calumet territory, provides for the construction of a channel of 2,000 cubic feet per second capacity from the Little Calumet River near Blue Island to the Main Drainage Canal at Sag Bridge, with a system of. sewers that will intercept all of the sewage of the district now discharging into the Calumet River and carry it to the channel.

The estimated cost of the channel and sewer system is approximately $8,000,000.

Report of Committee on Waterworks. H. M. Ely, Chairman. The committee urges the necessity of laws for the protection of streams from pollution. A draft of a bill is given and the committee recommends the appointment of a committee to act with the State Board of Health and the Water Survey in securing necessary legislation.

Report of Committee on Sewers. J. W. Dappert, Chairman. The committee reports information concerning the sewerage system in the state. The data which relates to the character and extent of sewerage systems in approximately 100 cities and villages is tabulated.

SANITARY DISTRICT OF CHICAGO.

A report on Sewage Disposal by George M. Wisner was published in 1911. The report outlines the present condition of the main channel and its feeders. It points out the line of action which should be followed to increase the dilution capacity of the canal as a whole to prevent local nuisance, and suggests means to adequately purify the sewage of the District after the population shall have exceeded the number that can be taken care of by the dilution method. This number will be exceeded in 1920. Since construction of the necessary plant takes time to design and build, it is advisable to have immediate action.

A testing station has been in operation at 39th Street and the Lake, under the direction of Mr. Langdon Pearse, and the report is based largely on the results obtained there.

The Sanitary District Act of 1889 established a dilution of 3.3 cubic feet per second for every 1,000. people sewering into the canal. The dilution was fixed from the standpoint of nuisance, no consideration was given to the probable affect on fish life, and was deduced largely on the assumption of handling human excreta only, and did not provide enough margin for industrial wastes.

The oxygen in the water of the canal is frequently exhausted at Lockport. Odors are noticeable at Lockport and as far down as Joliet. They are not yet considered a definite nuisance. Fish life has practically disappeared from the canal. In the Illinois River, fish life had decreased before the opening of the canal. The catch is said to have increased after the opening. Observations of the dissolved oxygen in the river during the summer show an amount below the supposed requirements of fish until after the water has passed the Marseilles dam. There is a general increase down stream.

Large deposits of sludge have collected in the forebay of the power house, and in the wider sections of the canal. These deposits should be prevented, wherever practicable, by the use of settling tanks, to keep sludge out of the canal.

The report states that the Des Plaines river above Joliet in the summer of 1910 was in a bad condition. The Illinois and Michigan Canal is a nuisance in Joliet. These conditions should be remedied.

The principal tributaries of the Illinois River are in good condition as shown by the amount of oxygen and the fish. The Sanitary District will always be the governing factor so far as human pollution is concerned. The pollution due to industrial wastes is another question, and it is important that their discharge into the canal and river be regulated.

There should be as rapid flow as possible. Dams hold back the settling material and permit fermentation.

It is estimated that 640,000 cubic yards of liquid sludge will be obtained from the domestic sewage each year. Twenty per cent. additional will come from the packing houses and more from other industrial concerns. Settling tanks are recommended to prevent trouble. The sewage of the North Shore towns should be intercepted, or, if discharged into the Lake, it should first be treated. Disposal works within the Sanitary District should be operated under the supervision of the Sanitary District.

The various methods of sewage disposal are described and discussed. The methods mentioned are dilution, screening, settling, sewage farms, sand filtration, contact beds and aëration. Two methods of procedure are available for extending the capacity of the canal. First, by settling the sewage of a large population; second, by settling and treating on sprinkling filters the sewage of a much smaller population. By a judicious combination of the two methods, it is believed that a most economical development can be secured.

Treatment will have to be begun in 1922, and in 1930, must be conducted on a basis equivalent to the complete purification of the sewage from 500,000 people. Assuming that purification by sedimentation will effect about 25% improvement, the sewage of 2,000,000 would have to be settled by 1930. Settling alone will not suffice after the year 1935. The first cost and the annual cost of various projects have been estimated.

Intercepting sewers will be needed in the Calumet region at a cost of $2,242,500, and an annual cost of $160,000. Settling projects or combined settling and sprinkling filter projects may be carried out as indicated in the table.

Designation.	Population Estimated in 1930.	First Cost.	Annual Cost in 1930.
Calumet	301,100	$ 695,750.00	$ 69,850.00
Thirty-ninth street	518,000	1,302,000.00	123,130.00
Lawrence avenue	218,200	746,000.00	66,900.00
North Branch	606,410	1,552,300.00	155,600.00
West Side	513,800	1,204,000.00	124,600.00
W. Twenty-second street	475,100	1,202,000.00	116,930.00
Stockyards, etc.	324,090	618,800.00	67,000.00
Calumet	301,100	2,761,700.00	261,800.00
NorthBranch	606,410	5,943,700.00	548,900.00
West Side	513,800	4,985,000.00	447,800.00

The sewage disposal situation and the water supply of Chicago are very closely related. The Sanitary District was established to remove sewage from Lake Michigan and to protect the water supply. Standards of sanitary science are higher than when the Sanitary District was established, and the demand is rising for the purification of all surface supplies. It is possible that it may be necessary to filter Chicago water in the future. This should certainly be done if any sewage, treated or untreated, be discharged into the Lake. While such discharge of sewage is not contemplated, yet considerable sewage enters the Lake in the Calumet Region, and until this is taken care of, it is recommended that the water supply obtained through the Sixty-eighth Street intake be sterilized with calcium hypochlorite. This treatment is shown to be comaratively inexpensive. Water taken in at the other intakes shouldbe treated in order to prevent possible pollution by boats and in time of storm.

It is considered advisable that the Calumet District in Indiana should be organized into a Sanitary District in order that the Lake water may not be polluted by sewage from the Indiana towns. Outlying towns on the North Shore and in the Calumet District should take care of their sewage by the construction of sewage disposal plants instead of the slow and expensive building of intercepting sewers.

The Sanitary District should continue to obtain accurate knowledge concerning the condition of the Illinois River and its tributaries in order that the information may be at hand to protect the District and its inhabitants from unjustified attacks. The order in which the various projects should be undertaken is outlined and the estimated cost for each five years is shown.

THE LAKE MICHIGAN WATER COMMISSION.

The First Report of the Commission was reviewed in a previous Bulletin.* The Second Report was issued in 1911. The members of the Commission, appointed by the Federal Departments, Governors of the various states, and by the Mayors of the various cities are the following:

CHICAGO—

W. A. Evans, M.D., Commissioner of Health.
Adolph Gehrmann, M.D., Columbus Laboratories.
C. D. Hill, Engineer Board of Local Improvements.
Thomas M. Sullivan, Trustee, The Sanitary District.

GRAND RAPIDS—

Perry Schurtz, M.D., Member Board of Health.

*University of Illinois Bulletin, State Water Survey Series, 8, 20–4.

INDIANA—

H. E. Barnard, B.S., Chemist, State Laboratory of Hygiene, Indianapolis.

R. L. Sackett, B.S., C. E., Professor of Municipal and Sanitary Engineering, Purdue University, Lafayette, Ind.

INDIANA CITIES—

A. J. Lauer, M.D., Secretary, Board of Health, Whiting, Ind.

ILLINOIS—

Edward Bartow, Ph.D., Director, State Water Survey, University of Illinois, Urbana.

MICHIGAN—

Frank W. Shumway, M.D., Secretary, State Board of Health. Lansing.

MILWAUKEE—

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UNITED STATES ARMY—

Major Charles S. Bromwell, Milwaukee, Wis.

UNITED STATES PUBLIC HEALTH AND MARINE HOSPITAL SERVICE—

G. B. Young, M.D., Chicago, Ill.

WISCONSIN—

Q. O. Sutherland, Member State Board of Health, Janesville, Wis.*

C. H. Sutherland, Member, State Board of Health, Janesville, Wis.

Three meetings have been held since the First Report was issued. Fourteen papers which have been presented are published.

Utilization of Hypochlorite of Lime as a Disinfectant for the Water Supply of Chicago, by John W. Alvord.

Sewage Disposal, by Langdon Pearse.

Sewage Disposal Plants in the States of Illinois, Indiana, Michigan and Wisconsin (a tabulation), by Langdon Pearse.

Sewage Purification Plants in Indiana, by R. L. Sackett.

Report on Sanitary Survey of Lake Michigan, Chicago to Waukegan, by Langdon Pearse, F. O. Tonney and Edward Bartow.

Relation of the Intake to Pure Water from the Great Lakes, by Chas. B. Burdick.

Composition and Treatment of Lake Michigan Water, by Edward Bartow and Lewis I. Birdsall.

The Field for Water Disinfection from a Sanitary Standpoint, by C. E. A. Winslow.

*Deceased.

In the "conclusions concerning the character of Lake Michigan Water," Dr. Evans has summarized the observations and reports of the Commission.

A study of the relation of the shipping on the Great Lakes to the spread of typhoid, shows that vessels are liable to pollute the waters of the Great Lakes and the Water Supplies taken therefrom. Precautions are suggested that will remove the danger.

The Calumet River district furnishes a large amount of sewage and trade wastes. Much of the organic matter settles and putrefies, especially at periods of low water. Some pollution is carried into the lake. This is especially true during flood stages. The formation of a sanitary district is recommended to study the conditions for the purpose of finding a method of taking care of the entire drainage of the Calumet region.

The putrescible wastes from the starch and glucose factory at Waukegan, have been treated with lime and filtered through presses in order to remove organic matter and to render them less liable to create a nuisance.

ILLINOIS WATER SUPPLY ASSOCIATION.

The Illinois Water Supply Association was organized in February, 1909. The constitution and the programs of the first and second meetings were published in a previous Bulletin.*

The third meeting was held at the University of Illinois, February 21 and 22, 1911. Officers for the year 1911–12 were elected as follows:

President, O. T. Smith, Superintendent and Secretary Freeport Water Co., Freeport.

First Vice-President, R. R. Parkin, Water Department, Elgin.

Second Vice-President, C. H. Cobb, Water Works Co., Kankakee.

Third Vice-President, H. M. Ely, Water Co., Danville.

Secretary-Treasurer, Edward Bartow, Director State Water Survey, Urbana.

The following papers were read and published in the third volume of the Proceedings of the Association (1911).

Report of the Secretary-Treasurer, Edward Bartow, Director State Water Survey, University of Illinois.

President's Address, A Delayed Message, C. E. Slocum, Superintendent Water Supply Company, Belleville.

Address, Possible Lines of Service of the University to Municipalities, David Kinley, Dean Graduate School, University of Illinois.

Report of Committee on Legislation, F. C. Amsbary, Chairman.

*University of Illinois Bulletin, Water Survey Series No. 8, 24–9.

Rate Making, F. C. Jordan, Secretary Indianapolis Water Co., Indianapolis, Ind.

Relation of the Intake to Pure Water from the Great Lakes, Charles B. Burdick, Hydraulic and Sanitary Engineer, Chicago.

Water Surveys, Chicago, T. C. Phillips, Engineer Water Surveys, Chicago.

Stoppage of Steam Pipes, S. W. Parr, Professor of Applied Chemistry, University of Illinois.

New Method of Chemical Treatment of Water, W. B. Bull, Chicago.

Bacteriology of the Swimming Pool, K. N. Atkins, Instructor in Bacteriology, University of Chicago.

A Simple Orifice Bucket for Measuring Water, M. L. Enger, Associate in Theoretical and Applied Mechanics, University of Illinois.

Condemnation of Land to Protect Wells, E. MacDonald, Superintendent Lincoln Water and Light Co., Lincoln.

Sewage Problem and its Relation to Water Supply (Illustrated), Langdon Pearse, Assistant Engineer Sanitary District of Chicago, Chicago.

Analysis of Chemicals used in Water Treatment, E. Bartow and H. P. Corson, University of Illinois.

Telescoping Tubes for Bacterial Cultures, W. F. Monfort, Chemist St. Louis Water Department, St. Louis, Mo.

Ozone Experiments in Water Treatment, W. F. Monfort, Chemist St. Louis Water Department, St. Louis, Mo.

Some Notes on Deep Well Pumping, F. C. Amsbary, Superintendent and Manager C. & U. Water Co., Champaign.

Diagram for Friction Loss in New Cast Iron Pipe, A. N. Talbot and M. L. Enger, University of Illinois.

Fallacies in the Bacterial Control of a Sewage Purification Plant, Dr. Arthur Lederer and Frank Bachmann, Sanitary District of Chicago, Chicago.

Removal of Iron from a Drift Well Water, A. N. Talbot, University of Illinois.

The Action of a Slow Sand Filter During the Process of Filtration, F. D. West, Chemist in Charge, Torresdale Laboratory, Philadelphia, Pa.

Merits of Automatic Devices for Mechanical Filter Plants, D. H. Goodwillie, Superintendent Filtration, Toledo, Ohio.

Uncertain Yield in Drift Wells, G. C. Habermeyer, Assoc. in Mun. and San. Engr., University of Illinois.

Trouble on the Mississippi at Low Water, W. R. Gelston, Superintendent Citizens' Water Works Co., Quincy.

The Purity of Shallow Well Waters, H. W. Hill, Director Division of Epidemiology, Minnesota State Board of Health, Minneapolis.

List of Members.

The membership of the Association in 1911 included 158 active members and 19 associates. Copies of the Proceedings are sent to members, others may obtain them by purchase from the Secretary. All persons interested in the water supplies and water problems of Illinois are eligible to membership.

RIVERS AND LAKES COMMISSION.

The Rivers and Lakes Commission of Illinois was created by an act of the Legislature approved June 10th, 1911. The Commission consists of three members, one civil engineer, one lawyer, and one person neither a lawyer nor a civil engineer who is intimately acquainted with the Rivers and Lakes of Illinois.

The Commission has jurisdiction and supervision over all the rivers and lakes in the state of Illinois wherein the state of Illinois or the people of the state of Illinois have any rights or interests. It is the duty of the Commission to collect any information which will tend to show the rights of the people of the state with reference to each body of water in the state. To prevent encroachment upon the shores or waters of any stream or lake. To receive complaints concerning encroachments, obstruction to navigation, or attempts to assert unlawful rights concerning docks, landings, etc., and to take action which may be necessary to correct wrongs. To take action which will encourage the use of public bodies of water for navigation. To prevent the pollution or defilement of the streams and lakes by the deposit of injurious substances so that fish or other aquatic life is destroyed. This shall not prevent the Sanitary District or any other lawfully organized drainage District from discharging its drainage into any rivers of the state of Illinois under authority conferred upon them so to do by the Legislature of the state. Data shall be made available to the public. It shall plan and devise methods for the preservation and beautifying of the public bodies of water of the state. It shall assist in any way possible in the reclamation or drainage of lands. Plans for structures in the public bodies of water of the state must be submitted to the Rivers and Lakes Commission for their approval.

It shall devise plans, ways and means for public reservations along the public bodies of water for the use of the people. It shall obtain data concerning the availability of the various streams for water power. It shall co-operate with the Fish Commission with reference to cultivation and preservation of fish. It shall investigate the carrying capacity of streams in times of flood that this capacity be not limited by encroachments. It shall examine the shores of Lake Michigan not less than four times each year to prevent encroachments.

The Attorney-General, the State's Attorney of any county or other authorized attorney shall be deemed to be the proper representative of the state of Illinois with full power and authority to prosecute in behalf of the Rivers and Lakes Commission all necessary suits or actions. The Rivers and Lakes Commission shall have full power over every public body of water in the State of Illinois, subject only to the paramount authority of the United States with reference to the navigation of such stream or streams.

In accordance with the above act, Mr. Robert R. McCormick was appointed Chairman, and Mr. Isham Randolph and A. W. Charles, Members of the Commission. The reports and publications of the Commission will be reviewed in later bulletins.

THE COMPOSITION OF INSOLUBLE GASES FORMED BY THE DECOMPOSITION OF ORGANIC MATTER.

BY R. H. JESSE, JR., PH.D.

In the fall of 1909, a gas explosion occurred in one of the septic tanks at Highland Park, Illinois. The State Water Survey was asked to make an investigation of the working conditions of the tank in order to determine, if possible, the causes that led to this explosion. In the course of the investigation samples of the gas evolved were collected from the tank in question, as well as from another of the Highland Park tanks, which had been working satisfactorily. The composition of these two samples was compared with that of two samples collected from the Urbana septic tank. While the amount of combustible gas (85% CH_4) was higher in the gas from the tank which exploded, there was enough (70–73% CH_4) in each of the other tanks to have caused an explosive mixture, if the proper proportions of air had been present. The composition of the gas, therefore, furnished no adequate explanation of the cause.* It may be recalled that a similar explosion in the Saratoga tank several years ago was much discussed at the time.[1]

It was interesting to compare the composition of these four samples with that of similar gases analyzed by other observers. A search of the literature revealed the fact that comparatively few such analyses were available. The most elaborate work is that of Kinnicutt and Eddy,[2] who have reported the composition of gases evolved from an experimental tank at Worcester, Mass. Collections and analyses were made each month for a period of thirteen months. The work of Dibdin and

*It may be of interest to mention that this tank is the cause of a suit now pending against the municipal authorities of Highland Park. The owners of the property adjacent to the tank insist that it is a nuisance because of the offensive odors which they say are given off. The tank handles the waste from a large laundry (5,000 patrons) and from a large hotel. The other tanks, of which there has been no complaint, handle the sewage from dwelling houses only.

[1]Mason, Jour. N. E. Water Works Assoc. The possibility of the presence of a spontaneously inflammable gas was debated. In this connection it is interesting to note that in 1851, Scanlan and Anderson reported phosphuretted hydrogen as a constituent of sewer air. They, however, give no details of their method of testing for this gas. *J. Chem. Soc., 3, 13* (1851).

[2]Sewerage Commission, Connecticut, Third Report, 1901.

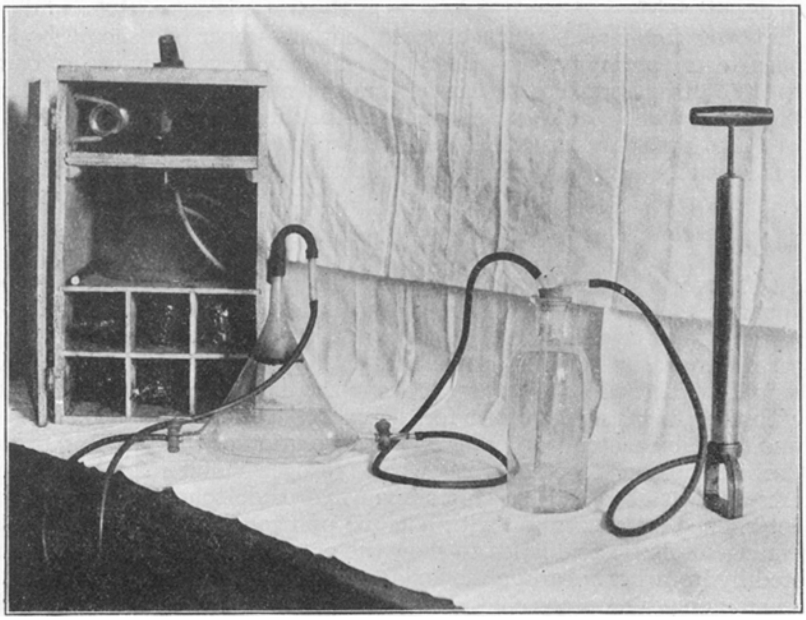
Rideal,[1] on the gases of a tank at Exeter, England, of Fowler,[2] at Manchester, and of Gill,[3] at Lawrence, Mass., was also available. The samples collected in Illinois differed considerably from the Worcester samples. This was especially true with respect to the nitrogen and carbon dioxide content. The highest nitrogen content of these first Illinois samples (5%) was about one-third as great as the lowest nitrogen and only one-twelfth as large as the highest reported from Worcester. The average carbon dioxide content of the western gases was more than twice as great as that of the eastern. There were still wider variations when comparison was made with the English samples. Therefore it was thought worth while to make a more extended study of the gases of Illinois tanks, in order to determine whether these differences were constant, and if so, whether they were indicative of any difference in the decomposition processes. In the summer of 1911, gases were collected from tanks at the following places in Illinois: Highland Park, Winnetka, Lake Forest, Woodstock, LaGrange, Downer's Grove,[4] Naperville, Wheaton, DeKalb, Edwardsville, Collinsville, Urbana, Champaign, and the experimental sewage plant of the Sanitary District at the 39th Street pumping station, Chicago. Upper Alton, Belleville, and Harvard were visited, but it was impossible to collect gases from their tanks because, for various reasons, they were not in working order. Samples were sent to us from Columbus, Ohio, Worcester, Mass., and other places outside the state. The gases generated by the sewage-polluted Illinois River were also collected and examined. This report presents the analyses of these gases with a discussion of the results.

Method of Collection.

The outfit used in collecting the samples is shown in the accompanying cut. A ten-inch glass funnel was connected by rubber tubing to a 500 c. c. cylindrical glass container fitted at each end with a well-ground glass stop-cock. The other end of the container was connected by means of a rubber tube to a glass tube which ended in a ground glass check-valve. This tube passed through a rubber stopper to the bottom of a stout glass bottle. Another tube which ended flush with the bottom of the stopper led from this bottle to a bicycle pump in which the leather plunger had been reversed so that the up-stroke caused the suction. The manner of operation is as follows: The top layer of sludge of a septic tank is broken and the funnel is dropped into the water. The pump is started and pumping is continued until the funnel, the connecting tubes, and the gas container are completely filled with water, and enough water has entered the bottle to seal the end of the longer

[1] Rideal, Sewage and the Bacterial Purification of Sewage, 3rd Ed., Page 97.
[2] Annual Report Rivers Dept. Manchester, 1901.
[3] Report Mass. State Board of Health, 1899, p. 422.
[4] Eng. Record, 3 Feb., 1906.

tube. A disc of copper gauze fastened into the funnel with sealing-wax served to filter out solid, particles which might cause clogging of the tubes. When the apparatus is full of water the stop-cocks are closed.



Apparatus for Collecting Gas Samples.

Where there is a good layer of sludge on the bottom of the tank, gas is generally trapped in this layer. By stirring this sludge with a pole, the gas rises and is caught under the funnel. Where there is not sufficient sludge on the bottom to hold the gas, samples may be collected generally by raising the funnel somewhat and moving it cautiously around under the unbroken layer of top sludge. In this case, however, care must be taken never to raise the funnel high enough to allow air to enter. This last method of collection is not to be recommended where the other method is practicable.

It is quite possible that the different constituents of the gas mixture will diffuse through the top sludge at different rates, so that the constituents of the residue may be quite different from those of the gas mixture originally generated by the tank. There is a possibility that this source of error affects also the gas trapped in the bottom layer, but it does not seem to be so probable.

When the funnel is about two-thirds full of gas, the gas container is raised to a vertical position, the end which is attached to the safety bottle *downwards,* and by pumping, the water is drawn from the container into the bottle and the gas enters the top of the container. The above process is repeated until all the water has been pumped out of the container.

Since suction has been used, at the end of this process the gas is under diminished pressure. As soon as the water is out of the container, the lower stop-cock should be closed, but the upper one should be left open for a few minutes in order that gas may have a chance to come to the ordinary pressure. In order that this may be accomplished, there should always be some gas remaining in the funnel.

The containers so filled, were transported to the laboratory in a box specially designed to hold the collection apparatus.

Method of Analysis.

The analysis was carried out by the use of the regular Hempel apparatus. The burettes were water-jacketed and temperature corrections were made wherever they were necessary. Samples of the gases were taken from the containers as they were needed for analysis. Since it was at times necessary to leave the displacing liquid in contact with the gas in the container for rather long periods, the displacement was made by mercury in order to avoid solution of the carbon dioxide. Carbon dioxide, together with what hydrogen sulfid may have been present, was absorbed by a potassium hydroxide solution; oxygen was determined by absorption with alkaline pyrogallol; frequent tests with fuming sulphuric acid failed to show the presence of any of the unsaturated hydrocarbons; carbon monoxide was determined by agitation with an ammoniacal cuprous chloride solution followed by a dilute sulphuric acid solution which removed ammonia fumes.

The combustible gases were determined with the ordinary explosion pipette and by the Drehschmidt-Winkler heated platium capillary tube method. At first it was difficult to obtain concordant results for the gases ran very high in methane. The difficulty was found to be due to the fact that the proportions of oxygen, combustible gas, and inert gas in the explosion mixture were not suitable. By the use of a mixture of air and pure oxygen in the proper proportions, the results were more satisfactory than when air alone was used or than when pure oxygen was used. Burettes filled with mercury were used for the combustion work, and much care was taken to avoid solution of the carbon dioxide formed in the combustion. Neglect of these precautions can easily cause errors of several per cent. In general these errors are in such a direction that the calculated hydrogen content appears high. This point will be discussed again later. To make sure that no such errors affected the results of these analyses hydrogen was separately determined by absorption with palladium sponge. The palladium tube was tested constantly during the work by the use of gas mixtures to which known quantities of hydrogen had been added. The amount of hydrogen absorbed in these test cases agreed with the amount taken within one-tenth of a cubic centimeter. This is an important point, because no hydrogen was found in any of the gases tested, although its presence is reported in other gases by other investigators.

It is usual in gas analyses to determine nitrogen by difference. The accumulated errors of the analysis thus fall upon this constituent. For this reason and because one of the principal differences between the gas samples first collected lay in the nitrogen content, it was thought worth while to actually determine the nitrogen as well as to calculate it by difference. This was accomplished by keeping an account of the amount of nitrogen introduced with the air and oxygen used for the combustion and by absorbing the excess oxygen after the combustion. The difference between the volume of the residue found and the volume of nitrogen introduced is the volume of nitrogen originally present. The nitrogen found in these two ways agreed in a manner which must be considered satisfactory when the errors affecting the determination by difference are considered.

Since any hydrogen sulfid present had been absorbed with the carbon dioxide, it was necessary to make a special test with a fresh sample of gas. It was found by blank tests that when 100 c. c. of gas containing 0.05 c. c. of hydrogen sulfid was passed through a very faintly acid solution of cadmium chloride, the solution was colored yellow. This served as a qualitative test. If no coloration was produced under these conditions no hydrogen sulfid was reported. Where a qualitative test was obtained a quantitative determination was made by passing known quantities through a N–50 iodine solution and titrating with sodium thiosulfat.

Results of the Analyses.

Table I, gives all the published analyses of septic tank gases that I have been able to find.

TABLE I. ANALYSES OF SEPTIC TANK GASES.

Source	CO_2	O_2	Heavy Hydro-carbons	Gas absorbed by Cu_2Cl_2	CH_4	H_2	N_2	Analyst or Authority
Exeter	3.9	22.7	....	....	4.5	2.2	66.1	Dibdin
	3.5	8.0	....	....	40.1	6.2	42.2	
Exeter	0.6	....	....	....	24.4	36.4	38.6	Rideal
Manchester	6.0	....	....	....	73.0	5.0	16.0	Fowler
Lawrence	3.4	0.5	0.3	0.6	78.9	....	16.3	Gill
Worcester								
October	5.6	1.9	....	0.8	75.3	....	16.4	Kinnicutt and Eddy
November	4.1	1.2	....	0.5	76.9	....	17.3	
December	2.5	2.0	....	0.4	69.5	....	25.6	
March	8.8	1.0	....	0.1	13.3	....	76.8	
April	9.8	0.9	....	0.2	28.4	....	60.7	
May	15.2	1.5	....	0.1	26.9	....	56.3	
June	17.0	1.2	....	0.2	52.1	....	29.5	
July	8.7	1.3	....	0.4	63.8	....	25.8	
September	8.0	1.6	....	0.4	57.8	....	32.2	
October	6.9	0.6	....	0.6	72.4	....	19.5	
November	6.3	0.7	....	0.3	79.2	....	13.5	
December	5.6	0.9	....	0.1	76.8	....	16.6	
Mean	8.2	1.2	....	0.34	57.7	....	32.5	

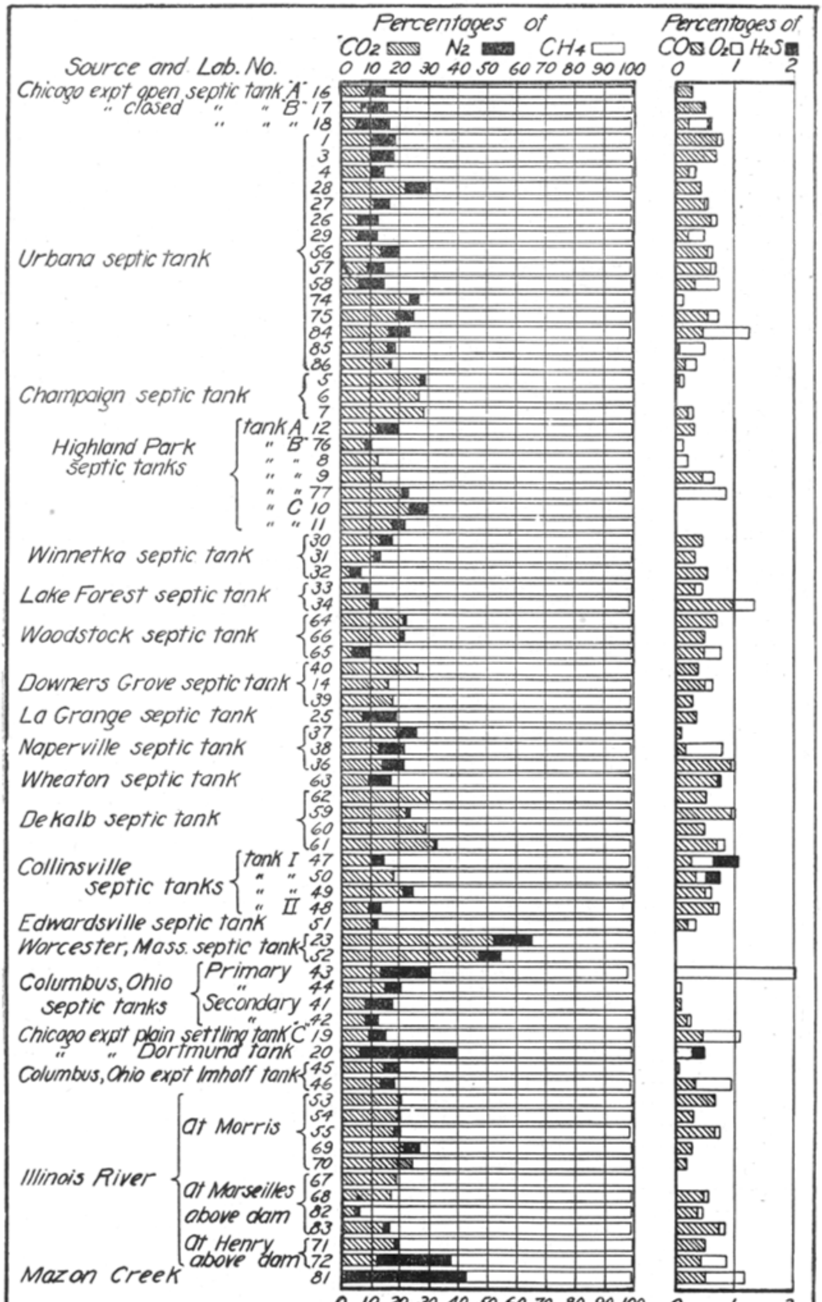


Diagram of Analyses of Gases from Sewage Tanks and Streams

In Table II, are the results of the analyses made in this laboratory. These are shown graphically also in the Figure.

TABLE II.

Lab. No.	Town	CO_2	O_2	Gas absorbed by Cu_2Cl_2	CH_4	N_2	H_2S
1	Urbana	10.83	0.1	0.7	81.03	7.34	....
3	Urbana	10.2	0.0	0.7	81.5	7.6	....
4	Urbana	10.2	0.11	0.22	85.10	4.37	....
28	Urbana	21.69	0.0	0.42	69.55	8.44	....
27	Urbana	11.36	0.05	0.50	83.4	4.79	....
26	Urbana	5.76	0.1	0.6	87.13	6.41	....
29	Urbana	5.89	0.3	0.22	87.36	6.23	....
56	Urbana	13.74	0.09	0.54	79.61	6.02	....
57	Urbana	9.11	0.09	0.60	84.73	5.47	....
58	Urbana	6.08	0.4	0.32	84.63	8.57	....
74	Urbana	23.57	0.13	0.0	73.3	3.0	....
75	Urbana	18.98	0.17	0.55	74.9	5.4	....
5	Champaign	27.1	0.08	0.05	71.43	1.34	....
6	Champaign	26.4	0.0	0.0	73.6	0.0	....
7	Champaign	28.18	0.1	0.2	71 .52	0.0	....
12	Highland Park, Tank A.	12.18	0.0	0.32	79.77	7.72	....
76	Highland Park, Tank B	8.44	0.13	0.0	89.5	1.8	....
8	Highland Park, Tank B.	12.80	0.2	0.0	87.0	0.0	....
9	Highland Park, Tank B.	13.7	0.2	0.45	86.1	0.0	....
77	Highland Park, Tank B	20.77	0.87	0.0	76.2	2.16	....
10	Highland Park, Tank C.	23.3	0.0	0.0	69.93	6.77	....
11	Highland Park, Tank C.	17.3	0.0	0.0	78.0	4.7	....
16	Chicago, Tank A, open septic.	8.60	0.0	0.30	84.92	6.18	....
17	Chicago, Tank B, closed septic.	6.99	0.0	0.46	84.2	8.3	0.04
18	Chicago, Tank B, closed septic.	5.17	0.32	0.22	83.1	11.1	0.09
19	Chicago, Tank C, settling tank.	9.31	0.62	0.45	83.9	5.72	....
20	Chicago, Dortmund tank.	6.42	0.30	0.0	60.0	33.06	0.22
24	Chicago, Sludge tank.	....	....	....	....	....	....
30	Winnetka	13.81	0.0	0.45	82,35	3.39	....
31	Winnetka	11.13	0.0	0.32	86.25	2.30	....
32	Winnetka	3.1	0.0	0.55	92.77	3.58	....
33	Lake Forest	7.1	0.13	0.33	89.8	2.64	....
34	Lake Forest	10.00	0.36	0.98	85.77	2.89	....
64	Woodstock	21.40	0.0	0.70	77.36	0.54	....
66	Woodstock	20.22	0.0	0.50	78.48	0.80	....
65	Woodstock	3.79	0.25	0.53	89.54	5.89	....
40	Downers Grove	26.28	0.0	0.4	73.32	0.0	....
14	Downers Grove	16.15	0.11	0.53	83.2	0.01	....
39	Downers Grove	17.07	0.0	0.30	82.63	0.00	....
25	LaGrange	7.31	0.0	0.37	80.81	11.51	....
37	Naperville	19.06	0.0	0.1	74.5	6.34	....
38	Naperville	13.04	0.62	0.18	77.52	8.64	....
36	Naperville.	14.19	0.09	0.95	77.65	7.12	....
63	Wheaton	9.33	0.0	0.72	82.10	7.85	0.04
62	DeKalb	30.52	0.0	0.59	68.89	0.0	....
59	DeKalb	22.24	0.05	0.95	75.37	1. 39	....
60	DeKalb	29,06	0.00	0.56	70.46	0.0	....

TABLE II.—Continued.

Lab. No.	Town.	CO_2	O_2	Gas absorbed by Cu_2Cl_2	CH_4	N_2	H_2S
61	DeKalb	32.00	0.13	0.72	66.93	0.22	....
47	Collinsville, Tank I	10.54	0.37	0.26	84.40	4.00	0.43
50	Collinsville, Tank I	17.98	0.23	0.34	81.26	0.00	0.19
49	Collinsville, Tank I	21.08	0.07	0.56	75.16	3.13	....
48	Collinsville, Tank II	9.46	0.09	0.65	86.00	3.80	....
51	Edwardsville	11.33	0.15	0.21	87.34	0.97	....
23	Worcester, Mass	52.15	0.0	0.0	34.76	13.09	....
52	Worcester, Mass	47.04	0.0	0.0	45.46	7.5	....
41	Columbus, O., secondary	8.11	0.0	0.1	83.5	9.29	....
42	Columbus, O., secondary	8.55	0.07	0.20	86.99	4.19	....
43	Columbus, O., primary	13.48	2.07	0.0	67.46	16.99	....
44	Columbus, O., primary	15.17	0.1	0.0	79.43	5.30	....
45	Columbus, O., Imhoff	14.45	0.05	0.0	80.13	5.37	....
46	Columbus, O., Imhoff	13.39	0.61	0.34	81.03	4.63	....

The analyses are not directly comparable with those of Kinnicutt, because his collections were made from a closed tank from which there was no escape for a gas except by solution. Our samples, however, in addition to the effect of solution, may have been affected by different rates of diffusion of the various constituents.

It is hard to make any general comparisons, for the gases vary a great deal even when they are taken from the same tank. It has already been mentioned that one of the most striking differences between the present analyses and those previously reported, lay in the nitrogen content. In many Illinois samples, there was no free nitrogen, while the average content of all the samples was much lower than in the samples from the eastern United States. In order to confirm this difference, analyses have been made of several samples from the Worcester, Massachusetts settling tank, collected for us by Professor F. Bonnet, Jr. and Mr. Almon Fales. The striking feature of this gas was its very high carbon dioxide content (about 50%).

In the summer of 1911, the Illinois River, which carries the sewage of Chicago, became highly polluted. Between the mouth of the Kankakee and Chillicothe there was some sludge on the river, much offensive odor, and a good deal of gas formation. The State Water Survey, in connection with the State Laboratory of Natural History, made dissolved oxygen determinations over this region. At the same time, samples of the gas were collected and analyzed. The results of these analyses are given in Table III. In order to compare these gases with those from stagnant pools, which are not polluted with sewage, there is given an analysis of a gas sample collected from Mazon Creek which enters the Illinois River near Morris. The difference between this gas and those from the Illinois River is as striking as is the similarity between the latter and the gases from septic tanks.

TABLE III.

Lab. No.	Town.	CO_2	O_2	Gas absorbed by Cu_2Cl_2	CH_4	N_2	H_2S
53	Illinois River, Morris	19.45	0.0	0.69	79.30	0.56	....
54	Illinois River, Morris	19.31	0.0	0.32	79.51	0.86	....
55	Illinois River. Morris	18.12	0.09	0.68	78.91	2.14	....
69	Illinois River, Morris	21.49	0.0	0.30	73.00	5.21	....
70	Illinois River, Morris	23.85	0.00	0.19	75.96	0.0	....
67	Ill. R. above dam, Marseilles	18.74	0.0	0.0	81.28	0.0	....
68	Ill. R. above dam, Marseilles	16.85	0.05	0.55	82.55	0.0	....
71	Ill. R. above dam, Henry	17.76	0.0	0.52	80.83	0.89	....
72	Ill. R. above dam, Henry	11.99	0.44	0.42	61.91	25.24	....
82	Ill. R. above dam, Marseilles	4.65	0.1	0.30	93.99	0.91	....
83	Ill. R. above dam, Marseilles	14.60	0.1	0.75	83.45	1.1	....
81	Mazon Creek	0.75	0.66	0.55	56.44	41.61	....

For the sake of comparison there are given in Table IV, some results obtained by Spitta,[1] on gases collected from the bottom of the Spree and also the results quoted by him for one sample from the Seine.

TABLE IV.

River	Locality.	CO_2	O_2	CO	H_2	CH_4	H_2S
Spree	Nordhafen	2.1	3.0	4.4	0.0	36.2	....
Spree	Nordhafen	6.0	2.2	3.5	0.0	37.2	....
Spree	Nordhafen	13.7	0.0	0.5	0.0	59.2	....
Spree	Oberbaumbrucke	1.46	0.87	0.58	2.55	18.3	....
Spree	Ebertsbrucke	2.88	3.29	9.89	1.56	8.39	....
Spree	Moabiter Brucke	1.04	4.17	11.89	0.0	13.67	....
Spree	Spandau.	1.40	0.93	4.21	0.0	22.5	....
Spree	Charlottenburger Schleuse.	2.1	0.0	0.4	0.0	12.2	....
Spree	Greuzgraben	5.4	1.8	0.2	0.0	16.3	....
Seine	Paris.	12.30	....	2.54	....	72.88	6.70

The gases from the Spree differ very widely from those of the Illinois River. Except in a single case, the carbon dioxide is much lower in the Spree. There is also a notable quantity of oxygen for a sewage-polluted stream, and a much lower per cent of methane. The reported amount of carbon monoxide is astounding, and it is to be doubted whether this is really carbon monoxide. We shall return to this point later. The Seine gas resembles the gases of the Illinois River much more closely, except in the very astonishing amount of hydrogen sulfid which is reported.

[1]Archiv für Hygiene, 38, 276ff.

If we wish to study the composition of these gases in relation to the reactions which take place, or if we wish to use the gas composition as an index of the working conditions of a tank, we shall, of course, have to classify the numerous reactions involved in the anærobic decomposition of organic matter. Rideal[1] has made the following classication of the chemical processes of the septic tank.

1. An hydrolysis of complex albuminous bodies, which takes place in two stages; (a) conversion to a soluble form, peptonization; (b) hydrolysis of the peptones into amino acids, leucin, tyrosin and aromatic bodies. This process involves no gas formation.

2. A splitting up of the amino acids into fatty or aromatic acids, with the formation of ammonia or nitrogen or both together.

3. The acids formed by the split of the albumin molecules break down into still simpler acids. In this process, hydrogen and methane are generated.

4. The hydrolysis of urea to carbon dioxide and ammonia, which unite to form ammonium carbonate.

5. The decomposition of cellulose into fatty acids and carbon dioxide with the evolution of hydrogen or methane.

6. The hydrolysis of starches, sugars and gums to butyric and lactic acids with the formation of carbon dioxide, hydrogen and water.

7. The decomposition of fats. This is practically nil under anærobic conditions.

8. The formation under the influence of bacteria of hydrogen sulfid and mercaptans from the sulfur in the organic molecule.

Perhaps it will be best to discuss these reactions under the heading of the different constituents of the gas mixture which result from them.

Carbon dioxide is the result of the breaking down of the complex organic acids, and of the decomposition of cellulose and carbohydrates. The amount varies widely in the different samples, the range being from 3% at Winnetka to 52% at Worcester, Mass. On account of its solubility, the proportion of this gas present in a sample is probably less than it should be.

There seems to be a variation in the amount of carbon dioxide in the different parts of the tank. The nearer the inlet the sample is taken, the greater the carbon dioxide content. This is not, however, an invariable rule. The horizontal columns of Table V show the carbon dioxide content of samples collected on the same day from different portions of the Urbana tank. The figures in each horizontal column are, therefore, comparable with one another. In each case the left hand column represents the sample taken nearest the inlet end. The samples from the Urbana tank are taken to illustrate this point because there are more samples from this tank than from any other.

[1]Sewage and the Bacterial Treatment of Sewage. 3rd Ed. p. 105 H.

TABLE V.

Inlet			Outlet
10.83	10.2	10.2	....
21.69	11.36	5.76	5.89
13.74	9.11	6.08	....
23.57	18.98	....	....
16.16 } 16.15 }	16.00	....	....

It is a question whether this indicates that the decomposition of cellulose and carbohydrate matter is accomplished early in the septic action. It is possible since the sludge accumulation is greatest at the inlet end of the tank that the increased carbon dioxide content is the result of long-continued action upon substances held in this sludge. One of the end products of organic oxidation is, of course, carbon dioxide. But we are dealing here with anærobic conditions and oxidation cannot play its usual role. The organic acids resulting from the splitting up of the albuminous molecule, and from the hydrolysis of carbohydrates are mostly soluble, and are not likely to be retained in the sludge. It is possible then that the varying amounts of carbon dioxide in the different parts of the tank may serve as an indication of the speed of the hydrolysis of these bodies.

Whether or not the amounts of carbon dioxide generated by the different tanks bear any relation to the amounts of cellulose and carbohydrates in the sewage is a matter to be determined only by data from analysis of the sewage.

Oxygen. The oxygen content is, of course, very small, since the process is supposed to be anærobic. In only three cases does it exceed 0.6%. From this point, it varies down to zero.

Carbon Monoxide. Like Kinnicutt, we have found that there is persistently present a small quantity (nearly always less than 10%) of a gas which is absorbed by ammoniacal cuprous chloride. It is practically certain that this gas is not carbon monoxide. Kinnicutt has tested his gases by means of the blood spectrum test, and with iodine pentoxide. Several blood spectrum tests on the present samples failed to give the slightest indication of carbon monoxide. The nature of this constituent is yet unknown. The small proportions in which it occurs makes it difficult to obtain sufficient quantities for thorough investigation. It is interesting in this connection to notice the very large quantities of carbon monoxide reported in the gases of the Spree.

Ammonia. Frequent tests with dilute acid showed that no ammonia was present in the gases. It is certain that ammonia is formed in the septic action, but apparently it all remains in solution.

Hydrogen. Careful tests with palladium sponge furnished convincing evidence that there is no occurrence of hydrogen in any of the gases analyzed. Kinnicutt reached this same conclusion in regard to the gas from the experimental tank at Worcester. Other investigators have, however, reported hydrogen. In this part of the gas analysis it is extremely easy to make errors which would make it appear that hydrogen is present. For the combustion, an aliquot portion of the residue is taken to represent the whole. There is in addition, a multiplication of the analytical error in the calculation; so that an actual error of 0.2 c. c. may be magnified very easily to several per cent. of the whole. It is, thus, quite probable that in most of the cases where small amounts of hydrogen have been reported, this is due to faulty analysis. On the other hand, it seems hardly possible that the 36% of hydrogen from Exeter reported by Rideal can be due to error.

There is no doubt that hydrogen can be formed as a product of many of the reactions described by Rideal. Thus, in the fermentation of the amino acids, cucin forms valerianic acid, ammonia, carbon dioxide and hydrogen, and tyrosin, when air is excluded, forms indol, carbon dioxide and hydrogen.1 In the decomposition of the fatty acids, we have the formation of hydrogen. Formic acid forms bicarbonates, carbon dioxide and hydrogen; one decomposition of lactic acid forms butyric acid, with propionic acid and hydrogen as by-products; malates may also form hydrogen. In the decomposition of cellulose, hydrogen or methane may be evolved according to the type of bacteria causing the hydrolysis. Frankland[2] has found that dulcitol when fermented in a peptone broth under the influence of *B. ethaceticus,* gives off gases which vary from 27–60% CO_2 , and from 39–48% H_2. Nitrogen is evolved during the first few days, but the amount then falls practically to zero. Similar results were obtained for mannitol. Pakes and Jollyman[3] have found that the gases evolved by *B. pyocyaneus* and *B. coli communis* consist of carbon dioxide and hydrogen and nitrogen, if nitrates are present. The gases formed by the action of *B. tetani* are hydrogen and carbon dioxide. We have made analyses of samples formed by *B. coli communis* in a peptone broth containing sugar. The conditions were anærobic. The results of these analyses are:

	CO_2	O_2	CO	CH_4	H_2	N_2
I	36.47	0.4	0.72	0.99	59.62	1.80
II	31.63	0.3		0.93	64.18	2.96

This is in fair agreement with the work of Pennington and Küssel[4] who report 62–70% H_2, 23–34% CO_2, and 1–4% CH_4. They further state that methane is not formed when oxygen is excluded.

It is thus seen that under conditions apparently similar to those which hold in the septic tank, we may have the formation of hydrogen from the splitting of the amino acids, from the fatty acids, and from the hydrolysis of cellulose and carbohydrates. Why is it that no hydrogen has been detected in the American septic tanks? It is true that, as the lightest constituent, hydrogen may be expected to make its escape by

[1]Neucki, J. prakt. Chem., XVII.

[2]J. Chem. SOc., 1892, 259; Proc. Chem. Soc. 110, 70–72; 114,132 (1892).

[3]J. Chem. Soc., 1901, 322, 459.

[4]J. Am. Chem. Soc., 22, 556 (1900).

diffusion faster than the others, but it is inconceivable that this escape can have been so complete that no trace remains in any of the samples. It would seem that this point is worthy of some investigation.

Nitrogen. Nitrogen results from the splitting of the albumin molecules and the further hydrolysis of the amino acids resulting from this split. The hydrolysis can go on in two ways: (a) with the production of ammonia or amines; (b) with the production of free nitrogen. Which of these cleavages will occur is determined by the conditions of the reaction. As a matter of fact, both reactions generally go on simultaneously in the septic tank. The above results furnish, so far as we are aware, the first examples of gases in which free nitrogen is absent. Gases collected from Champaign, one tank at Highland Park, Downer's Grove, DeKalb, and one tank at Collinsville, show no nitrogen at all. Many other samples show very small quantities. The average for these Illinois gases is below 8%. The reason for this low nitrogen content is not apparent.

Ehrenberg[1] has made some experiments on the evolution of nitrogen during the putrefaction of cow's urine, and feces. In a first series of experiments he found no nitrogen formation either under ærobic or anærobic conditions. In a second, series where the putrefactive processes were more intense, there was a formation of nitrates and an evolution of free nitrogen. Here there was also an evolution of methane at first. O. Kellner and Yoshu[2] have confirmed his work. They ascribe the formation of free nitrogen to secondary reactions. B. Tacke[3] found no evolution of nitrogen when nitrates were absent, but such an evolution took place in the presence of nitrates. The other gaseous products were carbon dioxide, hydrogen, methane, and hydrogen sulfid. Pakes and Jollyman[4] have found that nitrogen is generated under the influence of *B. coli communis* when nitrates are present. B. E. Dietzell[5], working on the putrefaction of blood and urine, found that the evolution of nitrogen depends on the formation of free nitrous acid which then reacts with leucine to form leucic acid, water, and nitrogen. Nitrous acid also attacks primary amines with the evolution of nitrogen. If chalk is present to neutralize the nitrous acid, the formation of free nitrogen is prevented.

It is perhaps not safe to draw too strict an analogy between these reactions and those that take place in the septic tank. All of the experiments just mentioned indicate that, for the formation of free nitrogen, there must be present some form of oxidized nitrogen. We could conceive of conditions in a tank which would prevent the formation of nitrates and nitrites. Then, according to the experiments, no nitrogen would be formed. The possibility is thus suggested that the

[1]Zeit. physiol. Chem., 11, 145–178.

Zeit. physiol. Chem., 12, 95–112.

[3]J. Chem. Soc., 1889, A, 738.

[4]Loc. cit.

[5]J. Chem. Soc., 1882, A, 811, 1122.

amount of free nitrogen may give some indication of the completeness of the anærobic condition of the tank. The results of Dietzell's experiments would also suggest that the amount of nitrogen generated might depend, to some extent, on the alkalinity of the sewage and, therefore, in a less degree, on the character of the water supply.

Methane. This gas was in all cases, except the gases from Worcester, Mass., the largest single constituent. The percentage varied with the variations of the nitrogen and carbon dioxide, since these three made up the bulk of the total. It is interesting to note that a case has been reported of a septic tank in Russia in which no methane was generated. In this tank, the total solids remained constant within experimental error, while 4.43% of the suspended matter passed into solution.[1]

It seems evident that septic action had never become established in this tank.

Hydrogen Sulfid. Miller[2] has isolated from the intestines an organism which causes decomposition of albumin with the generation of hydrogen sulfid. The *Bacterium sulphureum* has a similar action on. albuminoids. The *Bacterium hydrosulphureum ponticum* is able to reduce sulfats to sulfids. Beyerinck's[3] Genus Ærobacter forms-hydrogen sulfid from proteids and other compounds of sulfur except sulfates. Balistreri[4] has found eighteen different bacteria which produce hydrogen sulfid. Neucki and Sieber[5] have discovered hydrogen sulfid in the putrefaction products of serum albumin.

In spite of all this, hydrogen sulfid was found in four tanks only. The two giving the largest amount were the Dortmund tank of the Chicago experimental plant and one tank at Collinsville, in which the amount rose to 0.45%. The absence of hydrogen sulfid in the gases, however, does not prove that none was formed. Iron salts are an almost universal constituent of sewage, and these; of course, tend to remove the hydrogen sulfid as fast as it is formed.

It cannot be doubted that in some cases mercaptans are formed by sewage decomposition. Rideal has detected methyl mercaptan in the Exeter tank. Neucki and Sieber,[6] in the course of experiments on the products of putrefaction of serum, albumin by *B. liquifacius magnus,* has isolated this compound. If present at all in the Illinois tanks, the mercaptans must have remained in the liquid sewage. All tests with isatin in sulphuric acid[7] failed to give any indication of their presence in the gases.

[1]Sec. d'hyg. l'Inst. Imp. med. exper. Arch. Sci. biol., 16, 65–104.

[2]Deutsche Medizinische Wochenschrift, 1889, No. 49.

[3]J. Chem. Soc., 1901, A, ii, 119.

[4]Archiv für Hygiene, 1892, 10.

[5]J. Chem. Soc., 1890, A, 78.

[6]Lot. cit.

[7]Deniges, compt. rend., 1892, 350.

The principal result of this study of the gas formed in anærobic decomposition has been to raise several questions which will require further study before they can be answered. It has been suggested that the quantity of carbon dioxide evolved may run parallel to the amounts of cellulose and carbohydrates in the sewage, and that the amounts of this gas in different parts of the tank may serve as a measure of their rate of hydrolysis. The fact that no hydrogen is present in the gases has been confirmed. It has been pointed out that hydrogen may be expected as a product of many of the reactions which are supposed to take place. A study of the conditions which prevent the hydrogen formation is demanded. The conditions which prevent or reduce the disposal of nitrogen as free nitrogen are not clear. It seems that the way to study these problems is to perform analyses on gases generated by specific organisms or groups of organisms on sewage samples, the composition of which is known and can be controlled. Dr. Bartow and his associates in the Water Sur vey intend to continue the work along these lines.

This work was undertaken for the Water Survey at the suggestion of the Director, Dr. Edward Bartow. I am grateful for the interest he has shown in it, and for the help he has constantly given me during its progress. It is a pleasant duty, also, to acknowledge the efficient services of Mr. H. P. MacGregor, who helped me with the largest part of the work of collection and analysis.

OPINIONS RELATIVE TO PRINCIPLES GOVERNING STREAM POLLUTION.

By Paul Hansen.

A number of years spent in public sanitation work of an engineering nature, having special relation to problems involving stream pollution, has convinced the writer that popular opinions (where opinions of any kind exist) are. chaotic in regard to the degree to which streams may be contaminated. Among sanitarians, sanitary engineers and sanitary chemists, opinions relative to this important subject are decidedly unsettled.

While sanitary improvements are often suggested, and are usually supervised by experts, such improvements are rarely carried into effect except as a result of direct popular demand. If a popular demand for clean streams is to be stimulated and directed along rational lines, there must be some sort of popular education. Plainly, the ones to provide such education are the sanitarians, the sanitary engineers and the sanitary chemists. But if these experts are unsettled in their minds or differ widely in opinion as to fundamentals, what kind of popular education are we likely to get? Most likely education that will discredit the experts.

Most sanitarians rebel against making any general statements regarding stream pollution on the ground that every case is a problem in itself and must be solved in the light of a thorough knowledge of local conditions. Emphatically, an intimate knowledge of local conditions when attacking the solution of any specific problem is necessary to the giving of a competent specific opinion; but there is a distinct difference between a specific opinion and a general principle. Moreover, whenever a sanitary expert attacks a specific problem he consciously or unconsciously keeps certain general principles in mind and arranges his data concerning local conditions with respect to these general principles. It is true, on the other hand, that new combinations of local conditions often cause an open-minded person to discover defects in general principles which must then be altered in the light of the added experience; but the value of general principles used as a working hypothesis cannot be denied. With popular sentiment so favorable as it now is to sanitation in general and the prevention of stream pollution in particular, it seems high time that sanitary experts should get together and formulate the best set of general principles or working hypotheses that up to date experience and available facts will permit, in order that they may act more or less as a unit in forming and guiding popular opinion.

It is a mistake to suppose that general principles must be so circumstantial that they may be applied as a rule-of-thumb to any set of local conditions, but they at least should tell us what this agitation for cleaner streams is all about and what attitude of mind we should assume, in dealing with specific cases. With this to start on, future experience can be depended upon to add more and more knowledge until our general principles become a more complete guide, though they can probably never become an invariable guide.

The foregoing indicates the advantages that might be derived from securing a consensus of opinion relative to stream pollution from those who have given the subject long and careful thought. It is not hoped to settle the question, but rather to start a nucleus about which opinion may crystalize through a stimulated discussion of the subject.

METHODS EMPLOYED TO SECURE OPINIONS.

To secure opinions, a question blank was drawn up with a view to reaching as many of the important angles of the stream pollution problem as possible, and this blank was sent to men including sanitary officers, sanitary engineers, sanitary chemists and bacteriologists. There have been received fifty-one replies answering the questions directly, eight replies giving a general statement regarding stream pollution, but not directly following the questions, about a dozen replies declining for one reason or another to respond, and a number of others that promised to respond fully at a later date, but have not been heard from. The names of the respondents are given at the end of the paper. Throughout the paper will appear a number of quotations from various responses, but the impossibility of adequately representing views by isolated short quotations has led the writer to omit names in connection therewith.

The framing of the questions proved to be a rather difficult undertaking, and in the light of the replies received, it is apparent that a number of improvements could have been made. However, the results are, for the most part, very interesting, and will serve quite effectively to carry out the objects of this paper.

ASPECTS OF THE SUBJECT DEALT WITH.

For convenience, the subject of stream pollution was regarded as having seven aspects, and the questions were propounded for the purpose of bringing out views upon each of them.

First is the conception of the function of a stream in civilized countries. That is to say, is a stream to be regarded primarily as a medium for conveying a water supply to riparian owners to be used by them for any or all purposes for which water is useful? is it to be regarded as a natural drain for carrying off human wastes? or is it to be regarded as serving both of these purposes? To this aspect, two questions were devoted.

Second: Taking for granted that streams must, in some instances, serve as drainage courses for removing human pollution, brought about by human agencies, the next four questions were devoted to bringing out the extent and character of permissible pollution. These questions related to pollution with respect to the discharge of crude sewage, pollution with respect to public nuisances, and pollution with respect to public water supplies.

Third: One question was inserted dealing with the somewhat special problem so often encountered by those connected with State health work, namely, the feasibility of permitting the discharge of unpurified sewage from communities located on very small streams in the absence of any menace to health or objection on the part of riparian owners below.

Fourth: One question was devoted to the preservation of fish life in streams. This is a complex subject, and concerning which there is considerable popular misunderstanding. It was not practicable to bring out more than one or two of the many sides of the problem of preserving fish and other aquatic life.

Fifth: One question was given to a subject that is badly confused in the popular mind, namely, the relation of polluted streams to public health aside from the comparatively well known danger of using polluted streams as sources of public water supply.

Sixth: One question was propounded to bring out views concerning the esthetic. It is plain that in addition to considerations of health and economics, there must also enter the consideration of common decency.

Seventh: Finally, two questions were asked to bring out views regarding the manner in which stream pollution might advantageously be regulated by law.

DISCUSSION OF REPLIES.

To avoid as far as possible confusion is discussing the replies that were received, the above order will be followed and the questions will be taken up one by one. It would hardly be fair, however, to omit certain gratuitous replies not called for in the questions and not all of them complimentary to the writer. Some frankly said that nothing could be gained by an effort to secure a consensus of opinion, while others were inclined to think that such inquiries would place a vexatious problem in a fair way to be better understood and, therefore, more adequately solved. Some felt that at least a volume would be required to answer any one of the questions adequately, while others believed that the golden rule was sufficient to answer all of them. Some pronounced the problem entirely one of cold economics, while others felt that health and the esthetic alone merited consideration. As to the merits of all these general statements, some light may be shed by the following discussion of answers.

I. THE FUNCTION OF STREAMS—(1) *"Do you believe that a riparian owner has a just right to demand the maintenance of the water in a stream in its original and natural purity? Are there any exceptions to the rule?"*

Twenty-four responded in the affirmative, all but three qualified by exceptions. Twenty-three responded in the negative, with but seven qualified by some exceptions. Four evaded or did not reply to this question. On the basis of the above figures, it would appear that opinion is evenly divided, but a careful examination of the replies indicates a fairly definite concensus of opinion. The question was rendered somewhat awkward by the words "original and natural purity." A rather wide interpretation was given this phrase, but in all the qualified affirmative answers it was quite plain that something less than the original and natural purity was in mind. On the other hand, it was evident that those answering "yes" inclined toward higher standards of purity than those answering "no." A quotation from one of the replies will describe, in a manner that will no doubt meet with the approval of nearly all the respondents, the character of stream pollution that must of necessity, be permitted.

"In its original and natural purity the flow came from a water-shed inhabited only by savage races and wild animals. As that watershed came under servitude to civilized people, agriculture developed; lands were fertilized by the use of animal manures and decayed vegetation; they were rendered friable by cultivation. The run-off from the lands was thereafter tinctured with constituents of these fertilizers and the chemical elements of the soil itself, and the stream flow to that extent depreciated in purity. Against this condition no riparian owner should have right of redress; although protest is an inherent right of which man may not be deprived."

It is easy to see that a greater degree of purity than this cannot be demanded unless the whole watershed above the point at which a stream is used is owned or controlled by those using the water.

(2) *"Do you regard streams as drainage courses which should be permitted to receive all storm water and other natural surface drainage (not sewage or industrial wastes) regardless of how the character of this drainage may be modified by the presence of urban communities? Are there any exceptions?"*

The second question was intended to bring out clearly the function of streams as drainage courses for receiving surface run-off which of necessity must pollute the streams.

In this question as in the first, the word "natural" was subject to varying interpretations. The writer had in mind that drainage which comes from natural water courses and from local rain-fall though permitted to flow over roofs, streets, roads, yards and through storm water conduits before reaching a stream. It is believed that this meaning was generally understood, though one respondent took the view that "natural" must be distinguished from "artificial" in that the latter "flows through or over works of man; e. g., sewers, gutters or paved streets."

The question brought out quite a strong consensus of opinion, inasmuch as 41 replied "yes" as against nine who replied "no"; and of the latter, seven replies were qualified. Of the affirmative replies twenty-five were qualified by exceptions and sixteen made no exceptions. Only one respondent failed to make reply to this question.

Of the fifty who replied, 48 believe that streams may properly receive the kind of drainage described in the question, and the replies may be grouped under three heads as follows: Those who believe that, without exception, streams must receive all natural surface drainage, though it be contaminated by flowing over or through the works of man. 2nd, Those who believe that streams should receive all natural surface drainage excepting that which may be defiled to an unusual extent by some peculiar condition; in such cases, they believed that the polluted waters should be treated in the same category as sewage and industrial wastes. 3rd, Those who believe that there is no inherent right to the discharge of polluted natural surface drainage into streams, and that such drainage should be always considered in the same category with sewage, though local conditions in many instances will permit of its discharge into streams without treatment, while sewage itself may require treatment.

Illustrating these three views, the following quotations are given:

First view:—After replying affirmatively to the question, the respondent goes on to say: "It is a small price to pay for advantages of urban development. Besides, it is natural and inevitable."

Second view:—After answering the question in the affirmative, the respondent makes the following exception: "Where such surface drainage carries stock-yard washings or other impurities equally offensive and in considerable quantities."

Third view:—The streams are natural drainage courses, and the discharge of all storm water and other natural surface drainage should be permitted so long as the character thereof is not modified by private or public development. As soon as so modified, it is not natural surface drainage but a carrier of some content which may be objectionable. If objectionable, the content or the carrier with its content must be rendered unobjectionable or removed from the drainage course by the contributor of the content."

All these views contain elements that can be subscribed to by most sanitarians, but it will be noted that only the first takes cognizance of the cost and difficulty (impossibility, it is called) of removing or purifying surface drainage, should the surface drainage happen to interfere with riparian owners requiring a "pure water," or with persons who find the drainage "objectionable." Probably a statement upon which agreement can be most readily obtained would be somewhat as follows: Ordinarily, streams may receive natural surface drainage regardless of how this is modified by normal urban development, but there must be recognition of the existence of special cases where for one reason or another, stream pollution by surface drainage must be restricted.

II. THE EXTENT AND CHARACTER OF PERMISSIBLE POLLUTION — The first two questions in this group are leading questions. The remaining two questions are subsidiary, and are intended to bring out special phases of the first two.

(3) *"Do you regard with favor the discharge of crude sewage into streams under certain circumstances? If so, what are these circumstances?"*

There were thirty-six replies of "yes" and fourteen "no"; of the latter, however, six were qualified by certain exceptions, thus virtually making the replies affirmative, thereby leaving but eight unconditional negative replies. Regarding the circumstances under which crude sewage might be discharged into a stream, there seemed to be a fair agreement, though the opinions were variously expressed. Perhaps the limiting views of those who favor the discharge of crude sewage into streams is illustrated by the two following quotations: One respondent says:

"If the stream is already polluted by drainage of occupied land to an extent that renders the raw water dangerous for drinking purposes, then it (discharge of crude sewage into the stream) is permissible up to the malodorous point."

The other says that a stream may receive crude sewage,

"When the conditions are such that no one, either riparian owner, manufacturer or public is injuriously affected."

Those who replied in the unconditional negative believed that some form of treatment should always be installed, even though this comprised only screening or sedimentation with the object merely of removing unsightly floating solids and to prevent the formation of sludge banks. Notwithstanding the large number of affirmative replies, the writer is inclined to feel that a concensus of opinion can probably be reached on some such statement as the following: In connection with new installations of sewerage, or the construction of new outfall sewers, the discharge of crude sewage into streams should be regarded as permissible only under rarely exceptional conditions, for the reason that even in the largest streams some limited treatment is necessary to remove unsightly floating solids and to prevent the formation of malodorous and unsightly sludge banks in the vicinity of sewer outfalls. Many of the positive replies were no doubt made in the light of regarding as crude sewage that which had received screening or sedimentation only.

(4) *"Is the pollution of streams by industrial wastes or sewage to the point of creating malodorous or unsightly conditions (not however, involving health) permissible under any circumstances? If so, under what circumstances?"*

Of the replies, sixteen were affirmative and thirty-two negative. Six of the latter were qualified, so that virtually they are affirmative, though regarding pollution, such as described in the question as permissible only under the most unusual circumstances. Of two affirmative replies, one stated that bad odors should be permitted, but that unsightly conditions should not be permitted, while the other expressed the contrary view.

A representative negative opinion is as follows:

"Never. Industrial sewage can be purified to a point short of actual nuisance and at an expense not prohibitive."

The following clear statement of conditions under which malodorous and unsightly pollution may be permitted, is fairly representative of the affirmative replies:

"When an industry constitutes the making of a town and the character of the industry is such that the whole of the stream must be utilized for the industry, a minimum amount of malodor would be permissible from necessity."

Others would restrict this form of pollution to districts where there are no inhabitants or interests to be detrimentally affected by a nuisance. The above statement to the effect that industrial wastes can be purified to a point short of actual nuisance and at an expense not prohibitive, is rather broad and loose, for there are several industrial wastes which cannot be purified at a cost not prohibitive.

The question is a difficult one to generalize on, but it would seem that the great majority of sanitarians would subscribe to a statement like the following: In cases where a considerable number of persons are dependent upon an existing industry, and purification of the industrial wastes would so cripple the industry as to make continued operation impossible, then a minimum nuisance from odors and stream discoloration should be favored, provided the larger interests of other industries or of the community in general are not interfered with. On the other hand, the establishment of new industries producing liquid-waste should be confined in location to the banks of those streams which afford an ample dilution to prevent any objectionable conditions or which have been entirely given up to industrial interests.

(5) *"Do you deem it practicable to so purify sewage before discharging same into a stream above and within polluting distance of a public water supply intake so as to safeguard such water supply against contamination, assuming that the water supply is not purified? If so, under what conditions?"*

In the replies to this question, there was a very strong majority in the negative— "no" forty-three and "yes" six. Of the former, only four were qualified, yet many of those who answered in the negative remarked that it was possible, but not practicable, to purify sewage to the degree indicated in the question. As an expression of this view is the following:

"Things can be accomplished by engineers, but the accomplishment does not guarantee a successful continuous operation."

One of the qualified negative replies states that hypochlorites may be used as an emergency measure, but that treatment of the water supply is preferable. Though the number of replies in the affirmative is small, yet some of them are rather striking and convincing. One maintains that for isolated private residences there are methods of sewage purification, which will entirely protect a water supply drawn from the same watershed. These comprise as a final treatment broad irrigation or subsurface drainage, this in turn supplemented by sterilization under some conditions.

One respondent points out that something analogous to sewage treatment for the protection of a water supply is being done by the Metropolitan Water and Sewerage Commission of Massachusetts in purifying small sewage-polluted streams by passing the waters through intermittent sand filters before admitting them to impounding reservoirs. He calls attention to the fact that hundreds of laborers on the sewage farms of Paris, France, regularly drink from springs of purified sewage without injurious results. Nevertheless, sewage farms on the watershed of an untreated public water supply can hardly be regarded with equanimity.

It seems that the opinion most likely to meet with general approval is that sewage purification cannot be regarded as a means for rendering a stream suitable for a public water supply without the use of water purification, partly because sewage purification is not always reliable, but also because the presence of sewage presages the existence of objectionable surface run-off which ordinarily is not and cannot be purified. There may be occasional instances where sewage purification alone may be relied upon to protect public water supplies.

The last of the four questions relative to the extent to which stream pollution is permissible under various circumstances, reads as follows:

(6) *"Do you think it permissible to discharge crude sewage into a stream from which public water supplies are drawn provided the water supplies are purified? If so, under what conditions?"*

To this question, twenty replied "yes" and thirty replied "no." The question was evaded in but one instance. Of the thirty "no's," ten were qualified so as to admit the occasional permissibility of discharging crude sewage into a stream under the conditions described. If these ten opinions may be considered as agreeing in a general way with the responses in the affirmative, then the figures above given become reversed.

The most complete statement of the conditions under which crude sewage, after purification, may be discharged into a stream used for a public water supply, is given in the following:

"Yes, provided that self-purification of the stream is capable of maintaining the water in a condition such that water purification plants are able to render it pure enough for drinking. Efforts toward minimizing the pollution of streams by reasonable expenditures of money in purifying the sewage which must flow into them should always be the proper attitude to assume. But large expenditures for sewage purification merely to maintain a stream in its original condition, or even approximately its original condition in order to provide a comparatively pure water for drinking purposes, is not justifiable so long as present methods of drinking water purification are effective."

Another interesting affirmative view:

"This is done all over the world;" and the condition under which it may be practiced, "depends on many considerations: dilution, currents, velocity, element of time of travel from sewer outlet to water inlet, effect of deposits, etc."

On the negative side there were presented such statements as the following:

"Wholly inadvisable, but it is possible that there may be conditions where it cannot be avoided."

"This permission should not be granted (except for big streams like the Mississippi) for the reason that the factor of safety and ultimately the expense of water purification are affected unfavorably."

"No. A step in the wrong direction."

"No. Under no conditions or circumstances."

In writing replies to the above question, it is the writer's opinion that such sewage treatment as screening or brief sedimentation for preventing local nuisances was not considered as having any material influence upon the potentiality of a sewage to affect water supplies. With this in mind, it seems that the efficiency of sewage purification by dilution and natural agencies encountered in streams and other bodies of water should be recognized and some such rational view accepted as that expressed in the first quotation given under this question.

III. THE SPECIAL PROBLEM OF COMMUNITIES ON SMALL STREAMS. (7) *"Would you consider it just and reasonable to require communities located in rural or sparsely settled districts, and drained by small streams, to purify their sewage unless there is a complaint on the part of riparian owners? If so, under what circumstances?"*

Of all the questions, this one proved to be the most awkwardly worded, so that a numerical summary of the replies means but little. The problem that is most frequently presented to central authorities having to deal with matters relating to stream pollution, is: What disposition of sewage should be required for a small town drained only by small streams, when such town is about to install a new sewerage system? Where health is endangered or where there is vigorous complaint against the pollution of streams, the solution of the problem may be quite apparent, but there are many cases where health is not involved, so far as can be foreseen, and there are places where there is not likely to be any complaint, even though the streams are malodorous and unsightly. It would have been far better had question seven been qualified by inserting an assumption to the effect that though the streams would be badly contaminated, yet no jeopardy to health would be involved. As it was, thirty-two replies were affirmative, fourteen negative, and five evaded the question. Nine of the negatives were qualified so as to render them almost equivalent to affirmatives. The trend of opinion can be given by a few quotations representing various points of view:

"Yes. Every community should take care of its own wastes, and the obligation is no less because of sufferance on the part of injured parties."

"Yes. The complaint does not create the offense. The sewage should be purified when deemed necessary by a central authority, regardless of complaint."

"In general, yes. It is fair to all and makes for better enforcement of law in more serious cases. It is easier to get a small town started than it will be later to manage a city."

"Yes. Whenever the conditions are such that there should be complaint on the part of riparian owners or the public. They should be protected even though they may not realize the conditions."

"Yes, but not in every case. Depends on local conditions, character of country, growth of population, and many things."

"It is more important to keep unpolluted streams pure than to attempt to return to ideal conditions—streams already dedicated to the carrying of manufactural and sewage wastes."

"Yes, both because of the necessary example to be set and because of the use of the water below without full knowledge of the conditions above."

"No, unless the health of the riparian owners or their live stock are in danger."

"I see no reason for the community at large forcing the purification of sewage unless the condition of the stream is objectionable to the riparian owners, except in the very few instances where the condition of the stream may affect the general welfare of the state."

It is interesting to note that not one of the respondents took cognizance of the very real and practical difficulty in the way of having small communities purify sewage; namely, the almost utter hopelessness of inducing such communities to maintain sewage purification works in operating condition in the absence of some constantly threatened damage suits. Eternal vigilance on the part of some central authority supplied with abundant appropriations alone can hope to secure results. It should also be recognized that in those parts of the country where intermittent sand filters may be had at reasonable expense the difficulties are not so great as in those sections where other methods of sewage treatment must be resorted to because of the prohibitive price of sand.

The existing practical difficulties of inducing small towns (less than 10,000) to properly operate sewage treatment works are so great as to render it not worth while to require the installation of such works unless there is an objection to the resulting stream pollution, either on the part of riparian owners or the public, or unless there is a danger to public health involved.

IV. The Special Problem of the Protection of Fish Life.

(8) *"Do you think that protection of fish life in streams should preponderate over other industrial interests? If so, under what circumstances?"*

An enumeration of the replies of "yes" and "no" received would give no adequate idea of the consensus of opinion relative to this question, primarily due to the various interpretations placed upon the word "preponderate." On the other hand, nearly all the respondents took the pains to state rather explicitly what opinions they do hold. It is very clear from these statements, that the great majority do not advocate giving the fishing industry greater consideration than other industries of equal value. In other words, the majority would be quite willing to countenance the destruction of fish life in a stream provided this was necessary to the existence of an industry of greater value than that of fish life.

To the above prevailing opinion, there were some forceful dissensions. Among those who favored the opinion, several expressed interesting reservations or modifications. These various attitudes can be brought out best by the following series of quotations which have been selected to show a gradation of opinion between extremes.

A fairly representative view of those who would not have the protection of fish life preponderate over liquid-waste producing industries is expressed thus:

"The protection of fish life in streams is good practice from a commercial point of view. When the cost of the protection passes the value of the industry protected or when such protection involves a cost to another industry more than offsetting the additional return to the one protected, it is not good business."

Another expression of the same view but from a slightly different angle and with different emphasis is as follows:

"This (the protection of fish) is an entirely economic question and would depend: 1st, on the present value of the fish; 2nd, on the future value of the fish; 3rd, on the present value of other industrial interests; 4th, on the future value of other industrial interests."

One respondent does not believe that the protection of fish life should preponderate over liquid waste producing interests because:

"Some streets are for heavy teaming for industrial and commercial purposes, others are for residential or pleasure purposes; so with streams—some (not to the extent of becoming a nuisance) may well serve as carriers of wastes."

The next quotation espresses the idea that existing practice should determine which streams are to be dedicated to fisheries and which to waste disposal. The protection of fish life should preponderate :

"When, as along the Illinois River, the fishing industry is an established industry. If it is just for game purposes, I think exceptions should be made."

The next quotation brings out the view that because fish are valuable as a human food it is warrantable to give fish life greater protection than purely monetary values would dictate:

"If the fish industry is of value to supply food as compared with other industrial interests, the fish should be conserved. If the other industrial interests are more useful to the community than the fish supply would be, then the industries should be conserved, provided, of course, that the contamination of the water would do nothing more than destroy fish life."

In nearly all the answers the respondents rather lean toward using the financial value as a proper measure to determine whether fish life or liquid-waste producing industries should prevail. The following quotation lays stress on the number of human beings involved rather than on financial considerations:

"Here, again, the greatest good to the greatest number becomes a paramount issue. The preservation of fish in the interest of the sportsman should yield to the demands of industries that yield support to human beings. On the other hand, if the fish product is an important item in the food supply of numbers of people and the catch of that food supply constitutes an industry upon which any considerable number of men with their families must depend as a means of support, then other forms of industry should not be permitted to destroy the fishing interests."

Several respondents regard the destruction of fish life as a measure of the allowable limit of stream pollution. For example:

"The protection of fish life should usually preponderate over liquid waste producing industries for the reason that pollution bad enough to kill fish may also be bad from other standpoints."

Again, another respondent says:

"The protection of fish life should not directly preponderate over waste producing industries," and adds: "The destruction of fish is, however, accompanied or caused by a nuisance in the stream, the avoidance of which should preponderate over industrial interests."

While not specifically mentioned, this statement suggests those very foul nuisances from putrefying fish floating in the water or exposed along the banks when any sudden pollution causes fish to die in great numbers.

As already stated, there are some who believe that the protection of the fish industry should always preponderate over other industries, and one respondent expresses the belief that destroyers of fish should always be liable to damages for the destruction of fish life. He says:

"Fish life represents a public property. A private interest destroying it should pay into the public treasury its full value."

One respondent makes an eloquent plea for the protection of fish life on the ground of recreative possibilities. He states that the protection of fish life should preponderate in all cases, and adds:

"No one industrial plant is as valuable to society as the recreation possibilities of a fishing stream. Our greatest social need, and the one that we shall soon recognize, is opportunity for recreation. Add to this the food value, and I think there can be no question concerning the proper reply. We can better afford to pay a premium on manufactured products equivalent to the cost of purification works than to lose our fishing streams."

Not as a categorical answer to the question relative to the conservation of fish life, but as a general statement of the policy advocated by the National Bureau of Fisheries, is the following, which might be recommended, with but slight alteration, as an opinion upon which sanitarians may unite.

"In view of the ever decreasing margin berween the supply of food and its consumption, it is the view of the Bureau that the protection of fish life in streams and the waters into which they flow should in general preponderate over other industrial interests, excepting only those which, like agriculture, are themselves food producers. This appears to be a particularly valid contention in view of the fact that in many industries (and with improvements in methods this will become the case in respect to most of them) the discharge of deleterious matters into the streams is not a necessary concomitant of the industry, and is often an evidence of wasteful methods.

"There are, of course, exceptions to the general statement previously made. There are certain industries in which large volumes of more or less deleterious matter not susceptible of economic treatment are poured into the streams as the only possible means of disposal. This is the case with certain mining operations on which the prosperity and very existence of a great population is absolutely dependent. The Bureau believes that in such cases the presumptive preponderance of consideration for the food supply should be waived."

The above is a broad statement of principles that may with great advantage be applied to streams capable of harboring valuable fish life and not now defiled to an extent that is inimical to fish life. It must be remembered too that moderate pollution by orgainc matter is not detrimental to fish life, but rather promotes such life owing to the increased growth of plankton which is fostered thereby. Exceptions will, of course, occur, but the above may very advantageously be used as a guiding principle in approaching stream pollution problems.

V. HEALTH RELATIONS ASIDE FROM WATER SUPPLY. (9) *"Aside from the use of streams as sources of public water supply, to what extent, in your opinion, does stream pollution become a factor in public health?"*

Only three out of fifty stated flatly that, aside from the use of streams as sources of public water supply, no health relation exists in connection with stream pollution. All of the others pointed out certain menaces to public health from polluted streams, but in the great majority of cases these menaces were regarded of but slight consequences under ordinary circumstances. A number, however, pointed out instances in which public health might be seriously endangered, other than through the medium of public water supplies, prominent among which were eating shell fish from polluted waters and bathing in polluted waters. A great variety of ways in which infection might spread from polluted streams were mentioned :

1. Eating shell fish from polluted waters.
2. Bathing in polluted waters.
3. Drinking milk from cows whose udders have been soiled in a polluted stream.
4. Washing of milk or other food receptacles in polluted waters.
5. General debilitating effect of bad odors from badly polluted streams.
6. Drinking from polluted streams by hunters, campers, boatmen and careless persons.
7. Mechanical transmission of polluted spray from waterfalls.
8. Contamination of wells and cisterns by being overtopped with flood waters of a polluted stream.

9. Transmission by flies and other insects of infectious matter from shore deposits at and below sewer outfalls.

10. Infection from ice cut on polluted streams.

11. Illness from eating fish or crabs which have been injuriously affected by polluted waters. This has reference to rapid decomposition that may be set up in fish after they are caught.

It was also remarked that infection of domestic animals by drinking from polluted streams should not be overlooked, though this involved no menace to human beings. Perhaps the most generally accepted view is well expressed in the following quotation:

"Shellfish and bathing, two most important points. Others of minor degree. Odors probably bad in long run and certainly affect, by suggestion of danger, persons of certain temperament. A clean stream is probably a stimulus to cleaner habits in a community, and civic pride alone can do much."

A somewhat more cautious statement is the following:

"It is hard to measure" (the extent to which stream pollution becomes a factor in public health aside from use of the stream for public water supply), "yet we know that the pollution is carried to the human from polluted streams in many ways."

This latter statement suggests that while our general impressions regarding the effect of polluted streams on public health aside from their use as public water supplies may, in the main, be correct, yet it must be admitted that but little exact data are extant. In the very nature of the case, the data are difficult to obtain, but it is believed by the writer that investigations among camps that line so many of our inland streams during the summer time, and in rural districts, might reveal to some extent the source of much of the so-called residual typhoid—typhoid that cannot be traced to infected milk or infected drinking water.

The subject of the relation between polluted streams and public health, aside from the use of the streams as sources of public water supply, is somewhat deeper than has been generally supposed by sanitarians, yet it is believed that the first of the two statements above quoted, affords a good basis for a consensus of opinion, provided it is understood that many of the apparently minor causes of the spread of infection from polluted streams may under peculiar local conditions become paramount.

VI. ESTHETIC CONSIDERATIONS. (10) *"In your opinion, should esthetic considerations or considerations of civic decency be considered factors in solving problems involving stream pollution? If so, what would be the the general effect of recognizing such considerations?"*

Two respondents rather evaded this question, while all the rest were agreed that esthetics and civic decency should be considered factors in solving problems involving stream pollution. One of the evasive replies stated that:

"If streams are properly protected, the question will not arise."

Among those who answered in the affirmative, there was a considerable range of opinion as to what extent these esthetic and decency considerations should prevail, though there was a fair unanimity as to what the general effect would be. The secondary question would no doubt have brought out more interesting and instructive replies had it been worded something after this fashion: *"In what way and to what extent should such considerations be recognized?"* However, as will be observed from a series of quotations, quite a number of sides of the question were displayed.

As to reasons for and effect of including esthetics and decency as factors in solving problems of stream pollution, the following quotations give some interesting views:

"Most certainly. The result is a higher standard of living, an appreciation of the esthetic side of life, and a better physical and perhaps moral condition in the community."

"Public health is affected largely by surroundings which, if bright and clean, help to upbuild the body to resist attacks of disease."

"The general effect would be a lesson in sanitation and a respect for self by increase of civic pride. No decent bird has a right to soil its own nest."

"A channel filled with a loathsome mixture of sewage and fouled water is an offense to nostril and vision and a detriment to property values, and has a demoralizing influence; therefore, the self-respect of any community calls for its correction, and the expenditure of public means for that purpose becomes a legitimate use of the people's money."

Some of the replies illustrated how esthetic considerations should be applied.

"Unquestionably, large streams which would naturally be used for boating or bathing or which should constitute one of the elements for beautifying and lending to an attractive treatment of city planning, should receive no crude sewage above the stretch of the stream so used. The sewer outlets should be carried to the lower limits of the city or the sewage should be thoroughly clarified."

A number of respondents do not lose sight of the practical or financial considerations, and are inclined to restrict their views accordingly.

"I think esthetic and decency considerations should be given the same weight that they would in any other item of public utility."

"Yes, but always with an appreciation of relative value and the fact that there is about so much money for sanitary betterment, and the final question is to get in toto the greatest returns."

Summing up, it may be said that all believe that considerations of esthetics and civic decency should be factors in attacking problems involving the prevention of stream pollution: The weight that such considerations should be given is not clear and cannot be made clear in answers to a general question, because this is a matter that depends most intimately on local conditions. It may not be amiss to emphasize the fact that our streams and their valleys naturally form the beauty spots to which larger and larger numbers of our urban population are drawn every summer for recreation, and they also form the logical locations for park systems within the cities. Therefore, there is ample warrant for demanding the preservation of our water courses for recreation purposes, not only wherever it can be readily and cheaply done, but wherever the public requires recreation grounds. In sparsely settled districts, after considerations of health and property are settled, stream pollution problems require little or no expenditure of money to meet esthetic considerations, but in thickly settled districts the whole problem of stream pollution may require settlement upon esthetic considerations alone.

VII. LEGAL CONTROL OVER STREAM POLLUTION. (11) *"Do you think that the power of determining the limits of permissible stream pollution should be intrusted to some central state or national board, commission or other authority? If so, what territorial limits should be adopted and what checks, if any, should surround such authority?"*

All respondents, except two (who did not answer), favored some form of central control over the solution of problems relating to stream pollution. The great preponderance of opinion was in favor of state control, superseded by national control in the case of interstate or navigable streams. A few believe that as far as practicable the matter should remain in local hands, while others believe that national control only would suffice.

A small group (five) believe that the drainage district should be the unit, and that problems of stream pollution should be studied and solved by some central authority in each drainage area into which the country presumably can be divided. No suggestion was made as to how large or how small these drainage areas should be, nor was it pointed out how adjustments might be made with respect to larger streams into which tributary drainage areas might discharge. Likewise, in this country at any rate, serious practical difficulties may be encountered in securing and insuring proper harmony of action by drainage commissions for those drainage areas lying within two or more states.

These remarks are not made to criticise adversely the handling of stream pollution problems by drainage districts; the logic of this method from an engineering point of view cannot be denied, but the above mentioned extraneous considerations cannot be ignored, however unwelcome their interjection may be.

The first quotations represent those who, while believing in central authority, nevertheless feel that such authority should be invoked guardedly, and who point out certain dangers in the practice.

"Centralized authority will indoubtedly hasten the bettering of conditions, but such authority should not consist merely of the police power of the State. Sanitary science is not sufficiently well developed for central state or national boards to demand a betterment of conditions. They should undoubtedly have the police function, but it should be exercised with a great deal of discretion. On the other hand, their work should be largely of a consulting character, advising and assisting the local boards directly in charge of each individual problem. A national board or commission seems desirable, as well as a central board in each state. Legal, municipal and state boundary lines do not always coincide with the natural boundaries of a sanitary district. Hence there is need of a centralized authority to force, if necessary, local co-operation."

"A sanitary or directing body of sanitary experts, free from the influence of commercialism and free from bias, is a desideratum which should always be sought after. Such a sanitary body, while it might not have any direct control over smaller bodies, would have a powerful moral influence over them. On the other hand, sanitary bodies that go wrong, that ignore the public weal and take the sides of mercenary interests, are as great a curse as the right kind of sanitary bodies are a blessing. A very important question is how to check sanitary bodies. I do not know of any better check which should surround a body of this kind than the power of recall. Whenever such committee or any member of it loses sight of the public welfare, there should be some way of getting them off. That is about the only check that is necessary. Such a body needs no check when working for the public good."

The next quotations express the large majority opinion to the effect that the central authority should be a properly constituted state board in all matters having chiefly an intrastate bearing, and that this state authority should be superseded by national authority when interstate problems are involved.

"Navigable waters of the United States should have police supervision exercised by the government, not alone over navigation, but over the purity of the water in the streams. Over waters not coming under the term navigable waters of the United States, the states within whose borders these streams exist should exercise police control, which should be vested in either the state board of health or the water survey of the state."

"Territorial limits should be state limits in case of state streams; national in case of interstate streams; and international waters should be controlled by international commissions. In the first two cases the courts should and would be in a position to check actions of the controlling bodies."

"National control for interstate streams; state for local streams, the state laws being practical duplicates of the national laws—the two harmonizing in the same way as the national and state pure food laws. Appeal from such a board to the courts should be allowed, but nolegislative enactment should limit their authority.

"Uniform state laws rather than national. A national advisory body might help. Severe checks, through courts, and expert non-political membership."

The following quotation is representative of the home rule idea, relegating the solution of stream pollution problems to the smallest political subdivision that shows the ability to handle them.

"Each political unit down to the smallest should have immediate control over streams lying entirely in its own territory; with a right of appeal from the decisions of the smaller unit to the commission of the next larger. Since there are comparatively few streams whose waters do not ultimately find their way across more than one state, it would seem as though the national board might be ultimately appealed to in the majority of cases."

Referring to the drainage area as the territorial limit best adapted to control stream pollution:

"The drainage area would be the most satisfactory, otherwise states; federal control too distant."

"The only recognized authority should be one which controls the entire watershed, and not a state authority, and it should have full powers in the matter."

In closing the discussion relative to central control, it may be pertinent to again point. out that the strong consensus of opinion favors state control of stream pollution problems, supplemented by national control or co-operation, with respect to those drainage systems which do not lie wholly within the borders of one state. Control by minor subdivisions, it is the apparent opinion, cannot be relied upon, but the smaller subdivisions should be encouraged to take the initiative. Central control by drainage districts, regardless of political lines of demarcation, while it must appeal to all as being most logical from an engineering standpoint, has not yet been demonstrated to be generally feasible in the United States.

(12) *"Do you believe it just, wise and practicable to have general laws limiting the degree below which stream pollution is permissible? If so, what would you consider such limiting degree of pollution?"*

Thirty-eight respondents are of the belief that general laws of this character cannot be made and be just, wise and practicable, at least at the present time. Ten believe that such laws can be framed, though involving a great many considerations. Three evaded the question, but submitted remarks touching on the subject, from which quotations will be made farther on.

The consensus of opinion is that with present knowledge of the subject it is not feasible to cover specifically in the form of law the limits within which stream pollution may be permitted. This is but a logical sequence to the preponderance of opinions expressed in answer to the previous question. Nevertheless, it may be held that under our form of government, namely, a government of law and not of men, the laws should be explicit, but that a commission of experts or a commission employing experts is necessary to determine questions of fact in order that the application of the law may be made clear. To return, however, to the consensus of opinion actually expressed, it may be said that the basis of these opinions is the recognition of such a multitude of combinations and permutations of local factors as to render futile the attempt to construct a law covering all of them.

As in the replies to the other questions, there is a variety of shades of opinion, even among those essentially in agreement; these variations will be illustrated with a series of quotations.

"Each stream is a law unto itself. Would be impractical except in very general terms."

"Each case should be considered independently, as the character of the pollution differs greatly and the effect of a given pollution varies enormously with the conditions in and near streams."

"Each case must be settled on its own merits; what is right for one may be wrong for another—yet many cases might have the same standard. Time and changing conditions would also alter any degree of permissible pollution."

"A wise authority should judge, and its judgment be open to review by the courts with expert testimony on the other side. This would compel the state to maintain the best men. The personnel of the authority should itself be expert, not. mere office holders employing good men. The tenure of office should depend upon their making good in court, and court review should be made easy for towns, possibly by having the state employ outside experts as non-partisan witnesses."

"Such laws are too hard to define. The discretion of a competent sanitary engineer or board of engineers is better; no fixed rule is adequate with our present knowledge."

The next two quotations are from respondents who, while inclining to the belief that a general law limiting the extent of stream pollution is not now practicable, yet they see possible lines along which such a law might be framed as a desirable end.

"No chemical or bacteriological standard yet suggested seems practicable. It does not seem unreasonable to anticipate, however, that a standard might be devised which would combine chemical and bacteriological conditions of both sewage effluent and stream receiving same, including the free oxygen in each, relative flow of each, time required to reach nearest downstream city, etc. While equality of treatment might seem to call for some standard in the case of two cities, one in a thickly settled district and the other with the nearest city fifty miles or more lower down the stream, it would be an unnecessary hardship upon the latter to required as complete purification as would be demanded in the former. "

"I think the dissolved oxygen determination used by Phelps in the study of the pollution of New York harbor probably makes such laws possible. His standard may need to be revised, but he has the correct way of reaching a standard."

The next quotation is from one who believes it now possible to devise laws to accomplish the objects outlined in the question.

"I believe the limits should be of a practical nature—such degree as will not endanger health, visibly affect the appearance of the stream, cause deposits, give rise to odors or otherwise interfere with the enjoyment or use of the stream by riparian owners or the public, or interfere with fish or other life or render shell fish or other products unsuitable for food."

As already mentioned, the question was evaded by a few, but the following pertinent comments, coming from recognized high authorities, will prove interesting.

"I would not allow stream pollution except under very exceptional circumstances, and I would not allow it at all where the amount of sewage pollution was large enough to be recognized in any degree."

"I do not believe in any general laws which recognize a permissible pollution.' Effort should always be toward the elimination, not in limiting it. I may illustrate this by the attitude which has been taken towards the admission of injurious substances to food. There is a school which says that such substances may be admitted in small quantities, but such an admission means the defeat of the very purpose for which prohibition is intended. There should be no limit of permissible infection or pollution. The standard should be purity and this the only one that should be set up."

Harmonizing all the views expressed above seems an impossible task, but it is believed that none of the respondents would be seriously antagonistic to an arrangement such as the following:

(1st.) A general law requiring that streams be maintained in an inoffensive (not pure) condition and free from danger to health, and that this result be accomplished by such means as will best conserve the public interests.

(2nd.) A central expert commission or other authority intrusted with determining the questions of fact involved, such as deciding when a stream is inoffensive and when a stream is free from danger to health and which are the means for accomplishing these results that best conserve the public interests.

(3rd.) Ready appeal to non-partisan arbitration commissions, and finally to the courts against decisions of central authority.

GENERAL STATEMENTS RELATIVE TO THE WHOLE PROBLEM OF STREAM POLLUTION.

A number of respondents made a general statement of their views rather than give replies to specific questions. No attempt has been made in the foregoing compilation to extract from these general statements answers to the several questions. Others gave similar statements by way of remarks following the questions. Many of these statements are very interesting and very tersely put, and sum up the various phases of the subject already dealt with. For this reason, a few selections are given. The first of these inclines toward the consideration of stream pollution as primarily an economic problem, and reads as follows:

"Broadly, I may state that I believe the best and truest application of the conservation doctrine includes also due regard for the conservation of capital, and that when a town of medium size is forced to devote any large part of its resources toward purification works for an amount of street drainage, or even sewage, so small that the natural water course could digest it without offense to the sight or smell or destroying the fisheries, it is better to delay our efforts toward the ideal condition of original natural purity and permit the resources of the town to be devoted to other public improvements, such as parks or the acquisition of land for future public forest reservations and the like.

"The late Thomas B. Reed is reported to have said that one trouble with most clergymen was that they had no sense of proportion in regard to sins, and I fear that is true of some sanitarians.

"We must all the time remember that the volume of funds for public improvement is limited and not enough to go around, and must seek the outlet which will do the greatest good and lay the foundation most wisely for a beneficent future."

Another interesting general statement takes the point of view of equity between different classes of riparian owners and water users.

"I have very strong views to the effect that every case of stream pollution should be judged upon its own merits, and am distinctly opposed to any rules or laws of a blanket character, for blanket legislation which might fit one case might do grave injustice if applied to another. As a broad proposition, large streams, especially navigable ones, should be considered as draining a country rather than watering it; but the up-stream community should not grossly misuse such a drain so as to make it border upon a nuisance and render it difficult or impossible for the down-stream community to use its water for general supply after a reasonable and modern form of water purification. While an up-stream community should not grossly misuse the stream as a drain, it should, nevertheless, not be so unfairly treated as to be required to convert the city sewage into drinking water before dumping it into the river, because the down-stream community should in justice be asked to bear its appropriate portion of the general expense and use modern methods for purification of its water supply.

"Small streams which are in no way navigable should be placed in a very different class, and more stringent regulations should be enforced to safeguard their purity. And, finally, I am a distinct believer in the importance of the esthetic side of the question, and hold that the general appearance of a stream should be considered when undertaking to determine whether or not such stream could be damaged by the introduction of some proposed form of waste discharge."

A somewhat extreme view, which ignores more or less the balance between cost and benefit derived, is the following:

"Stream pollution is one of the most important problems connected with the sanitary welfare of the people. We must not forget, however, that the stream is the natural scavenger, and that the pollution of the stream must begin with the individual living on its banks, then with the hamlet or town, and gradually reach up to the city. For this reason, farmers should be taught to dispose of the sewage from their farms and house in a sanitary way and not allow any of it to go into the running stream. When this is done, we can then require the hamlet, the village, the town and the city to follow the same rule. It is just as important to dispose of sewage as it is to secure a water supply. The farmer should devote as much money to disposing of his sewage as he does to digging his well; and so the town and the city should spend as much towards caring for its sewage as it does towards getting a water supply. These go hand in hand."

The next quotation illustrates the view that streams must necessarily be contaminated, yet that stream pollution may be controlled so as to avoid both detriment to public welfare and excessive financial burden.

"I am a strong believer in the impossibility of maintaining streams in their 'original and natural purity' in any country that is being populated and cultivated. Even on such well-cared-for surfaces as you frequently find in western Europe, the streams, although much better than under the ordinary developing conditions of this country, would not be safe for water supplies, so far as their natural purity is concerned. The only question which can concern us is, how far can we allow our streams to receive the rain water washings, sewage overflows and other polluting matters from the watersheds?

"We may say the same with reference to industrial wastes, and ask whether it will not be best, as done in England, to condemn certain streams to be the recipients of such wastes, as the more economical solution of the entire situation.

"I believe that all water supplies taken from streams, even though they are believed to be pure, will eventually be filtered just before supplying a town. This is the law and custom in most European countries.

"The streams should be considered chiefly from the viewpoint of a nuisance, and this, of course, should always be prevented. They should also be considered from a viewpoint of food, fish, and oysters, and it should be determined whether it is cheaper to take food, fish and oysters elsewhere, or artificially create conditions which would make their taking from a stream liable to pollution a safe procedure. I thoroughly believe in clean rivers. We should endeavor to do all we can to keep them as clean as is possible under the controlling conditions. I believe that the only recognized authority should be one which controls the entire watershed, and not a State authority, and it should have full powers in the matter.

Finally, there will be presented the views of a German sanitarian which do not differ materially from the views expressed in the previous quotation.

"Every one has a right to pollute a stream when no one is damaged thereby. If, however, damage results from this pollution the person polluting the stream should pay for the damage he causes or build and operate such works that will prevent this damage. In respect to these damages, unpurified water from an open stream is never a good drinking water, and, therefore, no one can claim damages on account of this water being made unfit to drink without purification.

"The sewage from a sewered town should always be purified at least to the extent of removing the sludge. If the cost of purifying the sewage beyond the simple sludge removal is much greater than the damages that this purification would prevent, then the works for the higher degree of purification should not be built In the case of some trade wastes it is not at present possible that they be purified. In this case, if the value of this industry is greater than that of the interests affected by its discharges, this polluting industry should stay and new factories can be built. In some cases esthetic considerations and considerations of civic decency may affect this point of view.

"I do not think it advisable to make laws fixing the allowable degree of pollution. It is much better to have the standard different for each stream depending on circumstances and to have the stream under the control of some federation or commission. With this idea in proper operation, industrial districts may have rivers for sewage and other districts rivers for bathing and amusement, all depending on which will best serve the interests of that particular district."

SUMMARY.

A summary must consist largely of the writer's own opinion formed in the light of the various responses. It was pointed out in the beginning of the paper that such a compilation as is herewith presented cannot be expected to result in a statement that all sanitarians can accept, nor does the writer desire what follows to be considered a final, unchangeable opinion of his own views. The hope has been entertained, however, that a compilation such as this will be of value in giving some definite nucleus to what has hitherto been an incoherent mass of varying and conflicting ideas. Once the nucleus has been formed it may be built upon in the light of experience until there has accumulated a body of reliable opinion that will explain clearly the position of the sanitarian to the public.

What is said above applies purely to general principles, and not to ways and means for solving specific problems. It will always be necessary to have the services of experts to decide how many gallons, and what kinds of wastes may be discharged into a stream to keep within the limits of a desired result; the methods that are best adapted to treating sewage, and other wastes; the best methods of purifying water supplies taken from surface streams, and many other technical matters of vital importance. But the public must be made familiar with the general principles that govern if our movement for clean streams is to be effective, consistent, rapid and economical.

In the writer's opinion, molded by the foregoing, there are a few fundamental propositions to which sanitarians may generally agree. They are as follows:

1. No stream (unless the entire watershed is owned or controlled) can be maintained in its original and natural purity.

2. Streams may be, and should be, maintained free from danger to the public health, inoffensive to a proper public sense of decency, and beyond this they should be controlled so as to contribute the greatest serviceableness to the people at large. Within these limits, it is permissible to discharge any liquid wastes into streams; local conditions to control in every instance.

3. Public water supplies may be drawn from moderately polluted streams, provided the supply is adequately purified to prevent danger to health. The extent of pollution permissible under these conditions to be determined by the limitations imposed by the art of water purification, and to some extent by purely esthetic considerations.

4. The desirability of maintaining fish life in streams is largely an economic problem. In the case of streams along which fishing industries are established prior right should be considered a basis for preventing pollution dangerous to fish life or for awarding damages. The presence or absence and character of fish life may, under some circumstances, serve as an index of the extent of pollution.

5. Stream pollution is primarily a menace to human health through domestic water supplies which may be drawn from polluted streams; but there are various other avenues of danger to health, prominent among which are danger to bathers and pollution of shell fish, which should be duly recognized in considering any specific problem.

6. While the determination of permissible stream pollution must depend primarily on public health considerations and secondarily on economic considerations, esthetic considerations and civic decency must always be factors, and many times the controlling factors.

7. Control of stream pollution by laws defining specifically the extent to which streams may be polluted and enforced by the ordinary police power is unwieldy, unwise and unjust. Instead, the laws should be made very general and their enforcement, placed in the hands of central expert authority as interpreter of the laws in the light of local conditions. To guard against abuse, it should be made easy to appeal from decisions of the central authority to an impartial commission of experts and finally to the courts.

8. In the United States, the pollution of intrastate streams should be under state control, and interstate streams should be under federal control. Since, from an economic and engineering point of view, control by drainage boards over complete drainage areas is the logical and efficient form of control, it should be adopted wherever conditions permit, but with the present form of government it is not believed to be of universal applicability.

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DETERMINATION OF AMMONIA NITROGEN IN WATER.*

The test for free and albuminoid ammonia since its introduction in 1687† has played an important role in the sanitary examination of drinking water. Its easy manipulation and its simplicity quickly brought the method into common use. It has been criticised for various reasons, viz.: That it did not afford an exact measure of the nitrogenous organic matter present; that the yields of nitrogen vary according to the different nitrogenous substances which may be present; that determinations based on comparison of tints in solutions are not accurate; and that the presence of various salts and compounds ordinarily found in waters interferes with the action of the Nessler solution. Various experimenters have worked on this subject and experiments have been carried out so carefully that for the most part the method of manipulation is satisfactory. We have, however, found inaccuracies due to interference of substances in solution, and it is this phase of the subject that we have been investigating.

In the experimental work precautions have been taken to have a uniform rate of distillation, a uniform temperature for nesslerization, a uniform organic content in comparative tests. The apparatus, constructed entirely of glass, is placed in a room free from ammonia fumes. The apparatus used is the "Distilling Apparatus for the Determination of Ammonia" as used by the Department of Health of the City of Chicago. (See figure). It consists of a Jena glass flask (A) of one liter capacity, the neck of which is ground (B) to receive a connecting glass tube (C), the other end of which is joined by a mercury seal (D) to a condenser (E). The lower end of the condenser (F) dips into the Nessler tube (G).

We have found difficulty in obtaining absolutely ammonia free reagents and distilled water. The amount of ammonia present in the reagents and in the distilled water has, therefore, been determined and a correction made in each analysis.

Precautions were taken to have the air of the room free from ammonia. That this precaution was necessary was shown by the presence of ammonia due to two dogs and a wolf kept in a room near the dis-

*Abstract of thesis prepared by Benjamin Harrison Harrison, under the direction of Edward Bartow, and presented in partial fulfillment of the requirements for the degree of Bachelor of Science.

†Wankyln and Chapman, Jour. Chem. Soc. 1867. 445.

tilling room. An experiment was carried on to see if the presence of these animals would affect the ammonia content of the air. 0.036 parts per million of ammonia nitrogen were absorbed by a water exposed 24

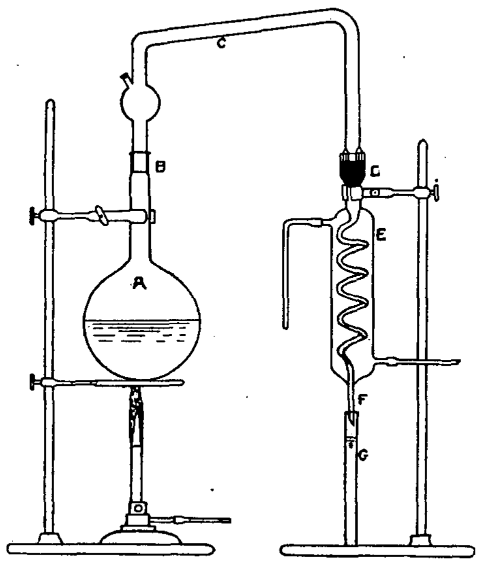


Diagram of an Ammonia Still.

hours in the distilling room, which adjoined the room in which the dogs were kept, and 0.566 parts per million were absorbed by a water exposed for the same time in the room where the dogs were kept. After the dogs had been removed and the rooms thoroughly cleaned and aired, other samples of water were tested in the same way and negative results were obtained.

In the experimental work done, the effect of the presence of calcium acid carbonate, magnesium chloride, and hydrogen sulphide, substances frequently found in the water supplies of Illinois, were studied.

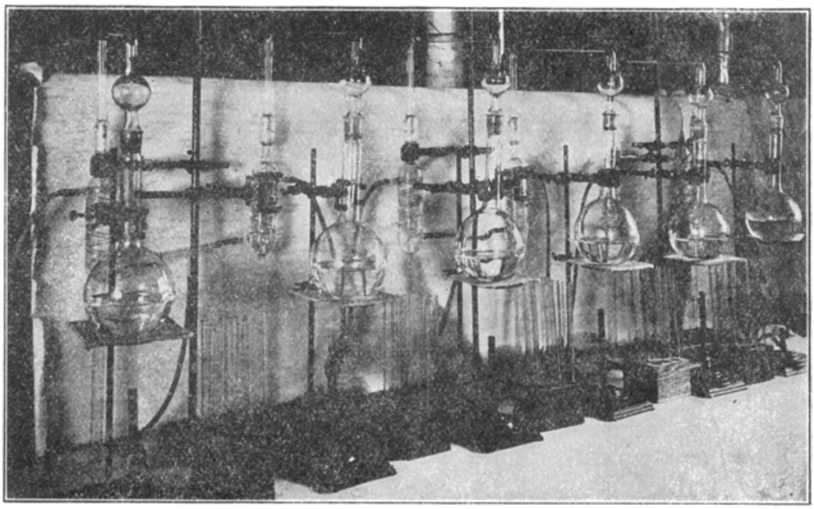
Effect of Calcium Acid Carbonate.—Calcium acid carbonate is the most common mineral constituent in Illinois water supplies. In order to study the effect of this substance alone, an artificial water was prepared by making a saturated solution of calcium hydroxide and passing carbon dioxide into the solution to convert the hydroxide into the acid carbonate. The solution was then diluted with ammonia free water to give the desired concentration of calcium acid carbonate. Portions consisting of 500 c. c. of the calcium acid carbonate solution, containing 280 parts per million of calcium carbonate, were used for each test. To the portions were added 0.06 and 0.12 parts of nitrogen per million, respectively. Distillations with and without the calcium acid carbonate give results as shown in the following table:

EFFECT OF CALCIUM ACID CARBONATE.

RESULTS ARE GIVEN IN PARTS PER MILLION.

Ammonia free water and .060 and .120 pts. per mil. N as NH_4Cl		Solution of calcium acid carbonate and .060 and .120 pts. per mil. N as NH_4Cl		Solution of calcium acid carbonate		
I	II	III	IV	V	VI	
.062	.060	.072	.076	.014	.018	
.....	.....	.016	.016	.....	.....	correction
.062	.060	.056	.060	.....	.....	corrected
.120	.120	.136	.136	.018	.022	
.....	.....	.020	.020	.....	.....	correction
.120	.120	.116	.116	.....	.....	corrected

It is evident from the above, that calcium acid carbonate does not interfere materially with the determination of ammonia.



Ammonia Distilling Apparatus.

Effect of Magnesium Chloride.—Kober* has shown that in the presence of magnesium chloride the ammonia is not given off on distillation. He illustrated this by adding 1 c. c. of a N/10 solution of ammonium chloride to a saturated solution of magnesium chloride,

*Jour. Chem. Soc., 30, 1279.

then adding three drops of a saturated solution of caustic soda and distilling. He was not able at any time to detect ammonia in the distillate.

Such a mixture could not be alkaline, and the experiment does not prove that ammonia would be held when an alkaline solution is distilled.

About 10% of the municipal water supplies of Illinois contain magnesium chloride, and the problem to be considered was whether the concentration of the magnesium chloride in these potable waters was large enough to have any restraining action on the ammonia distillation. The average amount of magnesium chloride in water supplies of Illinois towns is 26.8 parts per million, the highest being 75 parts. Two tests were made—one using 100 parts per million and the other 200 parts per million of magnesium chloride. In both cases, .08 parts of nitrogen as ammonium chloride were added.

EFFECT OF MAGNESIUM CHLORIDE.

RESULTS ARE GIVEN IN PARTS PER MILLION.

$MgCl_2$ Present	N obtained	Correction	N found	N as NH_4Cl added
200	.092	.014	.076	.080
200	.094	.014	.080	.080
100	.086	.012	.074	.080
100	.086	.012	.074	.080

From these tests, it is evident that the concentration of magnesium chloride existing in potable water in Illinois does not interfere materially with the determination of ammonia nitrogen.

Effect of Hydrogen Sulphide.—Hydrogen sulphide, however, interferes with the Nessler test as ordinarily carried out. When the amount of ammonia is large the interference may be prevented by precipitating the hydrogen sulphide with a lead or zinc salt and determining the ammonia by direct nesslerization. If the amount of ammonia is small, it is desirable to distill and nesslerize the distillates. In this procedure the results are very inaccurate. The inaccuracy is shown by our first test. We added 0.06 parts per million of ammonia nitrogen to a water in which 56 parts per million of purified hydrogen sulphide gas had been absorbed. Nesslerization after distillation showed equivalents of 0.082, 0.214 and 0.376 parts per million of nitrogen when only 0.06 parts per million had been taken. A repetition of the experiment gave similar inaccurate results.

A method that will give accurate results when hydrogen sulphide is present is needed because of its presence in a great number of mineral waters. No accurate data is at hand concerning the occurrence of hydrogen sulphide in the waters of Illinois, but it is known to be present in considerable quantity in a number of the deep wells in the northern part of the state. That it is present at times in very large amounts in waters from other states can be seen from a table prepared from data in U. S. Geological Survey bulletin, No. 32, Vol. 5, entitled, "Mineral Springs of the United States," by A. C. Peale.

MINERAL SPRINGS CONTAINING HYDROGEN SULPHIDE.

New York	Cu. in. per Imp. Gal.	Parts per Million
Avon Sulphur Springs		
Upper Spring	12.00	60.0
Lower Spring	10.02	50.1
New Bath Spring	31.28	156.4
Congress Hall Spring	27.63	138.2
Chittenango Springs		
White Sulphur Spring	.88	4.4
Cave Spring	2.75	13.8
Magnesia Spring	5.62	28.1
Columbia White Sulphur Spring.	4.49	22.5
Doxtatters, Rochester	17.28	86.4
Florida Spring	3.76	18.9
Lockport Mineral Spring	2.86	14.3
Sharon Springs		
White Sulphur Spring	20.59	102.5
Magnesia Spring	3.30	16.5
Red Sulphur Spring	10.50	52.5
Gardner Magnesia Spring	6.00	30.0
Massena or St. Regis Spring	5.30	26.5
Richfield Springs		
Spring, name unknown	24.24	121.2
Sulphur Spring	3.62	18.1
White Sulphur Spring	14.20	71.0
Magnesia Spring	.31	1.6
Virginia		
Buffalo Lithia Springs		
Spring No. 1	5.9	24.5
Spring No. 2	8.3	41.5
Spring No. 3	3.4	17.0
Augusta Springs		
Sulphur Spring No. 1	.91	4.6
Sulphur Spring No. 2	.24	1.2
Alabama		
Cullem Springs		
Sulphur Spring	97.10	485.5
Blount Mineral Springs		
Red Spring No. 1	14.96	74.8
Talladega Spring	82.00	410.0
Tennessee		
Cascade Springs	23.04	117.2
Crisp Springs	9.47	47.4
Fernvale Springs	14.64	73.2
Hurricane Springs	1.16	5.8
Jones Sulphur Well	1.17	5.9
Red Boiling Springs	4.50	22.5
White Creek Springs	40.25	201.3
West Nashville Sulphur Well	5.84	29.2
Michigan		
Mount Clemens Mineral Springs		
Mount Clemens Mineral Well	34.77	173.9
Medea Spring	40.00	200.0
Soolbad Spring	33.00	165.0
Ypsilanti Mineral Springs		
Ypsilanti Well	21.08	105.4
Moorman Well	32.21	161.1
Owen Mineral Well	15.52	77.6
Wyandotte White Sulphur Spring	20.00	100.0

There seems to be two possible methods of preventing the hydrogen sulphide from interfering with the test. It may be distilled off in the presence of some substance that will hold the ammonia which later may be set free and distilled, or may be held back itself by some substance which will allow the ammonia to be distilled. The use of sulphuric acid to retain the ammonia during digestion and concentration in the Kjeldahl process led us to try sulphuric acid.

Fifty c. c. of normal sulphuric acid was added to 500 c. c. of a water containing 20 parts per million of hydrogen sulphide and a known amount of ammonia nitrogen, then 100 c. c. of water was distilled over into two 50 c. c. tubes. The first 50 c. c. of the distillate was cloudy and smelled strongly of hydrogen sulphide gas; the second was practically clear. 50 c. c. of a normal solution of sodium hydroxide was then added to the residue and 200 c. c. of water was distilled and nesslerized. In the first series with 0.06 parts per million taken, 0.082, 0.080, 0.078 and 0.082 parts per million were found. This showed the necessity for control tests which were run in succeeding series. The readings with the corrections are shown in the following table:

DETERMINATION OF AMMONIA NITROGEN IN THE PRESENCE OF HYDROGEN SULPHIDE. RESULTS IN PARTS PER MILLION.

Total N. found.	Correction.	Nitrogen found.	Nitrogen taken.
0.082	0.026	0.056	0.060
0.086	0.026	0.060	0.060
0.082	0.026	0.056	0.060
0.416	0.030	0.386	0.400
0.400	0.030	0.370	0.400
0.136	0.020	0.116	0.120
0.256	0.020	0.236	0.240
0.528	0.020	0.508	0.500
1.040	0.020	1.020	1.000
2.000	0.020	1.980	2.000

The results are accurate enough for all practical purposes. We tried to hold the hydrogen sulphide with sodium hydroxide during the distillation of the ammonia, but the addition of sodium hydroxide was not satisfactory, as the sodium sulphide formed hydrolyzed and hydrogen sulphide was found in the distillate.

Phelps,* in discussing the direct nesslerization of sewage, suggests the precipitation of the hydrogen sulphide with lead or zinc acetate. We have tried lead acetate as a medium to hold the hydrogen sulphide, and have compared it with the sulphuric acid method, as shown in the following table:

*J. Infect. Dis., 1904, I., 327.

DETERMINATION OF AMMONIA NITROGEN BY ADDITION OF SULPHURIC ACID OR LEAD ACETATE.

RESULTS IN PARTS PER MILLION.

Total N found.	Correction.	Nitrogen found.	Nitrogen taken.	Method.
0.090	0.029	0.061	0.060	Sulphuric acid
0.088	0.029	0.059	0.060	Sulphuric acid
0.094	0.034	0.060	0.060	Sulphuric acid
0.090	0.034	0.056	0.060	Sulphuric acid
0.074	0.029	0.044	0.060	Lead acetate
0.056	0.029	0.027	0.060	Lead acetate
0.072	0.023	0.049	0.060	Lead acetate
0.074	0.017	0.057	0.060	Control, no H_2S
0.074	0.017	0.057	0.060	Control, no H_2S

The method with sulphuric acid gives results as accurate as can be obtained when there is no hydrogen sulphide present. The results obtained by the use of lead acetate are low.

In order to determine the effect of the addition of sulphuric acid on the so-called albuminoid nitrogen, a series of waters were analyzed with and without the addition of sulphuric acid. The results of the analyses of nine typical Illinois waters, as given in the following table, show that the sulphuric acid has no appreciable effect on the amount of the albuminoid nitrogen obtained. While the results are not identical, the variations are within the limits of experimental error.

THE EFFECT OF ADDING SULPHURIC ACID ON THE AMOUNT OF AMMONIA OBTAINED.

RESULTS IN PARTS PER MILLION.

	Free Ammonia.			Albuminoid Nitrogen.			Total Ammonia.		
Serial No.	Ordinary method.	Sulphuric acid method.	Average.	Ordinary method.	Sulphuric acid method.	Average.	Ordinary method.	Sulphuric acid method.	Average.
20993	0.010	0.040	0.028	0.088	0.096	0.092	0.104	0.136	0.120
21004	0.024	0.032	0.028	0.072	0.056	0.064	0.096	0.088	0.092
21005	0.048	0.056	0.052	0.112	0.096	0.104	0.160	0.152	0.156
21006	0.024	0.024	0.024	0.064	0.056	0.060	0.088	0.080	0.084
21007	0.120	0.144	0.132	0.432	0.432	0.432	0.552	0.576	0.569
21008	0.080	0.088	0.084	0.144	0.128	0.136	0.224	0.216	0.220
21086	0.544	0.544	0.544	0.288	0.288	0.288	0.832	0.832	0.832
21087	0.864	0.964	0.864	0.160	0.152	0.156	1.024	1.016	1.020
21088	0.144	0.152	0.148	0.104	0.096	0.100	0.248	0.248	0.248

CONCLUSIONS.

Calcium acid carbonate or magnesium chloride in the quantities present in potable waters, does not interfere with the determination of ammonia nitrogen.

Ammonia nitrogen cannot be determined in the usual manner in a water containing hydrogen sulphide.

Ammonia nitrogen may be determined by adding 50 c. c. of normal sulphuric acid and distilling off 100 c. c. of water which will contain the hydrogen sulphide, then adding 50 c. c. of normal sodium hydroxide solution and continuing the distillation for the determination of free ammonia.

The albuminoid nitrogen is then determined in the residue as usual.

The addition of sulphuric acid has no effect on the amount of free or albuminoid nitrogen obtained.

EXTENT AND COMPOSITION OF THE INCRUSTATION ON SOME FILTER SANDS.*

When lime is used in connection with water purification, there is a tendency to form an incrustation in the pipes or on the sand grains of the filters. In some cases the sand grains have become so large that it has been necessary to put in new sand. Cases have been reported where the sand near the bottom of the filters has caked into a solid mass.†

We have investigated the sand in some filters in Illinois. Samples of sand were sent to us from Danville (2), Kankakee, Quincy and Moline. We are indebted to H. M. Ely, Danville, C. H. Cobb, Kankakee, W. R. Gelston, Quincy, and to M. Olson, Moline, for information concerning the sand used.

The Danville plant used Red Wing, Minn., sand, having an effective size of 0.31 and a uniformity coefficient to 1.8. During periods of low turbidity from 0.27 to 0.7 grains per gallon of lime and from 0.58 to 1.5 grains per gallon of iron sulphate were used. In periods of high turbidity from 0.8 to 2.5 grains per gallon of lime and from 2.5 to 4.0 grains per gallon of iron sulphate were used. Filter No. 8 has been in use 7 years and filter No. 6, 5 years. A larger proportion of lime was used prior to the last 15 months.

The Kankakee plant uses Mount Tom sand. The size at the beginning is not known. The sand has been in use 9 years, but only during 1 year has 1 grain per gallon of iron sulphate and 2 grains per gallon of lime been used. During the remainder of the time alum has been the coagulant.

The Quincy plant uses Red Wing, Minn., sand, having an effective size of 0.38 and a uniformity coefficient of 2.1. While the sand has been in use a long time, it is not possible to tell the exact time, for about two years ago the sand was removed from the filters, screened, and the finest replaced. It has undoubtedly been in use more than 7 years, for Quincy was the first plant in the country to use the lime and iron sulphate process. During the last 4 years, an average of 2.05 grains per gallon of iron sulphate and 2.84 grains per gallon of lime were used.

*From thesis prepared by C. E. Millar, under the direction of Edward Bartow, and submitted in partial fulfillment of the requirements for the degree of Master of Science in Chemistry in the College of Science of the University of Illinois, June, 1911.

† Eng. and Min. J., May 6, 1908. Report of Ohio State Board of Health, 1908.

The Moline plant has been in operation without removal or change of the sand for five years. Alum has been used about nine months; previous to that, lime and iron sulphate were used regularly, 1 grain per gallon of iron sulphate and 3 grains per gallon of lime being used.

The sand received has been examined to determine the relative amount of the incrustation, the size of the incrusted grains, and the composition of the incrusation.

In determining the relative amount of the incrustation, we used approximately 250 c. c. of each filter sand, which we carefully weighed and treated with hydrochloric acid until all the carbonate was dissolved. The residue was washed and weighed. The results are shown in Table I.

TABLE I.

Name of Sand.	Danville, No. 8.	Danville, No. 6.	Kankakee.	Quincy.	Moline.
Weight of sand taken......	343.0	351.0	383.0	325.0	330.0
Weight of residual sand......	232.0	238.0	330.0	49.0	94.0
Weight of incrustation removed..	112.0	113.0	53.0	276.0	236.0
Per cent. of incrustation......	32.4	32.2	13.7	84.7	71.4
Per cent. increase by incrustation	47.9	47.7	15.9	633.0	249.0

As the filter sands are of quartz and are unaffected by acids, this treatment gives quite an accurate means of determining the increase. It is hard to realize what an enormous increase these figures imply. An incrustation amounting to 71 per cent. means that there is an increase by weight of 249 per cent., and an incrustation amounting to 84.7 per cent. represents an increase of 633 per cent. With this increase in the size of the grains there has been an equivalent loss of sand, which has been carried into the sewers. The increase in the size of the grains is accompanied by loss of efficiency. As the grains increase in size, the interstices between the grains are larger and fine particles more readily pass through.

The term "effective size" is used to indicate the size of sand grains used in filters. It is considered to be that size of grain such that 10% by weight of the particles are smaller and 90% larger than itself. The term "uniformity coefficient" is used to indicate whether or not there is a great range in the size of the grains. It is the ratio of the size of grain which has 60% of the sample finer than itself to the size which has 10% finer than itself.

The effective size and uniformity coefficient of the five sands have been determined as follows:

TABLE II.

	Effective size.	Coefficient of uniformity.
Danville No. 6	0.52 mm.	1.30
Danville No. 8	0.55 mm.	1.50
Kankakee	0.61 mm.	1.60
Moline..............................	0.60 mm.	1.90
Quincy..............................	0.77 mm.	1.67

A comparison of the effective size and the uniformity coefficient of the incrusted sand with the effective size and uniformity coefficient of the original sand, when that is available, shows that the effective size is greatly increased and the coefficient of uniformity decreased. In the case of the Danville sand, the effective size is increased by one-half, and in the case of the Quincy sand it is doubled.

Sand having an effective size above 40 mm. would not ordinarily be chosen for a filter sand. A calculation of the volume of the sand from Quincy before and after the incrustation formed shows a seven-fold increase. This corresponds to the 655% increase by weight shown by treatment with acid. The chemical composition of the incrustation from the several sands was determined as follows:

Ten grains were accurately weighed and the incrustation removed with hydrochloric acid. The remaining sand was carefully dried and weighed. The washings were added to the original solutions. The solutions were filtered, and the undissolved material determined as insoluble matter. The filtrates were made up to definite volume and aliquot portions analyzed by the ordinary method of limestone analysis.L The results are shown in Table III.

TABLE III. COMPOSITION OF INCRUSTATION ON FILTER SANDS.

Determinations Made.	Danville No. 6 .	Danville No. 8.	Kankakee	Quincy.	Moline.
Insoluble matter.	5.89	7.58	1.83	0.32	1.20
Oxides of iron and aluminium, $Fe_2O_3+Al_2O_3$	2.20	3.15	7.20	0.42	0.94
Magnesium oxide, MgO.	1.16	1.00	1.09	0.83	0.12
Calcium oxide, CaO.	49.58	47.70	47.75	54.03	53.10
Sulphur trioxide, SO_3.	0.17	0.17	0.31	0.14	0.12
Hypothetical combinations.					
Magnesium sulphate, $MgSO_4$.	0.26	0.25	0.48	0.21	0.18
Magnesium carbonate, $MgCO_3$	2.23	1.90	2.00	1.63	1.37
Calcium carbonate, $CaCO_3$	88.53	85.17	85.26	96.48	94.83
Ferrous carbonate, $FeCO_3$	3.19	4.57	10.44	0.61	1.37
Insoluble matter.	5.89	7.58	1.83	0.32	1.20
Total	100.10	99.47	100.01	99.25	98.95

The composition of the incrustation is of the same general character. Calcium carbonate is predominant. The analyses of the mineral content of the waters treated* show the composition of the waters to be similar. All contain considerable quantities of magnesium and calcium carbonate and magnesium sulphate. The larger quantity of insoluble matter in the incrustation from the Danville plant is doubtless due to the fact that at times the river becomes very turbid, and owing to the short period of sedimentation, large amounts of sediment are carried onto the

*U. S. Geological Survey, Water Supply Paper 239, 89.

filter beds. The high percentage of ferrous carbonate, which includes the aluminium content in the case of the Kankakee sand, is difficult to account for. No alum was used in this plant for a year prior to the time the sample was taken, so that the presence of aluminium hydroxide due to recent additions of alum is impossible. The water at Moline and Quincy have received parallel treatment with lime and iron sulphate. The comparison of the percentage of incrustation with the amount of coagulants used at the several plants shows Quincy heading the list with 8.84 grains of line, 2.05 grains of iron sulphate and an incrustation of 85%. Moline comes next with 3.00 grains of lime, 1 grain of iron sulphate and an incrustation of 71.4%. Danville ranks third with amounts of lime varying from .27 to 2.50 grains and iron sulphate from .58 to 4.00 grains. The incrustation is 32.3%. Kankakee comes last with an incrustation of 13.7%. This is doubtless due to the fact that lime and iron sulphate have been used at this plant for a very short time as compared with the other plants.

The foregoing as shown is the extent and character of the incrustation. We have tried to study the problem of the prevention of the incrustation due to the action of lime used in the treatment of water. The chief constituent of the incrustation is, as shown above, calcium carbonate. This is formed by the action of the lime on calcium bicarbonate according to the equation $Ca(OH)_2 + CaH_2(CO_3)_2 = 2CaCO_3 + 2H_2O$. This reaction is not instantaneous, but requires considerable time for its completion. While the greater part of the calcium carbonate is precipitated quickly, a considerable quantity remains at the end of two hours and an appreciable quantity at the end of six hours. The precipitation will take place more rapidly if the water is agitated. If the water is carried to the filter beds before the reaction is entirely finished, we must expect an incrustation on the sand. The incrustation may also be prevented by the addition of carbon dioxide, which will change the insoluble calcium carbonate to the very soluble calcium bicarbonate. The carbon dioxide may be added directly in gaseous form, or by the addition of iron sulphate or aluminium sulphate. and decomposition of the calcium carbonate. Carbon dioxide has been successfully used at Winnipeg. It was prepared by burning coke in the furnace under the boilers used to furnish steam for the power plant.

At Columbus, Ohio, ferrous sulphate is added to the raw water, and a little later, lime. After a period of sedimentation, a second addition of a very small amount of ferrous sulphate is made just before the water passes to the filters. The reason given for this second addition of coagulant is that it contributes a slight floc which settles on the filters and greatly increases the bacterial efficiency. A study of the data from the plant* shows, however, that the alkalinity is slightly reduced. A somewhat similar procedure is followed at New Orleans at the New Orleans plant with practically the same results.† It would seem possi-

*Municipal Journal and Engineer, 28, 656–60; 695–7.

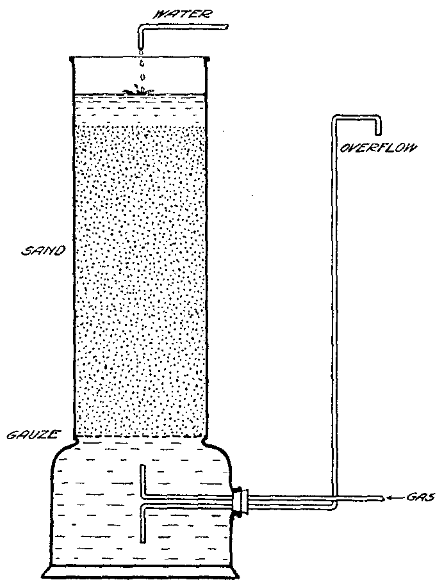
†Engineering Record, 61, 540–5.

ble to remove or at least materially decrease the alkalinity due to normal carbonates by the addition of a small amount of aluminium sulphate or ferrous sulphate after the treatment with lime. This was tested by adding definite amounts of aluminium sulphate or iron sulphate to water which had been previously softened by lime, filtering off a portion at definite intervals and titrating the filtrate with standard. acid, the aluminium sulphate and iron sulphate solutions having a strength of 1%. The results obtained show that the normal carbonates as indicated by the phenolphthalein alkalinity can be much reduced by either aluminium sulphate or ferrous sulphate, and that the reaction is almost instantaneous. In order to approximate working conditions, waters of the character generally treated in filter plants in this state were tested. Enough lime was added to raise the phenolphthalein alkalinity to about 20 parts per million, the methyl orange alkalinity being in all cases, more than twice the phenolphthalein alkalinity indicating the absence of hydrates. The reduction of phenolphthalein alkalinity in all cases was nearly instantaneous, as the reduction after two hours is practically the same as that immediately after mixing the solutions. The reduction of the alkalinity was greater for the aluminium sulphate as compared with an equivalent weight of iron sulphate. This would be expected because of the compostition of the two substances. Considering the relative cost of the chemicals, the treatment with iron sulphate is by far the cheaper. After the treatment with ferrous sulphate, the water, even after filtration, had a faint yellowish tint. This may be due to faulty manipulation on the small scale necessary in the laboratory.

All the tests indicate that the incrustation can be prevented, or at least much decreased, by the addition of a small amount of coagulant before the water passes to the filters. There is a possibility that the reaction may not be completed before the water passes through the filters, and that there may be an after precipitation. Our experiments indicate that this after precipitation is very slight and scarcely sufficient to cause trouble beyond the filters. If the coagulant can be added a little time before filtration, there is no danger that the after precipitate will cause trouble.

Since it is the custom in most filter plants, to stir the sand in the beds with compressed air at the time of washing, it occurred to us that this might be done with some gas that had some solvent action on the incrustation.

A portion of incrusted sand, which was dried and weighed, was placed above a wire gauze in a glass cylinder. (See figure). Below the gauze was a chamber with an opening into which a stopper was fitted, carrying one tube for the delivery of gas directly under the gauze and one tube for an outlet for the water which had passed through the sand into the chamber below. This tube was bent upwards and reached slightly above the level of the sand. Carbon dioxide was forced under constant pressure through the tube into the chamber from which it passed through the sand. At the same time, distilled water was allowed to flow into the surface of the sand and thence to find its way downward to the chamber below. From here it rose in the outlet tube and gradually overflowed. Considerable difficulty was experienced in regulating the gas pressure so that the water would overflow continuously and



Apparatus Used in Determining the Solvent Action of Carbon Dioxide on Incrusted Sand Grains.

slowly from the pipe. Occasionally the gas would force all the water from the chamber below the gauze and from the overflow pipe and hence considerable gas was lost, and the volume used is far in excess of the amount neccessary to accomplish the work. This process was repeated several times with the same sample of sand with the results as given below:

Amount of water used.	Amount of CO_2 used.	Original wt. of sand.	Final wt. of sand.	Amount of loss.
4,000 c. c.	20,000 c. c.	681.5 g.	675.0 g.	6.5 g.
2,000 c. c.	2,500 c. c.	675.5 g.	672.5 g.	2.5 g.
2,000 c. c.	2,000 c. c.	672.5 g.	669.0 g.	3.5 g.

The large amount of gas consumed in the first test may be accounted for by the solubility of the carbon dioxide in the water used to drive it form the gasometer. The same water was used in the other tests, but as it was nearly saturated it absorbed little gas. The water after passing through the apparatus was slightly turbid, and left a deposit on standing.

To be certain that the loss in weight was not simply due to the solvent action of the water or to the removal of some loose dirt clinging to the surface of the sand, the treatment was repeated, using air instead of carbon dioxide. No appreciable differences in the weight of the sample could be detected.

The same sample was again subjected to treatment with carbon dioxide, and water with the same results as before, proving beyond a doubt that loss in weight was due to carbon dioxide.

Considering that it might be impracticable to use pure carbon dioxide on a commercial scale, an experiment was tried with flue gases obtained form the furnaces of the University boilers.

Amount of water used.	Amount of gas used.	Original wt. of sand	Final wt. of sand.	Amount of loss.
2,000 c. c.	20,000 c. c.	669 g.	668 g.	1.0 g.
2,000 c. c.	20,000 c. c.	668 g.	667 g.	1.0 g.

The same sample of sand was used as in the previous experiments. At every treatment the sand decreased in weight, but the decrease was not so marked as when pure carbon dioxide was used.

The tests indicate that if the sand in the filters was stirred with flue gas instead of air, there would be a tendency to remove any incrustation, and since the incrustation forms very slowly, it seems probable that the use of flue gas every 24 hours would dissolve the incrustation as fast as it was formed, or it would prevent the growth or incrustation on sand grains. The flue gas would necessarily have to be purified before being used for such a purpose.

SANITARY SURVEY OF THE MISSISSIPPI RIVER AT MOLINE.*

As a result of agitation concerning the water supply of Moline, a commission of business men was appointed to investigate conditions. This commission submitted its report May 6th, 1911. From the analyses of the water taken from different points in the river, they reported that steps should be taken at once to obtain a better supply of water, and recommended that the intake be removed to a point above Campbell's Island. The recommendation was based on one analysis, made in May, of the water above Campbell's Island with 1,300 bacteria per cubic centimeter compared with three analyses of water from the channel opposite the city, made on January 9th, with 7,000 bacteria, on January 10th with 35,000 bacteria, February 4th with 292,000. The analyses had been made by different analysts. The time between the collection and the analysis of the samples had differed.

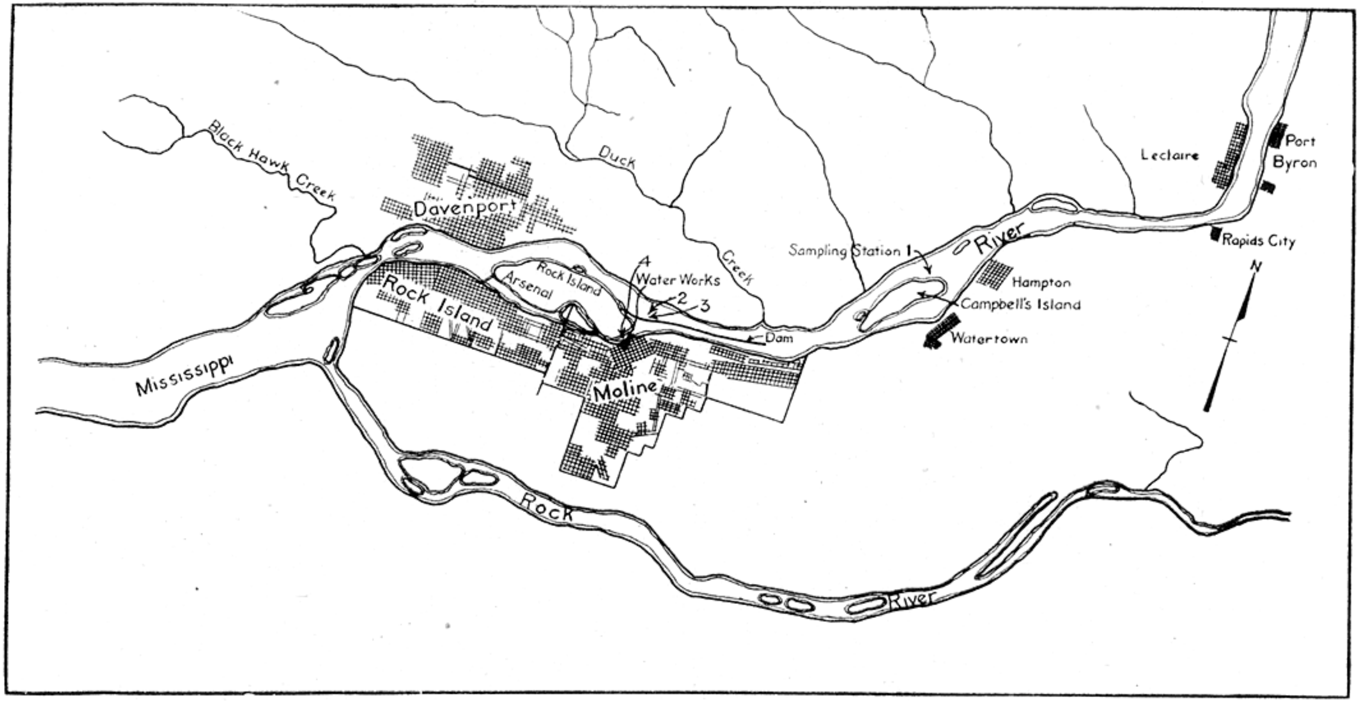
A change of the intake to Campbell's Island would mean the expenditure of a large sum of money, probably $500,000.

Mayor M. R. Carlson thought it ill advised to go into the matter without a more thorough and efficient chemical and bacteriological test.

On May 11th, 1911, the Mayor was authorized by the Commission to make the necessary tests. Mr. Lewis I. Birdsall, Chemist in charge of the Water Purification Plant at Rock Island, was engaged, and the co-operation of the State Water Survey was requested.

In response to this request, the State Water Survey has conducted a series of analyses to determine the relative character of the Mississippi river water at three points—viz: at a point above Campbell's Island (see map), at a point in the channel at the water works intake, and at a point in the pool near the pool intake. With these have been made analyses of the filtered water to determine the efficiency of the present filter. plant. All samples have been taken by the Director of the State Water Survey, accompanied by Mr. Lewis I. Birdsall, Commissioner Jahns, and in some cases by Mayor Carlson and Commissioner Anderson. At the same time and same places, samples of water were collected by Mr. Birdsall, and his report confirms the findings reported in this paper.

*Proc. Ill. Water Supply Assn., 1912, 165.



Map Showing Sampling Stations in a Survey of the Mississippi River at Moline.

Four analyses were made of water collected above Campbell's Island (1).* Comparing these with four analyses taken on the same dates from the channel at intake (3) we find (7) that the water from Campbell's Island is of practically the same character as the water from the channel. While the average number of bacteria from the channel is higher (20,550 and 11,350), in three of the four comparisons made, there were fewer bacteria in the channel at the intake than in the river at Campbell's Island. In my opinion, these results show conclusively that the city of Moline would not be warranted in building a new intake above Campbell's Island.

On two occasions, July and August, samples were taken from points approximately 150 feet out in the channel from the present channel intake. Comparing these results (2) with the results of the analyses of the water at intake (3) collected at the same time, July and August, it is seen (8) that no advantage would be gained by the extension of the intake.

A comparison of the water from the channel at the intake (3) with the water from the pool near the pool intake (4) shows the water from the pool to be a better water from the standpoint of turbidity, residue on evaporation, oxygen consumed, and albuminoid nitrogen. The average number of bacteria is much higher in the sample from the pool, but an inspection of the individual analyses shows that in three of the five comparisons the number of bacteria from the pool was lower than from the channel, the higher average being accounted for by finding 170,000 bacteria in the pool intake on August 15th. The tests for gas formers were positive in all of the 10 c. c. and 1 c. c. samples, and in the majority of the 0.1 c. c. samples, showing that the amount of purification would be practically equal whether the water were taken from the channel or the pool. Samples of water taken from the channel at intake in October and November (3) compared with samples of water taken from the intake well (5) on the same dates show a little better condition in the water in the intake well than that collected directly from the pool, though the difference is very slight. This comparison is of interest, since it shows the similiarity between the surface and deeper water.

A comparison of the water from the west and east side of the pool (4) (10) shows very slight differences. It would be difficult to choose between the two. These samples were taken, in each case, at least 100 feet from the shore.

The efficiency of the filtration plant is illustrated by a comparison of the water from the channel at intake (3) with the analyses of the water taken from the tap at the pumping station (6). As seen in (11), there is a very satisfactory reduction in the turbidity, color, residue, oxygen consumed, albuminoid ammonia, and in the number of bacteria per cubic centimeter. The bacterial examination of the filtered water has shown the water to be safe, and this comparison shows that it is

*Figures in parentheses refer to divisions of the appended table.

TABLE OF ANALYSES TO ACCOMPANY REPORT OF THE INVESTIGATION OF THE CHARACTER OF THE MISSISSIPPI RIVER WATER AT MOLINE, JULY, 1911, TO DECEMBER, 1911.

DATE	No.	Turbidity	Color	Odor	Residue		Chlorine	O. Cons.		Nitrogen as						Alkalinity	Bacteria per c. c.	Gas Formers			Indol.	Remarks
					Total	Dissolved		Total	Dissolved	Free Am. Total	Free Am. Dis.	Alb. Am. Total	Alb. Am. Dis.	NO_2	NO_3			10 c. c.	1.0 c. c.	0.1 c. c.		
MISSISSIPPI RIVER ABOVE CAMPBELL'S ISLAND. (1)																						
July 9	22128	250	30	1 E	208	....	2.	7.6	....	.104	....	.254	....	.000	.560	126	1100	1−	1+1−	1+1−	+	
Aug. 15	22314	1500	40	1 E	960	150	4.	17.2	5.0	.160	....	.960	.128	.045	.755	82	28600	1+	2+	2+	+	
Sept. 12	22424	90	45	1 E	243	....	1.	8.1	....	.048	....	.344	....	.014	.440	138	13000	1+	1+1−	2+	+	
Oct. 16	22539	300	170	1 E	440	110	.8	18.2	15.9	.096	....	.576	....	.006	.320	46	2700	1+	2+	1? 1−	+	
Average 4 mo	....	535	71	....	463	....	2.0	12.8	....	.102	....	.533	....	.016	.519	98	11350	+	+	+	+	
CHANNEL OF RIVER NEAR INTAKE—150 FEET OUT. (2)																						
July 9	22129	20	40	1 E	253	....	2.	7.6	....	.038	....	.366	....	.000	.320	130	. 900	1+	2+	1+1?	+	42 hrs.
Aug. 15	22315	1500	120	1 E	963	145	3.	17.1	6.2	.200	....	.980	.200	.060	.580	80	20000	1+	2+	2+	+	
Average 2 mo	....	890	80	.....	608	....	2.5	12.4	....	.119	....	.673	....	.030	.450	105	10450	+	+	+	+	
CHANNEL AT INTAKE. (3)																						
July 9	22131	330	40	2 E	258	....	2.0	7.5	....	.088	....	.272	....	.000	.240	128	900	1−	2+	2+	+	42 hrs.
Aug. 15	22316	1500	100	1 E	904	153	3.	17.5	5.4	.200	....	.980	.152	.060	.580	80	25000	1+	2+	1+1−	+	
Sept. 12	22420	100	40	1 E	265	....	3.	7.9	....	.056	....	.362	....	.014	.240	140	55000	1+	1+1?	1+1−	+	
Oct. 16	22540	155	155	1 E	265	129	.6	17.7	16.3	.072	....	.400	....	.004	.240	48	1300	1+	2+	2?	+	
Nov. 14	22677	250	100	1 E	407	163	1.2	17.0	9.0	.088	.144	.392	.224	.004	.920	104	15000	1+	2+	2+	+	
Average 2 mo	....	915	70	....	581	....	2.5	12.5	....	.144	....	.626	....	.030	.410	104	17000	+	+	+	+	
Average 4 mo	....	521	84	....	423	....	2.2	12.7	....	.104	....	.503	....	.019	.325	99	20550	+	+	+	+	
Average 5 mo	....	467	87	....	420	....	2.0	13.5	....	.101	....	.481	....	.016	.444	100	19440	+	+	+	+	
POOL NEAR INTAKE. (4)																						
July 9	22131	270	30	1 E	232	....	2.0	7.0	....	.044	....	.238	....	.000	.280	.128	300	1+	2+	1+1−	+	42 hrs.
Aug. 15	22317	720	120	1 E	440	182	3.0	12.1	5.6	.240	....	.480	.200	.068	.570	82	170000	1+	2+	1+1−	+	
Sept. 12	22421	125	40	2 E	317	....	2.0	7.6	....	.052	....	.388	....	.012	.320	134	22000	1+	2+	2+	+	West side
Sept. 12	22422	130	45	1 E	282	....	1.0	8.2	....	.062	....	.426	....	.015	.360	134	12500	1+	2+	1+1−	+	East side
Oct. 16	22541	140	170	1 E	242	116	1.6	17.5	16.2	.104	....	.544	.006	.006	.120	46	1200	1?	2+	1+1−	+	West side
Oct. 16	22542	140	170	1 E	233	100	1.2	16.5	15.5	.056	....	.376	....	.002	.480	46	1	1?	1+	1? 1−	+	East side
Nov. 14	22675	240	110	1 E	407	180	1.4	16.6	8.8	.088	.184	.400	.232	.002	.520	104	14000	1+	2+	2+	+	West side
Nov. 14	22678	240	110	1 E	423	167	1.4	16.9	9.0	.200	.128	.394	.248	.002	1.040	102	12000	1+	2+	1+1−	+	East side
Average 5 mo	....	300	94	....	325	....	1.9	12.2	....	.113	....	.396	....	.018	.454	99	40250	+	+	+	+	

INTAKE WELL. (5)																					
Oct. 16	22543	150	180	1E	245	98	.8	17.7	15.6	.112	....	.448	....	.002	.280	48	700	1 ?	2+	2 +	+	
Nov. 14	22674	230	100	1E	385	158	1.0	16.6	9.2	.096	.184	.384	.256	.002	.520	104	9600	1+	2 +	1+1−	+	
Average 2 mo	....	190	140	....	315	128	.9	17.2	12.4	.104	....	.416	....	.002	.400	76	5150	+	+	+	+	
FILTERED WATER FROM TAP IN OFFICE. (6)																					
July 9	22132	3	15	1 E	200	....	3.0	3.9	....	.016	....	.194	....	.000	.200	114	12	1+	2 −	2−	+	
Aug. 15	22318	0	0	0	175	....	4.0	1.8	....	.148	....	.110	....	.050	.510	72	350	1−	2 −	2−	−	
Sept. 12	22423	1	10	1E	207	....	3.0	4.1	....	.020	....	.160	....	.006	.320	122	75	1+	1+1−	2−	+	
Oct. 16	22544	2	8	1E	147	....	2.6	3.5	....	.080	....	.384	....	.005	.440	30	10	1+	2 −	2−	+	
Nov. 14	22676	20	20	1E	179	....	2.4	3.3	....	.064	....	.120	....	.000	.560	72	200	1−	1+1−	2−	−	
Average 5 mo	....	5	11	....	192	....	3.0	3.1	....	.066	....	.194	....	.012	.406	82	129	+	−	−	+	
COMPARISON OF WATER FROM CAMPBELL'S ISLAND (1) WITH WATER FROM CHANNEL AT INTAKE. (3) (7)																					
		535	71	....	463	....	2.0	12.8	....	.102	....	.533	....	.016	.519	98	11350	3 + 1 −	6 + 2 −	5+2−	4+	C'pb'lls Is
		521	84	....	423	....	2.2	12.7	....	.104	....	.503	....	.019	.325	99	20550	3 + 1 −	7+1?	4+2−	4+	Channel
COMPARISON OF WATER FROM CHANNEL 150 FT. FROM INTAKE (2) WITH WATER FROM CHANNEL AT INTAKE. (3) (8)																					
		890	80	....	608	....	2.5	12.4	....	.119	....	.673	....	.030	.450	105	10450	2+	4+	3+1?	2+	150 out
		915	70	....	581	....	2.5	12.5	....	.144	....	.626	....	.030	.410	104	17000	1+1−	4+	3+1−	2+	Nr. intake
COMPARISON OF WATER FROM CHANNEL AT INTAKE (3) WITH WATER FROM POOL NEAR POOL INTAKE (4) (9)																					
		467	87	....	420	....	2.0	13.5	....	.101	....	.481	....	.016	.444	100	19440	4+1−	9+1?	6+2−	5 +	Nr. intake
		300	94	....	325	....	1.9	12.2	....	.113	....	.396	....	.018	.454	99	40250	6+2?	15+	9+6−	8 +	Pool 8 an'l
COMPARISON OF WATER FROM WEST AND EAST SIDES OF POOL (4) (10)																					
		170	108	....	313	....	1.2	13.9	....	.106	....	.399	....	.006	.627	94	8200	2+1?	5+1?	2+3−	3+	East side
		168	107	....	323	....	1.7	13.9	....	.081	....	.444	....	.007	.320	95	12400	2+1?	6 +	5+1−	3+	West side
COMPARISON OF WATER FROM CHANNEL AT INTAKE (3) WITH TAP WATER—FILTERED (6) (11) Aver. 5 mo.																					
		467	87	....	420	....	2.0	13.5	....	.101	....	.481	....	.016	.444	100	19440	4+1−	9+1?	6 + 2 −	5+	At intake
		5	11	....	192	....	3.0	3.1	....	.066	....	.194	....	.012	.406	82	129	3 + 2−	2+8−	10−	3+	Tap water
Reduction	......	462	76	....	228	....	....	10.4	....	.035	....	.287	....	.004	.038	18	19310	....	....	....	....	
% reduction	......	98.9	87.3	....	54.3	....	....	77.0	....	34.6	....	59.7	....	25.0	8.5	18.0	99.3	....	....	....	....	

practicable to filter the Mississippi river water as now obtained opposite the present pumping station in Moline. In addition to the conclusion already drawn, the results of observations of the situation at Moline suggest two things which will be of assistance in furnishing the city of Moline with a pure drinking water.

First: Regular, daily, chemical and bacterial control of the plant. This will indicate at all times the efficiency of the filter plant and will enable those in charge to use the minimum amount of chemicals.

Second: The installation of meters to tend to check waste of water. If the water is not wasted, the present filter capacity will be sufficient to supply the city with pure water for several years to come.

COMPOSITION OF SEDIMENT FOUND IN WATER FROM DEEP DRIFT WELLS.*

The east central part of Illinois, an area of about 15,000 square miles, is covered by glacial drift to a depth of more than 100 feet. It is in this section that are located the so-called deep drift wells referred to in this paper. Many municipalities, including Bement, Champaign, Edwardsville, Farmer City, Hoopeston, LeRoy, Mason City, Mattoon, Normal, Paxton, Rantoul, Rossville, Tolono, Urbana, Watseka and a large number of private supplies, obtain their water supplies from these wells. They are usually one hundred or more feet in depth.

The good results obtained from a large number of analyses of the water made in the laboratory of the State Water Survey, as well as the low typhoid fever death rate in this locality, indicate clearly that from a hygienic standpoint these waters are of unquestionable purity.

A common characteristic of the water from deep drift wells, and the one that is now receiving serious attention by waterworks men, is the presence of iron in considerable amounts.

It has been pointed out by several investigators on the subject of iron removal that the amount of iron that will cause trouble varies with the character of the water. There are waters containing† as low as .10 parts per million of iron causing considerable trouble, and, again, others where iron runs as high as 1.0 part per million without any apparent ill effects.

The water as drawn from the drift wells is usually clear. On being allowed to stand after exposure to air, a yellowish or reddish brown gelatinous precipitate is formed. It is this precipitate settling in the mains and service pipes that causes trouble. Any disturbance or change of pressure, as on wash day or in case of a fire, stirs up the deposit and it appears in the water when drawn for use. With a water of this kind, plumbing fixtures are stained, rust spots appear on linen and a disagreeable odor and taste can often be detected. Clogging of the smaller service pipes is not uncommon.

Samples of the precipitate were collected from dead ends of mains and walls of reservoirs both exposed and hidden from light.

*Abstract of thesis prepared by W. F. Langelier, under the direction of Prof. Edward Bartow, and submitted in partial fulfillment of the requirements for the degree of Master of Science in Chemistry.

†Purification of Ground Waters Containing Iron and Manganese. Robert S. Weston. Trans. American Society of Civil Engineers, 64, 113.

Microscopical examination showed in all cases the presence of what is commonly called the iron bacterium "Crenothrix." There is a difference of opinion concerning the nature of this organism. The following is a brief history of the claims:

Rabenhorst,* in 1865, wrote concerning Crenothrix: "Discovered by Kühn in 1852, in the vicinity of Bunzlau (Silesia). Scattered Hypheothrix, interwoven either closely or loosely, contaminated and colored with oxide of iron. Filaments slightly curved; palely æruginous; indistinctly articulated; in places interrupted; having thick sheaths, folded and colorless. Diameter of filaments 0.0001—0.00012." Habitat in drain pipes.

Cohn,† in 1870, found the organism present in well waters in Breslau. Since it appeared to belong to an entirely new genus and species he called it "Brunnenfaden," "Well Thread" and, finally, Crenothrix. He made a thorough study of the organism, and fiindng but one kind, in which there was an abundant and peculiar spore formation, he proposed for it the specific name of "Polyspora."

In 1878, Prof. Oskar Brefeld and Dr. W. Zopf‡ identified Crenothrix in the Tegel water supply of Berlin. It was abundant in the reservoir and service pipes and present in the water from all of the wells which supplied the city. It was not found in the lake (Tegel) itself. Examinations of the soil showed that the distribution of Crenothrix in the ground was not merely superficial, but that it was to be found in water obtained from various depths. Zopf suggested the name Crenothrix Kühniana. The following year, Zopf found it present in unfiltered water from the river Spree.

In 1886, it was identified for the first time in the United States. Mr. George W. Rafter** found it present in the water supply of Jamestown, New York. The following year, Mr. G. H. Parker,†† of the Massachusetts State Board of Health, identified Crenothrix in several of the supplies of the State.

It was about this time that the Rotterdam water supply became infected with the growth. Prof. Hugo DeVries,‡‡ professor of Botany in the University of Amsterdam, was employed by a Commission appointed by the city authorities to make microscopical investigations. In his report, which is very complete, he says in part: "The iron bacteria are the largest forms in the whole group of bacteria. Although

*Fresh Water Algæ.

†Uber den Brunnenfaden, etc., by F. Cohn. Beit. zur Biol. I, 117–131.

‡Bericht an den Hohen Magistrat der Stadt Berlin, über die von ihnen angeführten Untersuchungen des Tegeler Wassers, Berlin, 1879. W. Zopf, Entwickelungs geschichtliche Untersuchung der Crenothrix polyspora, Die Ursache der Berliner Wassercalamität, Berlin, 1879.

**On Fresh Water Algæ by G. W. Rafter. Trans. Am. Soc. Civil Eng., Vol. 21.

††Report of the Biologist. Mass. S. B. of Health An. Rpt. 1887. Vol. 19.

‡‡H. DeVries, "Die Pflanzen und Thiere in den dunkeln Raümen der Rotterdamer Wasserleitung. Bericht über die Biologischen Untersuchungen der Crenothrix Commission zu Rotterdam, von Jahre 1887, 1–55, Jena 1890.

their cells are invisible to the naked eye, they are so united, end to end, as to form threads or filaments which in turn tend to make "flocks" or masses visible to the naked eye, often a millimeter and sometimes a centimeter or more in size. The most striking and characteristic property of the iron bacteria is their power of depositing in their sheath the oxide of iron. Entirely colorless and transparent at first, they gradually become pale yellow, and then darker, until, finally, they are deep brown. These organisms obtain their iron oxide form the dissolved iron salts in the water, especially the ferrous carbonate. Without soluble ferrous salts their life cannot long continue. In all probabiltiy, the oxidation of the ferrous to the ferric oxide forms an important part of the vital processes of these cells, and the brown substance deposited in the sheath is to be regarded, not as the refined product, but as the dross of the operation. They are nourished partly by the ordinary salts dissolved in water and partly by dissolved organic substances, which originate in the putrefaction of vegetable and animal remains. It appears to be a plant widely distributed throughout the world in drain pipes, deep wells, and other badly lighted chambers. It is due to its power of extraordinarily rapid increase that it often covers, in a few months after the introduction of its germs, or after the conditions for its nourishment have been favorable, the entire walls of the reservoir, of the drain pipes or conduits, with a felt as thick as a finger, of which single portions are soon sufficiently developed to be swept along with every current as brown or blackish flocks. In this way it comes to pass that it is a real calamity in water works, making the water disagreeable for domestic use and entirely unfit for many industrial purposes."

In 1902, Jackson* was able to grow Crenothrix artificially on gelatin-agar plates, both in an atmosphere of hydrogen and of carbon dioxide.

In 1888, Winogradsky† investigated the conditions most favorable to the growth of Crenothrix. His experiments showed that the organism could grow in the Strassburg well water to which only .005 to .0l per cent of calcium butyrate had been added. He confirmed the opinion held by Zopf that the existence of the organism was absolutely dependent upon the presence of certain salts of iron.

Whipple‡ places Crenothrix under the Schizomycetes, a class of the vegetable organisms Schizophyceæ in which the chief mode of propagation is that of cell division. Crenothrix does not contain chlorophyll. It is characterized by him as follows:

"Filaments cylindrical, transversely divided into cells surrounded by a gelatinous sheath which becomes yellowish-brown through deposits of iron or manganese. Multiplication takes place by transverse and occasionally by longitudinal fission. Cells also escape the sheath at the end or side, and, by division, form new filaments. Reproduction occurs

*J. Soc. of Chem. Ind., 21, 681.

†Uber Eisenbacterien. Botanische Zeit. 46, 260.

‡The Microscopy of Drinking Water. Wiley & Sons, 1906.

through spores formed from the cells within the sheaths. There is one principal species, C. Kühniana. It occurs in single filaments or in brownish tufts or mats, often of considerable thickness. The filaments are 1½ to 4 microns thick, and the sheath is several times the thickness of the filaments. Articulation is distinct. When the iron of the sheath is dissolved by dilute hydrochloric acid, the cells appear as distinct rectangles, each one somewhat removed from its neighbor. This appearance is characteristic of Crenothrix. During growth, the cells sometimes push themselves forward in the sheath, leaving the empty sheath behind. The older portion of the sheath is darker colored than the growing points. Crenothrix occurs chiefly in ground waters rich in organic matter, containing iron salts and carbonic acid, and deficient in dissolved oxygen. Its growth is favored by darkness."

Next in order we have the work of Dr. J. Campbell Brown,* whose researches were carried on in 1903. His paper is not limited to Crenothrix, but covers the whole subject of deposits in pipes or channels conveying potable water.

Up to this point, we have had no serious differences of opinion amongst the different investigators as to the theories of growth of the organism. Dr. Brown's theory of the iron phenomena is somewhat different. He describes it as follows: "The slime organisms live on the carbon compounds in a soluble organic compound of iron, which penetrates into their substance, even into the inner tube. Whether the iron performs any function or not, the carbon compounds support life, and the iron oxide is necessarily deposited throughout the whole mass of living matter, but chiefly in the active parts. It thickens the sheath, until the organism, throwing out fresh tips at one end, dies at the other end and breaks up into the gelatinous matter, which is seen when the iron is removed from masses of slime by oxalic acid."

Quoting again from his paper: "It is evident that acidity other than carbonic acid always characterizes water which produces this ferruginous slime; alkaline water never grows any, so far as the author has seen, nor does neutral water. Bicarbonates, which imply lime and magnesia, seem to be opposed rather than favorable to the growth, organic matter alone does not produce it, and a trace of iron in neutral or alkaline water is quite consistent with the absence of slime. But an appreciable quantity of iron in solution in combination with organic matter of an acid character is an invariable accompaniment of the slime."

Summing up what has been written, it would appear that the essential characteristics favoring its growth are ground waters, slightly acid in character, containing considerable organic matter, some iron, and free carbon dioxide, and deficient in dissolved oxygen. The absence of light is also considered beneficial. While our observations with water from the drift wells confirm some of the conclusions reached by previous writers, we have noticed a few differences that seem interesting.

*Deposits in Pipes. Proc. Inst. Civil Engineers. 156, 1.

As may be seen in Table I, the water obtained from the drift wells is fairly uniform as to character. It will be noticed that they all contain carbonates of calcium and magnesium and considerable iron. The former does not accord with observations of Dr. Brown. Perhaps the most interesting difference, however, is in the relation of the CO_2 and O, and the effect of light on the growth of the organisms.

TABLE I.

ANALYSES OF SOME TYPICAL DRIFT WELL WATERS.

RESULTS EXPRESSED IN PARTS PER MILLION.

Laboratory No.	7502	21706	21799	21801	1373	12316
Location	Urbana	LeRoy	Paxton	Hoopeston	Mattoon	Downs
County	Champaign	McLean	Ford	Vermilion	Coles	McLean
Depth	155 ft.	90 ft.	148 ft.	148 ft.	60 ft.	127 ft.
Potassium Nitrate	....	.5	1.8	1.1	.4	1.1
Potassium Chloride	4.3	7.4	4.2	2.1	4.7	1.9
Sodium Chloride	4.3	2.5	....	....	20.9	....
Sodium Sulphate	....	1.0	37.0	2.8	39.6	.9
Sodium Carbonate	74.7	36.8	86.1	40.3	15.6	51.1
Ammonium Carbonate	5.3	17.6	13.6	1.9	34.3	31.9
Magnesium Carbonate	108.1	148.9	140.3	108.4	185.1	151.2
Calcium Carbonate	163.2	249.6	201.2	163.0	257.9	236.6
Iron Carbonate	3.5	1.7	1.0	2.7	8.0	12.7
Alumina	1.2	5.6	2.5	1.4	19.2	10.4
Silica	18.6	20.7	17.0	14.1	25.2	22.4

The water at Urbana as it leaves the ground contains practically no dissolved oxygen and about 40 parts per million of free carbon dioxide (CO_2). Upon aëration, the dissolved oxygen is increased to approximately 7.0 p.p.m. and the water loses about 50% of its free CO_2. This water under these conditions has developed luxuriant growths of Crenothrix even when exposed to direct sunlight.

Table II gives results of analyses of four samples of sediment. Sample No. 1 was collected from the sides of the reservoir of the Champaign-Urbana Water Company. Sample No. 2 was obtained from an open trough carrying the water to an experimental filter at the pumping station of the Champaign-Urbana Water Company. Sample No. 3 was taken from the sides of the reservoir of the Mattoon Clear Water Company. Sample No. 4 was collected and sent to the laboratory by Mr. L. C. Lounsbury, Chemist and Superintendent of the Water Filtration Plant at Superior, Wisconsin.

The samples were all dried at 103° C., and ground to a fine powder. In addition, for the sake of comparison an analysis of a similar deposit reported by Mr. D. D. Jackson is given.*

*Jour. Soc. Chem. Ind., 21, 681.

TABLE II.—ANALYSES OF DRIED SEDIMENT.

	Champaign & Urbana. No. 1.	Champaign & Urbana. No. 2.	Mattoon. No. 3.	Superior. No. 4.	Reading Mass. by Jackson.
Fe_2O_3	31.98%	42.89%	27.26%	30.41%	31.6%
Al_2O_3	5.39	9.87	13.12	4.20	5.7
MnO	....	....	....	....	....
SiO_2	8.00	6.27	12.33	35.46	11.1
Bases	.43	.28	.10	3.59	4.2
Aluminium Silicate	....	....	....	....	10.4
CaO	5.48	4.31	4.94	2.27	....
MgO.........	Trace	Trace	Trace	....	....
Volatile.......	49.75	38.08	34.1	25.25	37.0
Carbon	11.40	....	....	....	......

It may be seen that roughly about one-third of the residue is iron oxide, another third organic matter, while the remaining third is mostly alumina and silica. The color of the samples ranged from yellowish brown in the sample from Mattoon, to a deep reddish brown in the Superior, Wisconsin, sample. The latter, it will be seen, contains some manganese.

The problem of getting rid of the Crenothrix growth in pipe lines, conduits, reservoirs, etc., is one that has not as yet been satisfactorily solved. Of course, the character of a water is always an important factor in deciding any kind of water treatment, whether for sanitary or for industrial purposes.

As Crenothrix has been encountered in various types of waters, the treatment for its removal in one instance would not necessarily be successful in another.

The successful methods now in use for the removal of this objectionable growth from mains, etc., are for the most part preventative measures. The food supply or conditions necessary for its growth are removed or altered. Since iron, organic matter and carbon dioxide seem to be most essential, methods depending on aeration and filtration are used. Treatment with chemicals has been resorted to in some instances.

The use of small porcelain or stone filters in private dwellings are sometimes of help, but do not usually remove odors and easily become clogged.

In some places, as at Freeport, Illinois,* treatment with lime, together with filtration, has proved effective. The lime has the function of neutralizing the CO_2 acidity as well as of precipitating the iron.

At Frankfort, Germany†, carbon dioxide is removed by filtering through limestone. This treatment has succeeded in preventing growths of a similar nature to Crenothrix.

*Experience with Growths in Water Mains. Owen T. Smith. Proc. Am. Water Works Assoc. 1904, 148.

†Die Entsauerung des Frankfurter Stadtwaldwassers; Scheelhaase–Journal für Gasbeleuchtung und Wasserversorgung. 52, 822.

Copper sulphate* which is proving so effective in the removal of algæ, has no effect upon Crenothrix.

The problem is by no means solved as yet, and offers to the biologist an excellent field for investigation.

*Copper as an Algicide and Disinfectant in Water Supplies. Moore & Kellerman, U. S. Dept. of Agriculture, Bureau of Plant Industry, Bulletins 64 and 76.

SANITARY SURVEY OF LAKE MICHIGAN WATERSHED IN ILLINOIS.*

In December, 1911, a sanitary survey was made of the North Shore suburbs of Chicago, including all cities and villages bordering on Lake Michigan between and including Evanston and Zion City. The object of this survey was to obtain information regarding sewerage, disposal of sewage and other municipal wastes, the source, quality and distribution of water supplies and the operation of water works systems. Individual reports on the several municipalities have been prepared, setting forth in detail the conditions found to exist and giving such data as was obtained. The object of this report is to sum up in a general way the main features. A map accompanying this report shows the natural drainage of the community, and the relations of the water works intakes to the sewer outfalls of the various cities and villages.

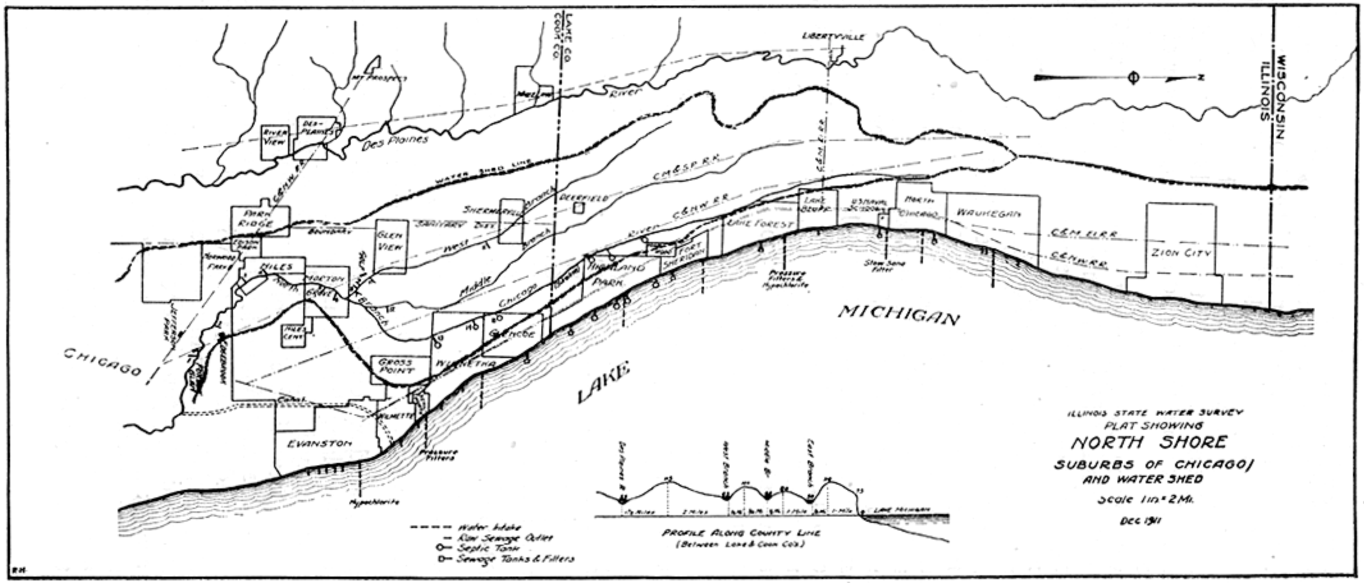
In the accompanying table are listed some of the data pertaining to the individual municipalities.

DATA PERTAINING TO NORTH SHORE TOWNS.

City or Village.	Population.			Source of Water Supply.	Length Intakes	Purification Water.	Natural Drainage.		Sewage Disposal.	
	1890	1900	1910		Depth Wells.		% to Lake.	% to Skokie	to Lake.	to Skokie
Evanston	......	19,259	24,978	Lake	5600'	H.	100	0	Raw	......
Wilmette	1458	2,300	4,943	Evanston	......	None	100	0	Raw	......
Kenilworth	......	336	881	Lake	1400′	P. F.	100	0	Raw	......
Gross Point	......	669	1,008	None	......	......	90	10	......	......
Winnetka	1079	1,833	3,168	Lake	3000′	None	50	50	Raw	1. S. T.
Glencoe	569	1,020	1,899	Winnetka	......	None	70	30	1. S. T.	2. S. T.
Highland Pk.	2163	2,806	4,209	Lake	3650′	None	85	15	4. S. T. 1 T&F	2. S. T
Highwood	451	1,575	1,219	Highland Park	......	None	60	40	......	1. S. T.
Ft. Sheridan	......	1,600	1,600	Lake	3500′	Boiled for drinking	100	0	T.&F.	......
Lake Forest	1203	2,215	3,349	Lake	1100′ 700′	P. F. H.	95	5	T.&F.	......
Lake Bluff	......	490	726	Wells	300′ & 2000′	None	95	5	Raw	......
U.S. Naval Sch.	0	0	750	Lake	1200′	S. S. F.	100	0	T.&F.	......
N. Chicago	......	1,150	3,306	Lake	400′	None	100	0	T.&F.	......
Waukegan	4915	9,426	16,069	Lake	4000′	None	100	0	Raw	......
ZionCity	0	0	4,789	None	......	......	100	0	......	......
		44,679	72,894							

S. T.—Septic Tank. F.—Filters. T. & F.—Septic Tank and Filters. H.—Hypochlorite. P. F.—Pressure Filters. S. S. F.—Slow Sand Filters.

*By Ralph Hilscher.



North Shore Suburbs of Chicago and Watershed.

There is a steady growth in population along practically the whole North Shore. The real estate business is active. The North Shore is essentially a residential community and is built up, for the greatest part, by a wealthy class of people. North Chicago, Waukegan and Zion City are the only points at which factories are located. Zion City has only one factory, but North Chicago and Waukegan are essentially manufacturing towns and support a number of industries of considerable size.

As shown on the accompanying map, the watershed line between the Lake Michigan and Chicago River drainage areas passes at an average distance of about one mile from the lake along nearly the whole North Shore. A rather wide beach extends along the shore for the whole distance, and behind this, quite abruptly, to heights ranging from 25 to 100 feet, rise the bluffs on which the North Shore towns are built. This high ground is cut into by a great many deep and winding ravines, and the whole is quite heavily wooded. The soil is principally yellow and blue clay to depths of 20 feet and more.

To the west of the divide, the slope is rather gradual to low and poorly drained land in the so-called Skokie valley. The east branch of the Chicago River, or Skokie, which drains this valley, is a very sluggish stream during the greater part of the year. The relative elevations, above lake level, of the bed of this stream for various points are shown in the following table:

Point West of.	Elev. bed.	Distance from previous point Miles.	Fall in ft. per mile.
North Chicago	106	.....	....
Naval Station	102	1.1	3.64
Lake Bluff	85	2.5	6.80
Lake Forest	65	2.5	8.00
Fort Sheridan	52	2.0	6.50
Highwood	50	1.8	1.11
Southern Highland Park	49	3.8	0.26
Kenilworth	40	4.5	2.00
Wilmette	34	3.0	1.33
Average			3.40

From Fort Sheridan, south, the worst conditions exist on this stream. North of Fort Sheridan, the fall in the stream is sufficient to provide a good flow; the valley is narrow, and some of the finest homes on the North Shore are located on the upland, near the Skokie. West of Highland Park, Glencoe and Winnetka, the fall in the stream bed is very slight, and the lands bordering it are wide, flat and marshy. As seen in December, 1911, the water in the stream was highly colored and the stream bed was thickly grown over with marsh grass.

There are six municipal sewer outlets to this stream, all of which are provided with septic tanks. Besides these, there are a few tanks on private estates scattered along from Lake Forest to Winnetka. The municipal tanks are all on low land, and at distances of ¼ to ½ mile from the stream. The effluents from these tanks are conducted to the Skokie through open ditches, and it is said that very foul and objectionable conditions frequently occur. Some of these ditches pass along beside public highways, and on one such road in Highland Park three houses are built fronting on the effluent ditch. In Winnetka, a resident, who had built within 100 yards of a septic tank, stated that water from the Skokie had backed up through the effluent ditch into his cellar.

There are 23 points of sewage discharge into Lake Michigan on the North Shore, averaging about 1.2 miles apart. There are nine points of intake for public water supplies averaging about three miles apart. At 10 of the 23 sewer outlets there are purification works of one kind or another.

Five of these purification works include filters, while at the other five, septic tanks only are provided. Two of the filters shown on the map, namely, at Lake Forest and Glencoe, have given unsatisfactory results and have been out of use for some time. At these two plants, therefore, only treatment in septic tanks is given the sewage.

Of the nine water supply intakes on the North Shore (supplying 12 municipalities), there are four (supplying five municipalities) at which the water is treated in some manner. There are a total of 66,371 people on the North Shore who are being supplied with Lake water. Of these, 34,901, or about 53%, are supplied with water that has been treated. This figure does not include Fort Sheridan, where all water used for human consumption is boiled.*

There seems to be a prevailing opinion that currents flowing southward exist on the lake along the North Shore, and that currents northward rarely occur. It is generally believed for this reason that intakes should be to the north of sewer outlets and, with two exceptions, every town taking its supply from the lake has located its intake to the north of its own sewer outlets. North Chicago is building an outlet north of its intake, but is preparing to filter the sewage. Highland Park, the other exception, has two outlets to the north, as well as three to the south.

There is a strong desire on the part of the North Shore residents, to dispose of their sewage otherwise than in the lake, but no very definite steps have been taken toward that end. Considerable interest is being evinced in securing a satisfactory outlet for both the sewage now draining eastward to the lake and that disposed of in the Skokie, and the following organizations are taking a part in the solution of this problem:

Lake Michigan Sanitary Association.

North Shore Sanitary Association.

North Shore Citizens' Association (over 500 members).

Cook County Truck Gardeners' and Farmers' Association (1,000 members).

*The construction of a filter plant is under consideration.

Various Village Boards.
Chicago Association of Commerce.
Chicago Sanitary District.

The Sanitary District includes the southern part of the territory considered in this report, namely, Evanston, Wilmette, Kenilworth, Gross Point, Winnetka, and Glencoe, which cities and villages are the homes of about 50% of the entire population on the North Shore. This part of the sanitary district has paid taxes to the district for several years, and considerable complaint is to be heard from some who assert that no benefits have been received, and that prospects of receiving benefits are remote. A canal has been constructed from the Wilmette shore to the Chicago River, and pumping facilities installed for raising the lake water about 6 feet into this canal for flushing and diluting purposes. This canal will provide a suitable outlet for the Wilmette sewage at a comparatively low cost to that village. It would, however, be extremely costly to divert the Evanston sewage to this canal, and there is no prospect of such a measure being considered, for the present at least.

Following are some extracts from an address given before the Lake Michigan Sanitary Association, February 18, 1911, by Mr. Frank A. Windes, consulting engineer of Winnetka.

"A recent tour of inspection along the west branch and along the middle branch of the Chicago river, from Shermerville, down to the main north branch, at its connection with the north shore channel, revealed some startling facts. Cattle pastured in the Skokie district waded in and drank the effluent from the septic tanks and sewers, and in some cases drank the water from the streams, almost dry except for the raw sewage found therein. Children bathed, or rather went swimming, in the water contaminated by the foulest kind of sewage.

"The sanitary district is in duty bound to provide suitable and necessary sanitary drainage for the entire territory adequate to remedy unsanitary conditions and to prevent such conditions from existing. This district has also the power to construct such channels, drains, etc., as are necessary. It seems that for the north shore towns to unite in a smaller sanitary district of their own for the purpose of working out their drainage scheme would not be legal. These municipalities could, however, unite to construct a common outlet sewer down to the outfall, but this would necessitate securing the right of way through the other villages, which at present is almost impossible. This method of procedure is certain to involve litigation, delay and heavy expense. Should the municipalities interested proceed to construct the outlet necessary without the assistance of the sanitary drainage district, the property in these municipalities would still be subject to the burden of general taxation by the sanitary district.

"For the north shore municipalities to undertake to construct separate outlet sewers would be out of the question. The sanitary district has the power, under the law of 1889, authorizing the creation of such district, to construct the outlet, and to pay therefor either by general taxation or by special assessment levied upon the property benefited by such improvement. It appears to have been the policy of the sanitary trustees thus far not to adopt the method of special assessment, but to raise all money needed by general taxation. It is impossible under our present special assessment laws for the villages to unite and construct a common outlet.

"As has been said, the Chicago sanitary district, at present, extends only as far north as the Cook county line. Ravinia, Highland Park, Highwood, Fort Sheridan, Lake Forest and Lake Bluff are to a large extent, within the watershed of the sanitary district. The Chicago sanitary district at present has its engineers in the field gathering data with a view to providing some relief to the Skokie, and to extending this relief as far north as Lake Forest. A scheme to construct a large conduit along the lake shore, in about the location of Sheridan road, has received considerable attention, but is not fully determined upon."

There have been several plans suggested as solutions of the North Shore sewage disposal problem. As stated above, it has been suggested that an intercepting sewer along the lake front be constructed to carry all North Shore sewage down to the Wilmette canal. Such a plan would need to include pumping facilities at a few points along the line. Sewage from the slopes on the Skokie side would also require pumping if carried away by a lake front sewer. It has been suggested that an interceptor along the Skokie Valley also be built in addition to a lake front sewer. Another suggestion that has received consideration is that a tunnel be driven through the ridge beneath all the North Shore towns, this tunnel to conduct the sewage to the canal at Wilmette.

As the situation stands now, several towns are delaying sewer work for the reason that the outlet eventually to be provided is uncertain, and no town wants to build sewers that might possibly be useless in the future.

SUMMARY.*

All of the water supplies along the North Shore require improvement, and the State Water Survey can find a fruitful field for its activities in these towns. To enumerate: Waukegan, North Chicago, Fort Sheridan, Highland Park and Winnetka obtain their water supplies directly from the lake without treatment of any sort. In every case there is ample evidence, analytical and otherwise, that the water is subject to sewage contamination. The United States Naval Training Station, Lake Forest and Kenilworth have filtration plants, but the efficiency of the plants at Lake Forest and Kenilworth is doubtful. It is even questionable whether the filter plant at the United States Naval Training Station is reliable at all times, for it is of the slow sand type, and not adapted to the treating of turbid waters such as are

*By Paul Hansen.

obtained through the intake at this point. At Lake Forest, hypochlorite treatment is being used in conjunction with filtration and this probably introduces a large element of safety. Nevertheless, recent analyses from Lake Forest indicate that the water is not always satisfactory. Evanston has rendered its water practically safe by the installation of a hypochlorite treatment plant, and the construction of a filter plant is practically assured at an early date.

The sewage conditions along the north shore are far from what they should be, but it is not likely that anything can be done in this direction until a rational and consistent policy of co-operation among the various towns is decided upon. There are a number of sewage purification plants along the north shore. Most of these involve some form of tank treatment only. Five include filter beds. Of these latter, two are now under construction. One seems to be operating in a fairly satisfactory manner and the other two are totally neglected. Inasmuch as there is no immediate prospect of a comprehensive treatment of the sewerage question along the north shore, it is at least advisable to operate the existing sewage purification plants at their highest efficiency, and to this end they should all be studied with a view to instituting such supervision of operation and modifications in design as will insure acceptable results.

The State Water Survey, in co-operation with the Rivers and Lakes Commission, ought to arrange for a meeting of representatives from all of the North Shore towns and the Sanitary District of Chicago to hear various discussions by competent persons on ways and means for solving the north shore problem. Such a meeting might lead to the appointment of competent committees to study and report in detail upon various phases of the project of co-operation among the north shore communities, and thus ultimately lead to the adoption of a comprehensive and feasible plan for correcting the annoyances due to improper sewage disposal now existing among the north shore towns.

EXPERIMENTS IN THE REMOVAL OF IRON FROM THE WATER SUPPLY OF THE UNIVERSITY OF ILLINOIS.*

The water supply of the University of Illinois is obtained from wells 150 feet deep in drift. From a hygienic standpoint, the water is pure, and as drawn from the ground is clear and colorless. It contains two parts per million of iron (Fe). On exposure to the air, the water becomes yellow and turbid and loses its attractive appearance. The iron is precipitated in the form of a brownish sediment which, at times, imparts an objectionable taste to the water, causes rust on clothes washed in it and sometimes stains enameled plumbing fixtures. It encourages the growth of certain algæ such as Crenothrix, which thrive in iron-bearing waters. The iron is present in solution as the acid carbonate and is soluble in water containing excess of carbon dioxide and no oxygen.

A history of the development of deferrization processes is given by Robert Spurr Weston† in a paper entitled: "The Purification of Ground Waters containing Iron and Manganese." In this paper is also given descriptions of some iron removal plants in operation in Germany.

The following is a list of several iron removal plants, with references showing where descriptions of them can be obtained:

Plants using aëration and filtration—Charlottenburg ([1]), Prenzlau ([2]), Kiel ([3]), Far Rockaway ([3]), Harburg ([4]), Richmond, Mo. ([5]).

Plants using pressure filters—Hanover ([4]), Muenchen–Gladbach ([4]), Furstenwalde-a-Spree ([4]), Asbury Park, N. J. ([6]).

Plants using chemical treatment followed by rapid filtration—Keyport, N. J. ([7]), Reading, Mass. ([8]), and Superior, Wis. ([7]) ([8]).

([1]) Eng. News, 34, 147.

([2]) Eng. Record, 42,566. ([3]) Eng. News, 43, 238. ([4]) Trans. Am. Soc. C. E., 54, 112. ([5]) Hubbard and Kiersted, "Waterworks Management and Maintenance." p. 87.

([6]) Eng. Record, 40,412.

([7]) Proc. Am. W. W. Assoc. 1909, 280. ([8]) Eng. Record, 54, 601. Eng. News, 45,141.

*Abstract of thesis prepared by W. G. Stromquist, under the direction of Prof A. N. Talbot, and submitted in partial fulfillment of the requirement for the degree of Bachelor of Science in Municipal and Sanitary Engineering.

†Trans. Am. Soc. Civil Engineers, 54, 112.

LABORATORY EXPERIMENTS WITH THE UNIVERSITY WATER SUPPLY.

The experiments were made in the hydraulics laboratory, using the experimental mechanical filter and special apparatus. Analyses were made in the laboratory of the State Water Survey.

Preliminary Tests—Preliminary tests were made by placing equal amounts of water in two bottles, partially filling the bottles. One bottle was vigorously shaken and the other was set away without shaking. Analysis of the water later indicated that aeration accelerates the precipitation of the iron.

Tests Using Aeration, Sedimentation, and Filtration—As a result of the preliminary experiments, it was decided to aërate the water obtained directly from the discharge pipe of one of the deep well pumps. A 4-inch vertical pipe was attached to the discharge pipe and an aërator, consisting of circular disks and rings was designed to slip over this pipe and aërate the water by a series of falls through the device. On passing through this aërator, the dissolved oxygen in the water was increased from 0.9 to 5.1 parts per million, if the full discharge of the pump, 125,000 gallons per day, passed through it. The best results were obtained when the water flowed in broken sheets. From the aërator, the water was caught in a small tank from which it was carried to a settling tank of 3,000 gallons capacity. A float valve in the settling tank regulated the flow, the water being allowed to overflow the small collecting tank. From the settling tank, the water flowed to a mechanical filter which could be stirred with air and washed with water from the University mains. The rate of filtration could be readily controlled. The sand has an effective size of .43 millimeters and a uniformity coefficient of 1.51.

A rate of filtration of 6,250 gallons per day through the filter is equivalent to a rate of 125,000,000 gallons per acre per day.

A series of tests was run, with results as shown in the following table.

RESULTS ARE GIVEN IN PARTS PER MILLION.

Sample.	Dissolved Oxygen. Aver.	Max.	Min.	Iron. Aver.	Max.	Min.
(1) Pump discharge.	0.9	1.7	0.5	1.7	2.1	1.1
(2) Between collecting tank and settling tank.	5.4	7.1	1.9	1.6	2.1	0.9
(3) Settling tank effluent.	2.5	5.9	0.5	1.4	2.0	0.7
(4) Filter effluent.	1.3	3.7	0.5	0.7	1.8	0:3

These results show the average removal in the settling basin to be about 15% and the average total removal by sedimentation and filtration to be about 58%.

An aërator formed of perforated trays was tried. This aërator consisted of three dish pans, with perforated bottoms, placed so that the water would fall from one to the other through a distance of eighteen inches.

In several cases the filter became entirely clogged in a few hours so that water would stand three or four feet deep above the sand in the filter and none pass through. It was noticed that the precipitate was held in a layer at the surface about $\frac{3}{8}$ of an inch thick.

Tests with Gravel Filters—The tests with the mechanical filter indicate that frequent washings would have to be made owing to the rapid clogging of the filter. Preliminary filtration through gravel as a means of relieving the sand filter by removing some of the iron before it enters the filter was tried.

This method is used in the Peuch-Chabal* system of multiple filtration installed at Magdeburg, where the river water used carries a large amount of suspended matter.

The aërated water was passed through a series of four bottles containing gravel ranging in size from $\frac{3}{4}$ inch to $\frac{1}{4}$ inch. Arrangements were made to aërate the water in passing from one bottle to the other. A similar set of three bottles, with gravel varying in size from $\frac{1}{2}$ to $\frac{1}{4}$ inch, was arranged for the upward flow through gravel.

A small sand filter containing sand having an effective size of 0.82 m. m. and a uniformity coefficient of 1.46 was added to determine the effect of subsequent filtration through sand.

In all t,he tests with filtration through gravel the water first passed through the dish-pan aërator. In the experiment with downward filtration a brown coating was obtained on the funnels and tubes in twenty-four hours after beginning the test. This coloration was well marked even in the outlet tubes, where the water flowed quite rapidly. A growth was observed through the whole apparatus—in the wooden trough and aërator, the pipe and on the gravel. This growth consisted of dark brown filaments. When the gravel was cleaned, a sample of the deposit was taken for chemical analysis. An offensive odor, and charring of the residue on evaporation, gave evidence of the presence of a large amount of organic matter. A microscopic examination showed the presence of Crenothrix and other organisms. This growth was so abundant that at times it would clog the perforations of the aërator. The pipe from the receiving tank to the Hydraulic Laboratory also became clogged.

The growth was most abundant in the first bottle, which would become clogged first; the third bottle, containing fine gravel, clogging next. The tubes became heavily coated and were stained a dark brown. The deposit was distributed through the whole depth of the sand of the sand filter. No coloration was noticed on the tube through which the filtered water flowed.

The results obtained in the tests made with upward filtration through gravel followed by sand filtration are given in the following table :

*Engineering, 89, 117, 132, 164.

THE FIGURES DENOTE PARTS PER MILLION OF IRON (Fe).

Hours run sand filter.	Approx. rate in mil. gal. per acre per day.	I Supply Pipe.	II Outlet 1st Bottle.	III Outlet 2nd Bottle.	IV Outlet 3rd Bottle.	V Filter Effluent.
2	......	1.4	1.4	1.2	1.0	0.3
27	......	1.5	1.3	1.2	1.1	0.0
½	220	1.5	1.4	1.2	0.9	0.1
16	200	1.4	1.4	1.2	1.0	0.0
24	160	1.5	1.4	1.2	1 1	0.0
40	74	1.4	1.3	1.1	1.0	0.0
Average,		1.45	1.37	1.18	1.02	0.07
Average percent removed,		......	5.5	18.6	29.7	95.2

DISCUSSION OF RESULTS.

The aërator with perforations gave, in general, a greater increase of dissolved oxygen than the other type of aërator. But it requires pumping the water to a greater height, and the growth of Crenothrix interferes with its efficient operation by clogging the openings. Either type is of simple construction and could easily be adapted to the needs of a pumping plant such as the one for the cities of Champaign and Urbana.

Sedimentation had very little effect; the effluent from the settling-tank as a rule had as high iron content as the water entering the tank, or at best only 0.1 or 0.2 parts per million were removed. The test made when the water was held in the tank for some time showed that only after 36 hours was any appreciable effect noticed, and then only about 50% was removed.

The best results were obtained when the dissolved oxygen was most increased in the passing of the water through the aërator, and when the filter effluent contained about the same amount of dissolved oxygen as the new water. This would indicate that with a greater degree of aëration, better results might have been obtained. This statement is supported by the results of the later tests where preliminary filtration through gravel was used. The iron was practically entirely removed by the final filtration through sand and the filtered water contained from 4.5 to 6.1 parts per million of dissolved oxygen. The large amount of oxygen in the effluent was probably due to the repeated aëration as the water passed from one bottle to the other.

The effect of preliminary filtration through gravel varied, from 20 to 50% of the iron being removed. The results do not show which size of gravel is the most efficient, or whether upward or downward filtration is the better. It appears that a rate of filtration for the sand filters of 125,000,000 gallons per acre per day is as effective as a slower rate. A test made for that purpose showed that some removal is obtained immediately on starting after the gravel had been washed. With the sand filter following the gravel, in two hours, an effluent was obtained with only 0.3 parts per million of iron, and in another case, 0.1 parts per million in ½ hour after starting the filter. The last case mentioned, was after the sand had been washed thoroughly. In the first case, only the upper half of the sand had been removed and washed. It is probable the sediment on the remainder of the sand aided in retaining the iron in the water first passed through after the cleaning of the filter.

CONCLUSION.

From results obtained in the experiments made, the following conclusions can be drawn:

That aëration and filtration can remove the iron from this water.

That the more thorough the aëration, the better are the results obtained.

That sedimentation is of no advantage. The time required for sedimentation to be effective is so great that it would not be practicable to build reservoirs large enough to do any good.

That a rate of filtration of at least 125,000,000 gallons per acre per day can be used as effectively as a slower rate both for sand and gravel filters.

That some preliminary treatment may be employed to relieve the final sand filter and reduce the frequency of washing the filter.

The following questions should be investigated:

How long a time is required after aëration for the reaction to take place so that filtration will remove the iron?

The best size of gravel to be used for roughing filters and the depth of filtering material to be used.

Whether the growth of Crenothrix on the roughing filter is advantageous or not.

REMOVAL OF IRON FROM A DRIFT WELL WATER.*

BY ARTHUR N. TALBOT.

Although iron may not affect the potability of a water supply, its presence may be objectionable to consumers. It may produce a stain on porcelain and clayware fixtures. The sediment which has collected in the mains during periods of light draft of water may be stirred up during the heavier drafts and render the water almost unusable. A growth of Crenothrix is stimulated in the mains and may become troublesome. Work requiring clear water, like dairying and photography, may be interfered with. Turbidity on exposure to the air, sediment in the water more or less variable in amount, and other objections in appearance may make the water unsatisfactory to the consumer.

The Urbana and Champaign Water Company and the University of Illinois obtain their supplies from wells 140 to 150 feet deep, which draw their water from fine sand in the drift. This water contains about two parts of iron per million. As pumped from the wells, the water holds about 40 parts of carbon dioxide per million, and practically no dissolved oxygen. The aëration obtained in discharging into the reservoirs gives dissolved oxygen to an amount of four parts per million before the water is pumped into the mains. Considerable trouble has been found with the growth of Crenothrix in the mains and around faucets and other places where water drips. The collection of sediment in mains at dead ends and in connected lines having little use has been such as to give trouble when a current is formed by the opening of fire hydrants or by other large drafts of water, and the sediment is stirred up and carried through the service pipe. It is difficult to convince the householder that the trouble is caused only by an iron compound which is unobjectionable from a hygienic standpoint and which does not interfere with the potability of the water or its usefulness in the house, especially if the Crenothrix gives an odor to the water and the iron stains linen. The small amount of iron would not be so troublesome if it were distributed through the supply in the way it comes from the wells, but when the total amount of iron and the accompanying growths are largely concentrated at particular times, and in special localities in the city the difficulties are emphasized. Under these circumstances an effort is being made to determine the best

*Proc. Ill. Water Supply Assn. 3, 151.

way of removing the iron from what is otherwise an excellent water, and this paper will give some account of experimental work which has been done.

Experiments have been carried on in the Hydraulic Laboratory of the University of Illinois for several years past, and tests have been made to remove the iron by the application of lime, by sedimentation in a reservoir, by aëration, by filtration, and by a combination of these. The results obtained with the use of lime were unsatisfactory in many ways. It was found that a long period of rest was necessary to secure the deposit of any large proportion of the iron through sedimentation alone. The result of this experimental work pointed to thorough aeration and filtration through gravel and sand without the help of chemicals as the most advantageous method. Preliminary tests on a small scale along these lines were made in the Hydraulic Laboratory in the spring of 1910, and it was then decided to make more extensive experiments at the plant of the Urbana and Champaign Water Co. in

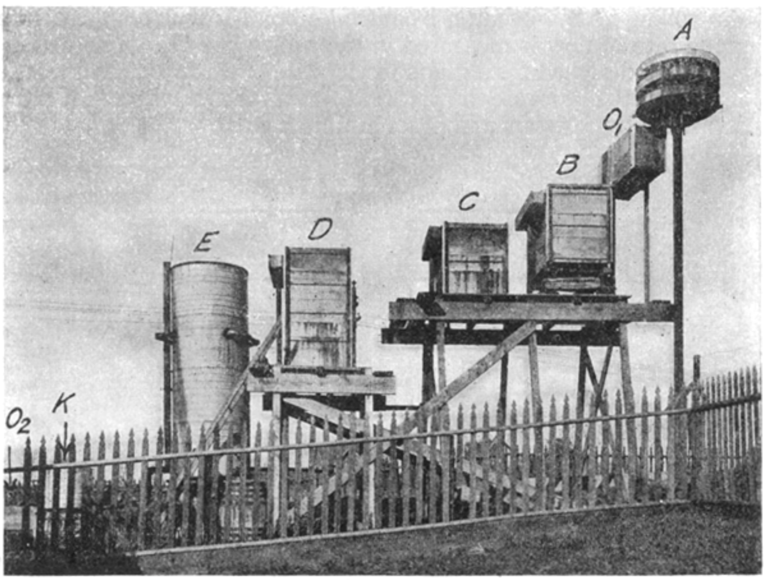


Fig. 1. Experimental Iron Removal Plant at Urbana, Illlnois.

order to give information upon which the design of a filter plant might be based. The experimental plant embraced a combination of aëration, upward filtration through gravel, and rapid filtration through sand. The gravel filters were tried with the thought that their use might relieve the sand filter by increasing the intervals between washings and reducing the loss of head in the filter generally. Upward filtration through gravel is the Peuch-Chabal system of multiple filtration in use at Magdeburg, Germany, where the river water used carries suspended matter. The apparatus was arranged so that one or more of the filters could be cut out from operation.

Fig. 1 is a general view of the experimental plant. The water was pumped direct from a well through the vertical pipe at the right in the view and discharged into the aërator at the top, a pipe at the ground level having a hand valve for regulation being used to allow excess water from the well to be discharged into the service reservoir. After passing the aërator, the water entered the orifice box O, where the rate of flow was measured. The water then passed successively through gravel filters B, C, and D, being aerated each time in its flow over the weir discharge of the filter box. In each case the maximum head available is the difference in level between the weirs of two consecutive filters about $1\frac{1}{2}$ feet, but for filters B and C the available head could be increased by cutting out a filter. From the last gravel filter, the water passed to the top of the sand filter, an overflow providing that the flow through the filter did not exceed the rate wanted in the experiment. A controlling float valve in the controller box K regulates the discharge, and the rate of flow is measured in the orifice box O_2. The valves and piping were designed for a much higher rate of filtration than was found practicable, the purpose being not to have the experimental filtration rate limited by resistance in pipes and fittings.

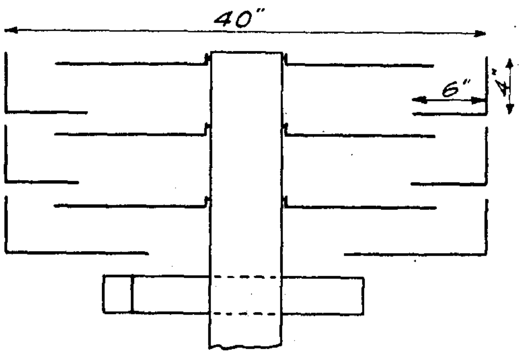


Fig. 2. Section Through Aërator.

A section of the aërator is shown in Fig. 2. It consists of a series of trays arranged so the water will flow off the outer edge of one tray, drop upon the next and flow off its inner edge, etc., and finally be collected and carried away. This form of aërator was devised as not likely to be affected by the deposits or growths or by the formation of ice in winter. Perforated trays giving the sprinkling action were found to clog very soon with the deposit of iron and the organic slimy growths which form in and about the holes even in a moving stream of water. This aërator was found to be very effective and may be recommended for use with such waters as were used in these tests. The length of edge of the aërator per step was $3\frac{1}{2}$ feet and the total length 21 feet. The aërator gave high aëration for a flow of 50 to 80 gallons per minute; larger sizes may readily be made. The absorption of oxygen as the water descends through the aërator may be seen from Fig. 3. There was a further aëration in the passage over the weir outlets of

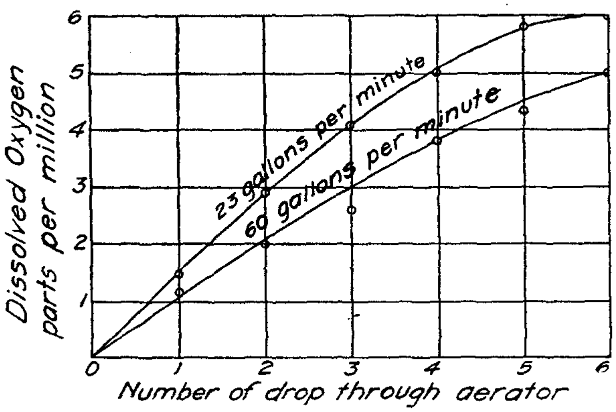


Fig. 3. Absorption of Oxygen in Descent through Aërator.

the gravel filters, but not much may be expected of flow over weirs unless the stream is thin. It may be noted here that it seems probable that the absorption of oxygen by the water is most rapid at the time when the stream breaks over the edge of the step of the aërator and when this stream strikes the next surface. Possibly there is some gain of oxygen through the surface of a sheet of water during the fall.

The gravel filters were 2 ft. 6 in. x 3 ft. 4 in. horizontal section. The gravel was supported on screens 6 inches above the bottom of the filters. Two sizes of gravel were used—the coarser passed a screen having 2 meshes to the inch and was retained on a screen having 3 meshes to the inch, and the finer passed a screen with 3 meshes to the inch and was retained on a screen with 8 meshes to the inch. Filters B and C (see Fig. 1) were used with 1 foot of coarser gravel and filter D with 1 ft. of finer gravel. In later experiments, filter C was used with 2 ft. of coarser gravel and filter D with 3 ft. of coarser gravel.

The sand filter was 40 inches in diameter, making a section of about $8\frac{1}{2}$ sq. ft. At a rate of 125,000,000 gallons per acre per day, a common rate in filtration work, this gave a capacity of about 25,000 gallons per day. The strainer system contained 48 strainers, made by the Roberts Manufacturing Company, connected to a manifold of pipe forming the drainage system. Six aches of gravel were placed over the bottom, and the thickness of filter sand varied from 8 inches to 27 inches in different experiments.

The sand was the part of "torpedo sand" formed by screening out the particles which would pass a 12-mesh screen and would not pass an 8-mesh screen. This sand had an effective size of 0.76 millimeters and a uniformity coefficient of 3.0. It is considerably coarser than ordinary filter sand, the "Red Wing" filter sand used in the experimental filter at the University of Illinois having an effective size of 0.43 millimeters and a uniformity coefficient of 1.51. Vertical glass tubes connected above the filtration sand and below the strainer system permitted the loss of head through the filter to be measured. There was an available head of about 8 feet. The controlling device in the tank below the filter operated satisfactorily.

For washing the sand filter both air and water were used. Air was admitted for a few minutes before the wash water was turned on in order to get the sediment well stirred up and loosened from the sand. The gravel filters were washed by draining them, stirring the gravel with a shovel and washing with a hose, a method which, of course, would not be practicable on a large scale.

In the experimental work several series of tests were made. Variations were made in the rate of filtration, and in the combination of gravel filters and sand filter. Observations were made to determine the head required to operate the filter and its increase through the time between washings, to find the amount of water used for washing, and to learn the change in amount of iron, dissolved oxygen, and carbon dioxide in the effluent at different times between washings. These tests were carried on through August, September and October, 1910. Sufficient information was obtained to warrant saying that the results are very encouraging for the removal of 80 or 90 per cent. of the iron by aëration and simple filtration. The tests are to be continued in order to develop information for use in designing and. constructing a filtration plant. Some of the results which have been obtained will be briefly stated.

The three gravel filters removed about one-half of the iron, about 25% being taken out by the first gravel filter. When filter C was the only gravel filter used, 37% of iron was removed by it, and when filter D was the only gravel filter used, 45% was taken out. These were at rates of 130 to 155 million gallons per acre per day. When filters B and D were run at the rate of 250 million gallons per acre per day, 45% was. removed. It could be seen that these filters removed a considerable part of the iron. This will relieve the sand filter from part of its load, possibly increasing the time between washings of the sand filter and perhaps permitting a higher rate of filtration in the sand filter. Whether the advantages which may be obtained are great enough to pay for the added cost of construction and operation involved in the use of gravel filters remains to be determined.

The sand filter removed most of the remaining iron, the results showing iron in the effluent ranging from zero up to 0.3 part per million under normal operation. When the gravel filters were cut out, the effluent of the sand filter seemed as good as when the effluent from the gravel was used. When used alone the filter seemed to clog more quickly and did not remain in working condition as long, though the varying condition of the filters with reference to washings and organic growths do not permit even this to be stated as established. The sand filter was generally operated at the rate of 125,000,000 gallons per acre per day. Fig 4 gives several curves which show the increase in head

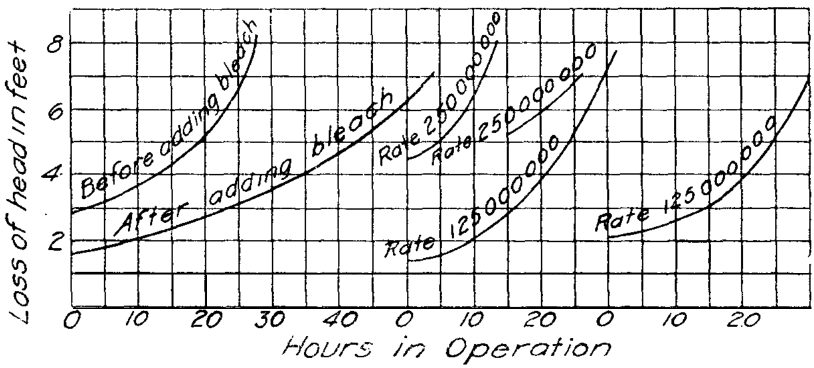


Fig. 4. Curves Showing Loss of Head in Filter Sand.

between washings. An attempt was made to operate the filter at double the usual rate. The diagram shows that the loss of head in the clean filter is very high at the higher filtration rate, and the time between necessary washings became quite short. The effluent was as good at the higher rate. It seems that the filter may not well be worked at rates much exceeding the standard rate of 125,000,000 gallons per day unless a coarser sand is used.

After the sand filter had been in operation for some time, it was found that the effluent contained considerable iron, sometimes as much as 1 part per million. The head required to operate the filter also was abnormally high, even after the filter had been washed. An abnormal amount of oxygen was used during the passage of water through the filter. An examination of the sand in the filter showed a considerable slimy growth on and about the grains of sand. This growth was very much like that found in the preliminary experiments in the Laboratory. It seemed quite evident that the growth of the organisms was absorbing the dissolved oxygen from the water in such a way that the iron did not have an opportunity to become oxidized. An application of 40 grams of bleaching powder was made, and the filter was then washed The result was a marked decrease in the head required on the filter and an improvement in the effluent. In Fig 4 the loss of head in two consecutive runs, one before adding the bleach and one after adding, is shown. It still remains to be determined whether the drainage of the filter and the resulting drying and breaking up of the organism as an accessory feature is desirable in keeping the filter in working order. The prevention of active growth in the filter is evidently essential to the effectiveness of the filter in removing iron from the water.

The immediate work connected with the tests was done by Mr. W. G. Stromquist, University of Illinois, Class of 1910 in Municipal and Sanitary Engineering, under the supervision of Professor E. Bartow, Director of the State Water Survey, and myself. Mr. Stromquist is entitled to much credit for the manner in which the work was carried out. Mr. F. C. Amsbary, Superintendent and Manager of the Champaign and Urbana Water Company has been very helpful in making suggestions and giving assistance. It is expected that the Water Company will later construct an iron-removal filtration plant.

TYPHOID FEVER EPIDEMIC AT ROCK ISLAND.

The new water purification plant for the City of Rock Island, was about ready to be put into operation in the spring of 1911, at the time when the ice was ready to go out.

In order to save the citizens from the bad water, the filter plant was put in operation on February 15, and it was published in the papers that the filter was running. The citizens began to use, as they supposed, good water. But this filter plant put filtered water into a reservoir of 12,000,000 gallons capacity which contained poor water, and in addition all the mains were filled with the poor water. Typhoid fever

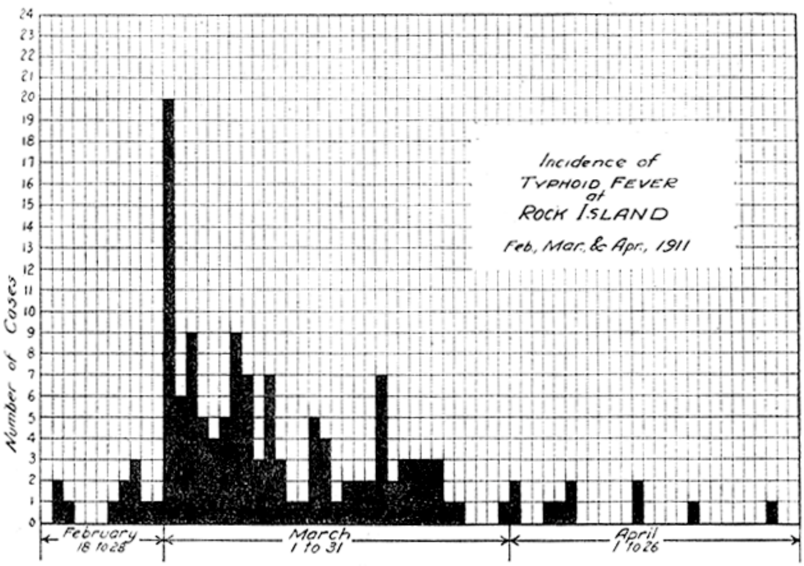
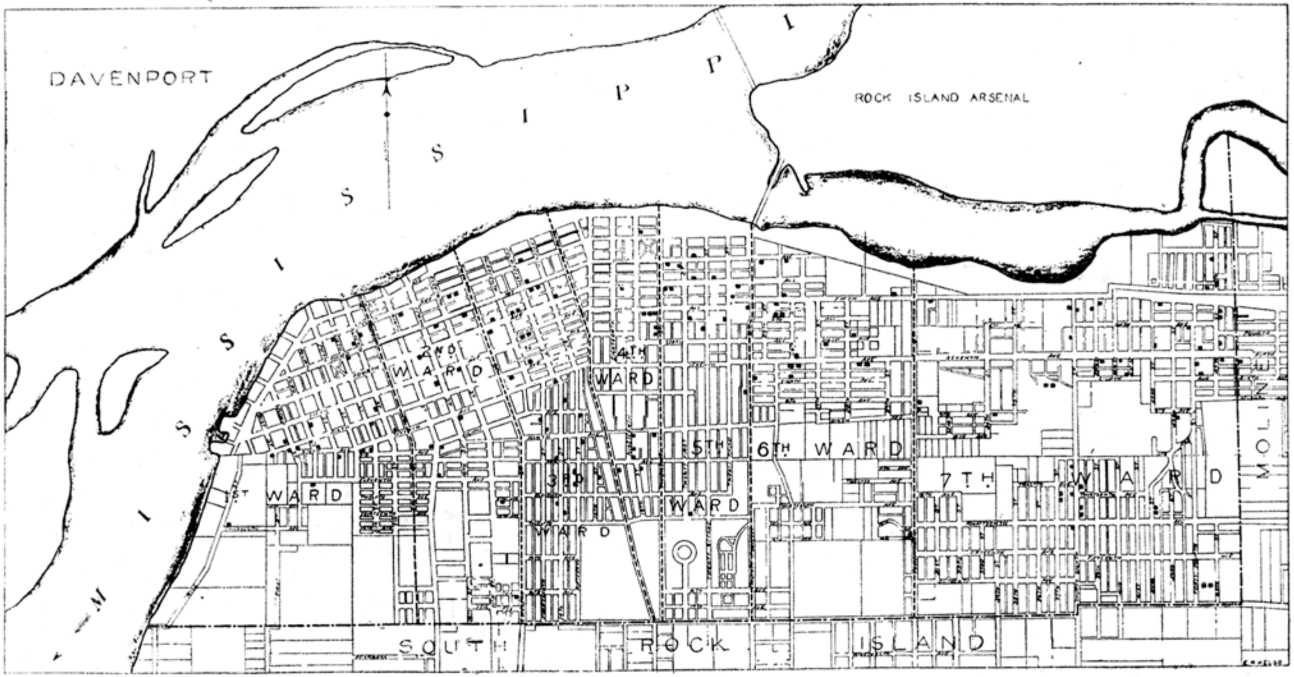


Diagram. Incidence of Typhoid Fever at Rock Island.

was noticeable two weeks after the filter plant was put in operation. (See diagram.) Alarmed, the authorities sent water to the State Water Survey. The water reached us about four weeks after the filter plant was put in operation. From the time a water is received it takes us 72 hours to complete an analysis, so that it was March 13 before the



DISTRIBUTION OF TYPHOID FEVER AT ROCK ISLAND ILL.
FEBURARY 19 TO APRIL 24 1911.

water submitted for analysis was reported. The water was reported as good, but on March 15 the filter plant was shut down for some necessary repairs and the raw water was again pumped into the reservoirs, giving the city bad water again. As a result, during February, March and April, 140 cases of typhoid fever with 14 deaths were reported.

When the filter plant was again put in operation the typhoid fever ceased, and there were very few more cases during the rest of the year. This outbreak of typhoid fever was evidently water-borne. The cases were widely distributed, as shown on the map. In Moline, which adjoins Rock Island, and where filtered water was used throughout the whole year, only two or three cases of typhoid fever were reported during the period in which Rock Island had 140.

Dr. A. N. Mueller, health officer at Rock Island, used every possible effort to prevent contact cases. He sent to each house instructions concerning the care of the patient and the excreta. The newspapers assisted by publishing the same instructions.

With the new filter plant in continuous operation and under competent control, there should never be a recurrence of the typhoid fever epidemic at Rock Island.

SANITARY SURVEY OF THE VERMILION* RIVER.

During the summer of 1911, the State Water Survey was asked concerning the possibility of obtaining a deep well water supply for the city of Streator. The object was to remedy offensive sewage conditions in the river below the sewers. It was suggested to us that by obtaining water for the city supply from deep wells, the river water would be left in the stream to dilute the city sewage during the dry weather.

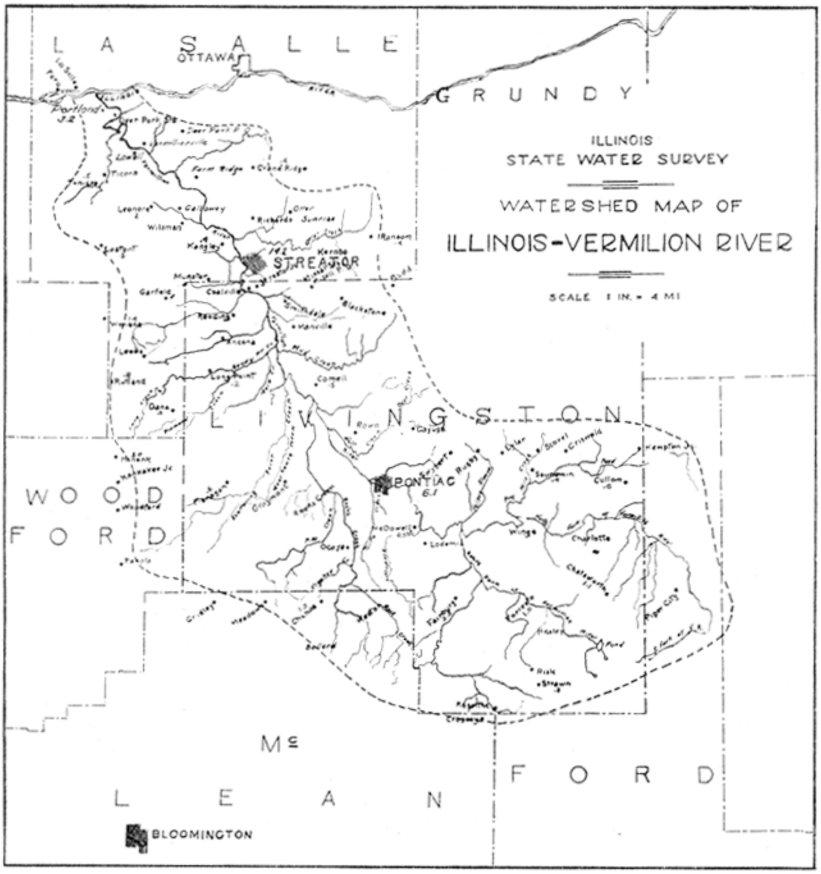
A visit to Streator and the more important points on the watershed was made by W. F. Langelier during October and November, and he has prepared a report on the subject.

GEOGRAPHICAL AND TOPOGRAPHICAL FEATURES OF THE WATERSHED.

The Vermilion River is a tributary of the Illinois River, and is sometimes called Illinois-Vermilion to differentiate it from the Wabash-Vermilion, a stream emptying into the Wabash River. The Illinois-Vermilion rises in southeastern Livingston and northern Ford counties. Its course is northwestward through Livingston county into south central LaSalle county, emptying into the Illinois River just above LaSalle. The area of the watershed is approximately 1,400 square miles, being roughly 75 miles long and 20 miles broad. For the first 50 miles of its course, the bed of the river has a very gradual slope, descending about 2 feet to the mile. This part of the watershed is very flat and the river has scarcely any valley. The slope of the bed for the lower 25 miles of its course is more abrupt, there being a total descent of 150 feet, equivalent to 6 feet per mile. Here the velocity of flow is greater, and a valley has been cut in the more rocky formations. At one time, the watershed contained extensive marshes. The Vermilion swamps in eastern Livingston and northern Ford counties were the last of these marshes to be drained. The work has been completed during the last few years.

The watershed is within the glacial drift area, and the drift has a depth of from 25 to 100 feet. In many places the surface drift consists of fine blue clay which furnishes the material for important manufacturies of clay products. Coal measures underlie different sections of the watershed, and coal is mined in some places, notably Streator. The land is highly cultivated, only a very small portion being wooded.

*The Illinois-Vermilion.



Map of Vermilion River Watershed.

POPULATION.

The following population figures have been estimated from the 1910 U. S. Census Report, and the watershed map, included in this report.

Total population on watershed	68,000
Total urban population (communities 1,000 or more)	28,500
Total rural population	39,500
Average population per square mile	48

There are six cities within the watershed having a population of one thousand or over. They are:

	1910	1900	1890
Streator	14,252	14,079	11,414
Pontiac	6,090	4,266	2,784
Portland	3,194	......	....
Fairbury	2,505	2,187	2,324
Chenoa	1,314	1,512	1,226
Chatsworth	1,112	1,038	827

RAINFALL.

The following tables and diagrams show the rainfall data available. These data are taken from government reports.

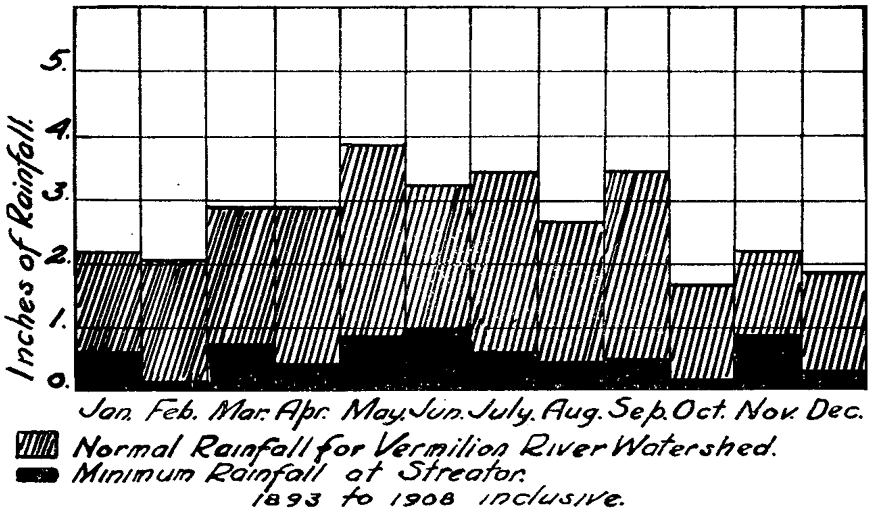


Diagram Showing Rainfall Data at Streator.

VERMILION RIVER WATERSHED RAINFALL DATA.

NORMAL MONTHLY AND ANNUAL.

Station.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
LaSalle	2.16	2.44	2.82	3.10	3.92	3.99	3.27	2.60	3.20	2.58	2.64	2.28	35.26
Streator, 1893–1908	2.10	1.63	3.27	2.57	3.48	3.30	4.20	3.07	3.38	1.39	2.29	1.72	32.40
Pontiac, 1903–1908	2.70	2.24	3.23	3.69	4.52	2.01	4.15	2.23	3.56	1.43	1.77	2.17	33.70
Dwight	2.22	2.14	2.69	2.69	3.59	3.94	2.40	2.60	2.71	1.67	2.54	1.71	32.00
Minonk, 1895–1908	1.87	1.94	2.72	2.57	3.88	3.14	3.25	3.19	3.76	1.46	1.92	1.69	31.39

NORMAL MONTHLY AND ANNUALLY FOR THE WHOLE WATERSHED.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov	Dec.	Annual
2.22	2.08	2.94	2.92	3.88	3.28	3.45	2.74	3.32	1.71	2.23	1.91	32.35

MAXIMUM AND MINIMUM RAINFALL MONTHLY AT STREATOR, 1893-1908.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct.	Nov.	Dec.	Annual.
Maximum.........	5.65	3.73	6.93	6.17	7.16	10.64	8.59	7.13	7.60	3.24	4.54	5.89	53.37
Minimum.......	.59	.10	.65	.41	.80	.96	.62	.41	.39	.05	.78	.34	25.14

MAXIMUM AND MINIMUM RAINFALL MONTHLY AT PONTIAC, 1903-1908.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Maximum	5.62	4.52	5.73	4.94	8.72	3.00	6.35	4.47	5.79	2.76	2.61	3.05	38.30
Miniumm	.80	.15	2.54	2.18	1.77	1.39	1.78	.80	1.53	.17	.06	1.51	27.99

In winter, the water in the stream is usually low. A freshet usually occurs in March or April followed by a moderate flow until June. Some years there is a rise during June, due to heavy rains. During the remainder of the summer, there is generally a gradual decrease due to evaporation and run-off, and it is usually durmg this period that the river is at its lowest stages. The stream rises again in the fall to above normal, but seldom overflows its banks. Consequently, moderate and low stages cover about 10 months during the year. Freshets last only a few days.

The run-off for a stream depends upon the rainfall, slope of the surface, the drainage efficiency, geological conditions, vegetation, temperature, etc. The Vermilion River watershed, with its perfect tile lines, etc., satisfies the conditions that tend to make the water level fluctuate readily with slight variations in rainfall.

POLLUTION OF STREAMS AND TRIBUTARIES.

Pontiac and Streator are the only municipalities discharging all their sewage into the river. Fairbury has no sanitary sewers, but storm sewers discharge directly into the stream. Chenoa has a few small tile drains which contribute small quantities of sewage into minor tributaries of the main stream.

The water supply is not seriously affected by the pollution, inasmuch as both Streator and Pontiac filter and disinfect their water supplies, keeping suitable laboratory control of the operation.

Local nuisances may arise near the the sewer outlets. The population of Pontiac sewering into the river is estimated to be approximately 3,000. During the greater part of the year, the river below Pontiac to the junction with Rooks Creek is highly polluted.

At Streator, a large part of the city sewage is discharged into a small creek flowing through the city into the river. Other points of discharge, as well as this one, are well within the city limits. The population of Streator is 14,000, and it is estimated that about 80% of the dwellings are connected with the sewerage system. It would seem, therefore, that this amount of sewage, with the small amount of dilution it receives during the dry weather in summer, would cause serious nuisances. The prevailing public opinion is that at the present time, the condition is not in any way serious.

RUN-OFF DATA.

The flow in the Vermilion River is very irregular. Actual flow measurements have never been made, but an indication of the minimum flow may be obtained from the water pumpage records at Pontiac and Streator. During a large part of the year, Pontiac pumps nearly the entire stream flow, equivalent to about 1,000,000 gallons per 24 hours. At that point, the watershed area is approximately 470 square miles, or about one-third of the entire watershed.

While the condition at Streator is not as serious, there also the water company usually finds it difficult for a few weeks during the summer to obtain sufficient water from the river. The greater part of the flow at Streator is water collected by the tributaries Rooks and Mud Creeks. The latter stream, which rises in the north central part of Livingston county, carries in suspension during periods of wet weather, considerable amounts of very fine blue clay which it is very difficult to remove. The average daily pumpage at Streator for the year 1910 was slightly over 2,000,000 gallons, which is practically all the dry weather flow.

During periods of dry weather, the city sewage of Streator is diluted only by the wash water from the filter plant and by the drainage from the coal mines. The mine drainage emptying into the river below the water works dam renders the water too hard to use satisfactorily for industrial purposes.

GROUND WATER.

The ground water obtainable within the watershed includes shallow dug wells, tubular wells in drift and tubular wells in rock. The shallow dug or open wells are common, and most of the rural population depend entirely upon them for their water supply. The wells vary from 10 to 30 feet in depth. The formation usually penetrated is clay, and consequently the amount of water available varies greatly with the seasons. From a sanitary standpoint, these supplies are not as satisfactory as those obtained from a greater depth.

Fairbury, Chatsworth and Chenoa each obtain their public supplies from deep tubular wells. These wells enter the St. Peter sandstone, which is at an approximate depth of 2,000 feet. Chemical analyses of the Fairbury and Chatsworth supplies are given in the following table.

ANALYSES OF WATER FROM DEEP WELLS AT FAIRBURY AND CHATSWORTH.

No. 22659. City suppy of Fairbury. Well 2,000' deep into St. Peter Sandstone. No. 18438. City supply of Chatsworth. Well 1,315' deep.

SANITARY CHEMICAL.

	22659	18438		22657	18438
Turbidity	3.	10.	Nitrogen as		
Color	Blue	30.	Free Ammonia	.672	3.600
Odor	IV	0	Albuminoid Ammonia	.056	.320
Residue	1200.	696.	Nitrites	.000	.068
Chlorine	470.	9 .	Nitrates	.400	.092
Oxygen Consumed	.4	8.9	Alkalinity	320.	477.

MINERAL ANALYSIS.

Ions	Parts per Mil.		Hypothetical Combinations.		Pts. per Mil.		Grs. per Gal.	
	22659	18438			22659	18438	22659	18438
Potassium. . . K	13.3	....	Potassium Nitrate	KNO_3	.3	....	.02	....
Sodium, ... Na	432.1	31.0	Potassium chloride	KC1.	25.2	....	1.47	....
Ammonium. . . NH_4	1.2	4.6	Sodium nitrate	$NaNO_3$	....	.5	....	.03
Magnesium. . . . Mg	14.6	35.1	Sodium chloride	NaCl	788.8	14.9	46.01	.87
Calcium. . . . . Ca	42 .0	76.3	Sodium sulphate	Na_2SO_4	102.4	219.0	5.97	12.77
Iron. . . . . Fe	Trace	.3	Sodium carbonate	Na_2CO_3	202.8	124.3	11.83	7.25
Aluminum. . . . Al	Trace	3.5	Ammonium carbonate	$(NH_4)_2CO_3$	6.4	12.2	.37	.71
Silica. . . . . . . SiO_2	12 .0	11.7	Magnesium carbonate	$MgCO_3$	50.6	121.5	2.95	7.09
Nitrate. . . . . . NO_3	.2	.4	Calcium carbonate	$CaCO_3$	104.8	190.0	6.12	11.08
Chloride. Cl	490.0	9.0	Ferrous carbonate	$FeCO_3$	Trace	.6	....	.03
Sulphate. . . . . SO_4	69.2	48.0	Alumina	Al_2O_3	....	3.5	....	.20
			Silica	SiO_2	12.0	11.7	.70	.68
			Bases	....	.5	3.6	.03	.21
			Total		1293.8	701.8	75.45	40.92

Bacteriological examinations of these supplies have shown them to be of unquestionable purity. At Fairbury, however, hydrogen sulphide is present in sufficient quantity in the water as it comes from the well to impart a disagreeable taste and odor to the water.

At Streator, the St. Peter sandstone is reached at a depth of 500 feet. Several wells have been drilled, but the presence of hydrogen sulphide, together with considerable mineral matter, makes the water, unless treated, undesirable for either drinking or industrial purposes.

Four samples of deep well water were collected in different parts of Streator to determine their value for drinking and industrial purposes. Chemical analyses of these, together with other samples sent in to the laboratory, are given in the table. For comparison, an analysis of the present city supply from the Vermilion River is given.

No. 22601 was collected from the Western Glass Company's well. A strong odor and taste of hydrogen sulphide was noted and a field determination of this gas was made November 7, 1911. The water is used in boilers, and does not give serious trouble.

No. 22602 was collected from the Vulcan Detinning Company's well. The well is 563' deep. The well driller's record is as follows: Drift 50', Coal measures 170', Trenton Limestone 140', St. Peter Sandstone 203', Casing extends 200'. 8" diameter. Capacity of well, 60 gallons per minute. The odor is the same as No. 22601. This company aërates the water and also dilutes it with condensed steam before using in their boilers.

No. 22603 was collected from well owned by the Streator Paving Brick Company. A strong odor and taste of hydrogen sulphide was noted, and a field determination of the same was made November 7th.

No. 22605 was collected from a 2400' flowing thermal well owned by the city. The record of the well is as follows: Drift 30', Coal measure 211', Trenton Limestone 203', St. Peter Sandstone 225', Calciferous Limestone 90', Calciferous Sandstone 133', White Limestone 211', White Sandstone 37', Gray Limestone 50', Red Sandstone 15', Gray Limestone 32', White Sandstone 168', Blue Shale 100', Dark Limestone 73', Variable Sandstone 187', Soft, White Limestone 60', Variable Clay Shales 158', Red Sandstone 80', Blue Clay Shale 50', Bluish Limestone 50', Potsdam Sandstone 333'. Total 2,496'.

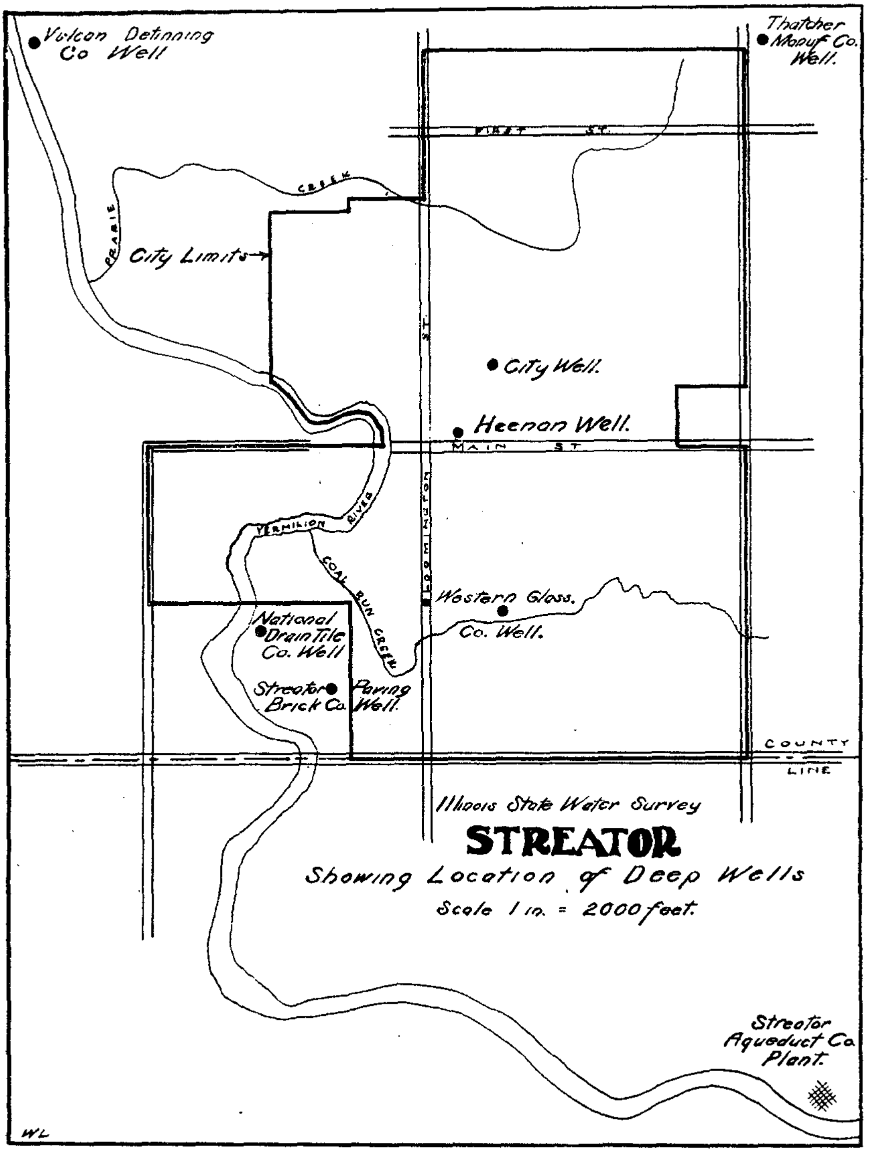
No. 17898, same as No. 26203, but was collected August 10, 1908.

No. 21402 sample was sent to Survey by Thatcher Manufacturing Company, July 26, 1910. This well is 440' drilled.

No. 21765 was a sample sent in by the National Drain Tile Company. Collected from their 700' well, January 19, 1911. A recent communication from this company informs us that the use of this water in boilers was abandoned after a trial of four months' duration.

The analysis of the city supply represents the average quality of the river water, being computed from analyses of daily samples collected during a period of one year. This analysis, expressing the results simply in ionic form, is given in U. S. Geological Survey Water Supply Paper 239.

The river water contains much less mineral matter than the well water, and, properly purified, is a better source for a city supply.



Location of Deep Wells at Streator.

Analyses of Water from Deep Wells

Laboratory No	17898	22603	22601	22602
Date Collected	Aug. 10, 1908	Oct. 31, 1911	Oct. 31, 1911	Oct. 31, 1911
Owner	Paving Brick Mfg.	Pvg. Brk. Mfg. Co.	Western Glass Co.	Vulcan Detin. Co.
Depth	660' Bored	660' Bored	640' Bored	563'
Strata	St. Peter Sandstone	St Peter Sandstone	St Peter Sandstone	St Peter Sandstone
Capacity	......	......	60 gal. per min.	60 gal. per min.
Turbidity	40	10	2	5
Color	60	Greenish Blue	Blue	35
Odor	Hydrogen Sulphide	Hydrgn. Sulphide	Hydrgn. Sulphide	Hydrgn. Sulphide
H_2S	......	15.0	14.5	Not determined
	Milligrams per 1000 c.c.	Milligrams per 1000 c. c.	Milligrams per 1000 c. c.	Milligrams per 1000 c. c.
Total residue	1423.	1074.	739.	1138.
Chlorine	360.	410.	210.	410.
Oxygen consumed	25.4	18.3	16.0	15.4
Nitrogen as Free ammonia	1.280	1.160	.688	.880
Nitrogen as Alb. ammonia	.064	.224	.232	.232
Nitrogen as Nitrites	.000	.000	.000	.005
Nitrogen as Nitrates	.280	.12	1.32	.20
Alkalinity	740.	362.	306.	342.
Potassium	......	49.7	26.3	49.0
Sodium Na	452.3	300.7	192.8	312.2
Ammonium (NH_4)	1.7	1.5	.9	1.1
Magnesium Mg	30.2	23.9	11.9	6.8
Calcium Ca	48.5	56.0	48.9	61.8
Ferrous Fe } Aluminium Al. }	4.6	Trace	.2	.3
Aluminium Al.		Trace	......	Trace
Silica SiO_2	18.0	10.0	9.6	......
Nitrate NO_3	1.2	.5	5.8	.9
Chloride Cl	300.	410.	210.	410.
Sulphate SO_4	104.	62.1	61.6	21.7
Carbonate CO_3	......	362.	306.	342.

Hypothetical

	Parts per Million	Grains per U.S.Gal.	Parts per Million	Grains per U.S.Gal.	Parts per Million	Grains per U.S.Gal.	Parts per Million	Grains per U.S.Gal.
Potassium Nitrate	......	......	.8	.05	9.5	.55	.15	.09
Potassium Chloride	......	......	94.1	5.49	43.1	2.51	92.2	5.38
Sodium Nitrate	1.6	.09	......	......	......	......	......	......
Sodium Chloride	594.1	34.65	602.8	35.16	312.7	18.24	604.3	35.25
Sodium Sulphate	153.9	8.98	91.9	5.36	91.2	5.32	32.1	1.88
Sodium Carbonate	386.4	22.58	76.9	4.48	92.1	5.38	146.4	8.54
Ammonium Carbonate	4.5	.26	......	......	4.7	.27	2.9	.17
Magnesium Sulphate	......	......	......	......	......	......	......	......
Magnesium Carbonate	104.6	6.10	82.8	4.83	41.2	2.40	23.6	1.37
Calcium Chloride	......	......	......	......	......	......	......	......
Calcium Sulphate	......	......	......	......	......	......	......	......
Calcium Carbonate	121.1	7.06	139.8	8.16	122.1	7.13	154.3	9.00
Oxide of Iron and Aluminium	4.6	.27	Trace	Trace	44.0	2.57	......	......
Ferrous Sulphate	......	......	......	......	......	......	......	......
Ferrous Carbonate	......	......	......	......	......	......	.6	.03
Alumina	......	......	......	......	......	......	Trace	Trace
Aluminium Sulphate	......	......	......	......	......	......	......	......
Silica	18.0	1.05	10.0	.58	9.6	.56	12.8	.75
Sulphuric Acid	......	......	......	......	......	......	......	......
Bases	7.0	.41	......	......	......	......	......	......
Total	1395.8	81.46	1099.1	64.11	770.6	44.95	1070.7	62.46

and Vermilion River at Streator

22605	21765	21402		
Oct. 31, 1911	Jan. 18, 1911	July 26, 1910	Vermilion River	
Cty. Well, Monroe St.	Ntl. Dr. Tile Co.	Thatcher Mfg. Co.	Average Quality.	
2400'	700'	440' Drilled	...	
Potsdam Sandstone	...	...	...	
...	...	...	...	
60	...	20	...	
18	...	10	...	
0	...	Earthy	...	
Not determined	...	...	...	
Milligrams per 1000 c. c.	Milligrams per 1000 c. c.	Milligrams per 1000 c. c.	Milligrams per 1000 c. c.	
12858.	4778.	952.	...	
7100.	70.	330.	...	
19.3	...	10.0	...	
3.920	...	...	...	
.232	...	...	...	
.007	...	.000	...	
.040	.24	.080	...	
236.	Acidity 880.	380.	...	
346.8	...	12.4	...	
3732.0	...	290.8	18.	
5.0	...	...	...	
143.3	259.	23.0	29.	
693.3	373.	52.0	55.	
6.3	560.	...	.2	
5.0	23.	...	...	
12.0	...	6.6	14.0	
.2	Trace	...	12.	
7100.	70.	330.	6.9	
403.2	2768.	24.2	68.	
...	...	380.	201.	

Combinations.

Parts per Million	Grains per U.S.Gal.	Parts per Million	Grains per U.S.Gal.	Parts per Million	Grains per U.S.Gal.	Parts per Million	Grains per U.S.Gal.	
.3	.02	...	...	...	...	...	...	KNO_3
470.1	27.43	...	...	23.6	1.38	...	...	KCl
...	...	...	...	...	...	16.5	.97	$NaNO_3$
9471.7	552.48	115.	6.70	526.1	30.69	11.4	.67	$NaCl$
...	...	99.	5.77	35.8	2.09	27.8	1.62	Na_2SO_4
14.8	.86	...	...	191.1	11.20	...	...	Na_2CO_3
...	...	...	...	...	...	...	...	$(NH_4)_2CO_3$
...	...	1280.	74.66	...	...	61.7	3.60	$MgSO_4$
560.4	32.68	...	...	79.7	4.64	57.1	3.33	$MgCO_3$
1268.1	73.97	...	...	...	...	...	...	$CaCl_2$
571.5	33.34	1266.	73.73	...	...	...	...	$CaSO_4$
167.0	9.74	...	...	129.8	7.57	137.3	8.03	$CaCO_3$
...	...	...	...	3.0	.02	...	...	$Fe_2O_3+Al_2O_3$
...	...	1066.	62.16	...	...	...	...	$FeSO_4$
13.0	.76	$Fe(OH)_3$ 321	18.75	...	...	.4	.02	$FeCO_3$
10.0	.58	...	...	...	...	...	...	Al_2O_3
...	...	161.	9.39	...	...	...	...	$Al_2(SO_4)_3$
12.0	.70	...	...	6.6	.38	14.0	.82	SiO_2
...	...	76.	4.43	...	...	...	...	H_2SO_4
...	...	...	...	2.8	.16	...	...	
12558.9	732.56	4384.	255.59	998.5	58.13	326.2	19.06	

CONCLUSIONS.

From the foregoing, we conclude that the city of Streator would not be justified in changing from surface to ground water as a source of public supply. The presence of hydrogen sulphide and the high content of alkali salts in the ground water is decidedly objectionable. Moreover, the prevention of nuisance due to sewerage conditions would be relieved only slightly by such a change.

Although the Survey has not as yet sufficient data to warrant making further recommendations, it is intended to study this problem further and determine how the cities of Streator and Pontiac may best overcome any objectionable conditions which may exist below sewer outfalls during periods of low water.

PRELIMINARY REPORT UPON THE POLLUTION OF THE FOX RIVER IN REFERENCE TO GENEVA, ILLINOIS.*

In accordance with your instructions, we would report herewith on the pollution of the Fox River as affecting the city of Geneva, with especial reference to the desirability of the city of Geneva adopting some method of purifying its sewage before discharging it into the Fox River.

For this purpose we have, at your suggestion, co-operated with the Director of the Illinois State Water Survey, and collected such data as are readily available as to the population centers now sewering into the Fox River above Geneva, the minimum run-off of the river, and the character and amount of sewage now discharged into the river. Mr. Hilscher, representing the Illinois State Water Survey, accompanied by an assistant from the office of Alvord and Burdick, made a personal inspection of the localities, and obtained such general information as was necessary to enable us to from as accurate an opinion of the matter as possible. It was also the intention of the State Water Survey to make a series of sanitary analyses of the river to determine its present condition. This part of the work has not been carried out at this time, and is of less interest in any event during high water stages.

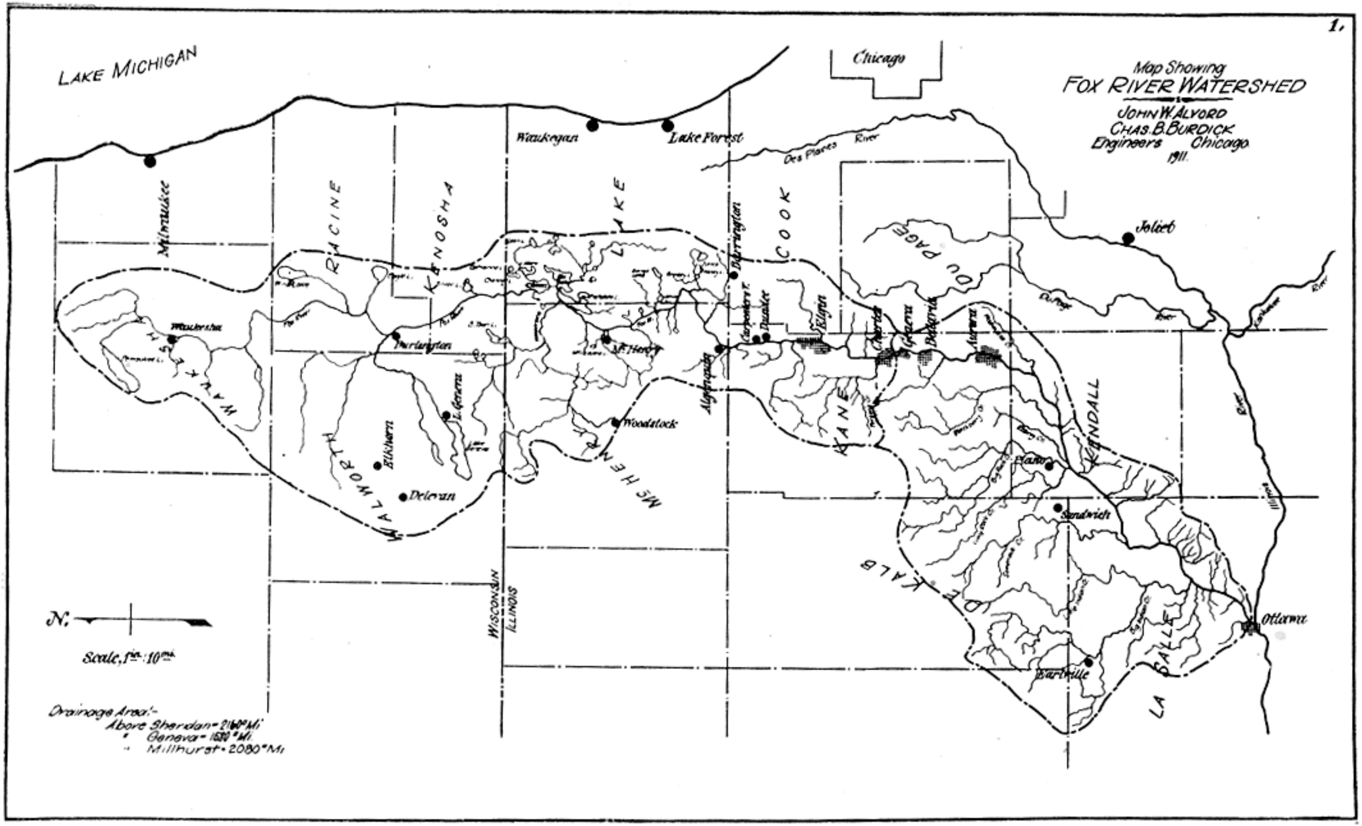
CHARACTERISTICS OF THE FOX RIVER WATERSHED.

The Fox River above Geneva has a drainage area of 1,580 square miles, lying in the northern part of Illinois and the southern part of Wisconsin, as is shown on the map attached to this report. The river furnishes an outlet for a number of small lakes located in northern Illinois and southern Wisconsin, among the larger of which are Pewaukee, Geneva and Fox Lakes.

The subsoil of the watershed is generally glacial drift, and is covered with a fertile top soil. The whole district might be said to be a densely populated farming district, well drained and fairly rolling.

Like most small streams of the alluvial plains of the Upper Mississippi Valley, the run-off of this river is extremely variable, the larger

*A Report to the Association of Citizens Formed to Prevent the Pollution of the Fox River, Geneva, Illinois, by John W. Alvord, Consulting Engineer of Chicago in co-operation with Edward Bartow, Director of the Illinois State Water Survey.



Map Showing Fox River Watershed.

amounts passing away in floods and the flow falling to very little during the dry months.

The only actual gaugings of the flow of the Fox River, extending over an extended period, that have been made are the series made by the United States Geological Survey at Sheridan, Illinois. These observations extended over a period of approximately eight months, and are shown in the following table. On the assumption that the run-off is proportional to the drainage area, we have also included the run-off at Geneva in this table.

DISCHARGE OF FOX RIVER IN CUBIC FOOT PER SECTION.
FROM GAGINGS BY U. S. G. S. AT SHERIDAN,* WITH ESTIMATED FLOW AT GENEVA. ILLINOIS.*

1905.	Maximum Day.		Minimum Day.		Mean	
	Sheridan.	Geneva.	Sheridan.	Geneva.	Sheridan.	Geneva.
Sept. 20-30	1050	795	710	524	831	612
October	1510	1115	420	310	863	637
November	1210	892	515	380	912	673
1906.						
Feb. 22-28	9780	7220	4080	3020	5770	4260
March	8020	5920	1270	837	3570	2630
April	4430	3270	1210	892	2540	1800
May	1760	1300	670	594	1020	755
June	755	556	260	192	422	312
July	670	495	240	177	336	248

*Drainage area above Sheridan, 2170 square miles; above Geneva, 1580 square miles.

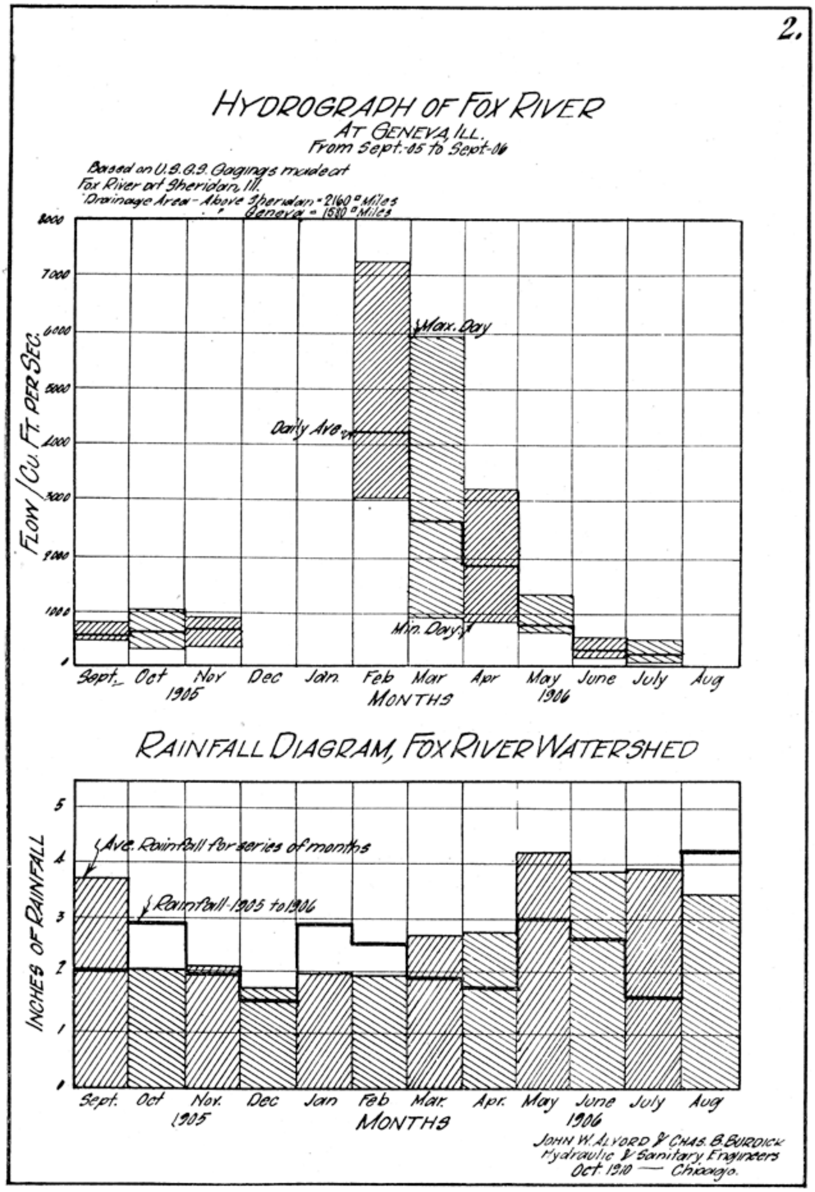
In the consideration of the flow of a river, it is desirable, in order to form an idea as to the variation of discharge, to have a series of gagings extending over a long period of years. In the case of the Fox River, however, such gagings have not been made.

LOW WATER OF 1911.

In order to obtain additional information on the low water flow of the river, several water power plants along the river were inspected, and such data as was available and necessary to estimate the low water flow during the dry summer of 1911 was collected.

At North Aurora, which is located a few miles below Geneva, three water wheels are now in use. Two of these wheels—a 56" old style wheel and a 48" Leffel—are owned by the Hartsburg & Hawley Co., and the third—a 44" special Leffel—is owned by D. C. Sperry foundry. There are also some wheels in an old flour mill at this point, but these have not been operated for a number of years.

The flow of the river at North Aurora is generally sufficient to operate these three wheels nine hours a day, by making use of the night storage; little or no water overflowing the dam for long periods. These



Hydrograph and Rainfall Diagram Fox River Watershed.

three wheels operating at the low water head of $6\frac{1}{2}$ feet, require a flow to 214 cubic feet per second, which rate for nine hours is equivalent to a rate of 80 cubic feet per second for twenty-four hours. Inasmuch as at times the flow is hardly sufficient to furnish the required water to operate these wheels, it is evident that the minimum flow sometimes falls below 80 cubic feet per second, as measured by this data.

We also obtained information that some time ago, in water power litigation at Batavia, the minimum flow was placed by expert testimony at 4,800 miner's inches. This is equivalent to a flow of approximately 120 cubic feet per second.

At Geneva, the minimum flow for the purpose of division of power is assumed to be 3,532 miner's inches, which is divided between the Chas. Pope Glucose Co., the Bennett Milling Co., and the W. H. Howell Co. This flow is equal to about 80 cubic feet per second.

In the summer of 1899, Mr. Alvord made a series of gagings of the Fox River at Dayton, Ill., for the Illinois and Michigan Canal Commissioners, and found the minimum flow of that year to be 150 cubic feet per second. This would mean a proportionately low water flow of 93 cubic feet per second at Geneva, the drainage area of the Fox River above Dayton being 2,565 square miles.

Considering the matter in the light of all the above information, we believe it is a conservative statement to say that the minimum flow of the Fox River at Geneva is often less than 100 cubic feet per second for periods of several months at a time, and for short periods of a week or more, falls below 80 cubic feet per second in dry years.

POLLUTING CONDITIONS.

The following is a summary of the conditions pertaining to the pollution of the Fox River by the cities located on the Fox River above Geneva:

Geneva, Ill. Population, 2,500.
- Obtains water supply from artesian wells.
- No general sewerage system at present.
- Contemplating the construction of sewers in near future.
- Sewage Purification—undecided.

St. Charles, Ill. Population, 4,000.
- Obtains water supply from artesian wells.
- No general sewerage system at present.
- Contemplating the construction of sewerage system in 1912.
- Sewage Purification, undecided—awaiting outcome of controversy at Geneva.

Elgin, Ill. Population, 26,000.
- Obtains water supply partly from artesian wells, and at times, from Fox River, filtered and mixed with well water.
- Sewerage System:
  - Northern part of city sewered by 17 miles of sanitary sewers. Outlet, 36".
  - South-east part of city sewered by 8 miles of combined sewers. Outlet, 75"x50".

West side has 8 miles of combined sewers in South-west part of town. Outlet 52"x56".
Six miles of additional short sewers with four outlets, on west side.
All sewers discharge into river without any purification.
City contemplating the construction of about 14 additional miles of sewers in 1912.

From inquiries made, it seems that considerable nuisance is caused by the discharge of the sewage into the river at low water periods, both in regard to odor and appearance, especially in the case of the outlet on the east side of the river near the A. E. & C. R. R. Depot.

East Dundee, Ill. Population, 1,400.
Obtains water supply from large well near river.
No sewerage system.

West Dundee, Ill. Population, 1,400.
Obtains water supply from springs east of town.
Sanitary sewerage system constructed 1910.
Outlet, 15"; about 6 miles of sewer.
No provision for purifying sewage.

Carpentersville, Ill. Population, 1,100.
No sewerage system.

It is improbable that any of the cities on the watershed above Carpentersville would have serious influence on the situation at Geneva, on account of the remoteness and also because of their small size. Such cities, with their respective populations, located on the watershed above Carpentersville, having a population of over 1,000, are as follows:

McHenry	1,000
Woodstock	4,300
Burlington	2,500
Lake Geneva	2,600
Delavan	2,200
Elkhorn	1,700
Waukesha	7,400

Of these, only Burlington, Woodstock and Waukesha have sewerage systems, and of these, the two latter are already provided with sewage purification plants.

RESUME OF CONDITIONS OF THE FOX RIVER.

From the foregoing information, it is apparent that very little has as yet been done toward sewage purification in the cities on the Fox River immediately above Geneva. The condition at Elgin already warrants some provision being made for treating its sewage before discharging it into the river. The discharging of the crude sewage of West Dundee into the river at a distance of only four miles above the river intake of part of the public water supply of the City of Elgin is a menace to the present water supply of Elgin.

As none of the municipalities south of Elgin takes its water supply from the river, the question to be considered is, how long the cities can expect to discharge their untreated sewage into the river without creating a nuisance. From reports, this condition is already evident at Elgin.

Some 20 years or more ago, the City of Elgin had an engineer of standing design a sewer system for that city. He reported that sewage purification would ultimately become necessary, and recommended, under these circumstances, that the separate system of sewers be adopted. A considerable portion of the city was sewered under these plans, but, unfortunately, later administrations lost sight of the importance of continuing this plan, and, as the outlying districts have introduced the combined system, this will undoubtedly much embarrass the city when disposal works are introduced.

In order to show the relation between the growing population and the dilution available at minimum flow of the river, we have on the diagram plotted the combined population of Geneva, St. Charles, Elgin, East Dundee, West Dundee, and Carpentersville, and also estimated the future combined population of these cities. Approximately 75% of the population is now provided with sewerage, and over 16% additional will be added next year, so that with all the population now in sight, and likely to early complete their sewerage systems, *there is now less than 3 cubic feet per second* (*2.8 cubic feet per second exactly*) *of water available at low water periods during the summer season for each 1,000 persons tributary to this part of the river.* Upon the basis of the estimated future population in 1916, the combined population will then be 40,000, at which time *less than $2\frac{1}{2}$ cubic feet per second, minimum flow, will be available for dilution of the sewage of each 1,000 persons during the summer season of dry years.*

PERMISSIBLE RATES OF DILUTION.

The amount of sewage which can be safely emptied into a flowing stream has been a matter of careful study for many years. A large number of studies have resulted in the belief that where trade waste is not unduly prominent, and domestic sewage only is being considered, that a proportion of from 3 to 7 cubic feet per second of fresh flowing water is necessary to oxidize, in an unobjectionable manner, the sewage of each 1,000 persons tributary to the outlet.

The variations within the limits above mentioned are caused by the lack of proper diffusion into the flowing stream, the condition of the stream as to dissolved oxygen, and, to some degree, the size of the stream; larger streams being generally capable of caring for smaller ratios of fresh to polluted water, without offense, than smaller streams can be depended upon to accomplish. Some years ago the Sanitary District of Chicago determined upon a dilution of $3\frac{1}{3}$ cubic feet per second per 1,000 population, but it has since been felt by sanitarians that on account of the large amount of trade wastes created in that city, that this allowance is somewhat small, and that a minimum of 4 cubic feet per second per 1,000 population is more nearly the amount necessary in order to avoid creating a nuisance. It is interesting, in this connection, to note that the Commission appointed by the Sanitary-

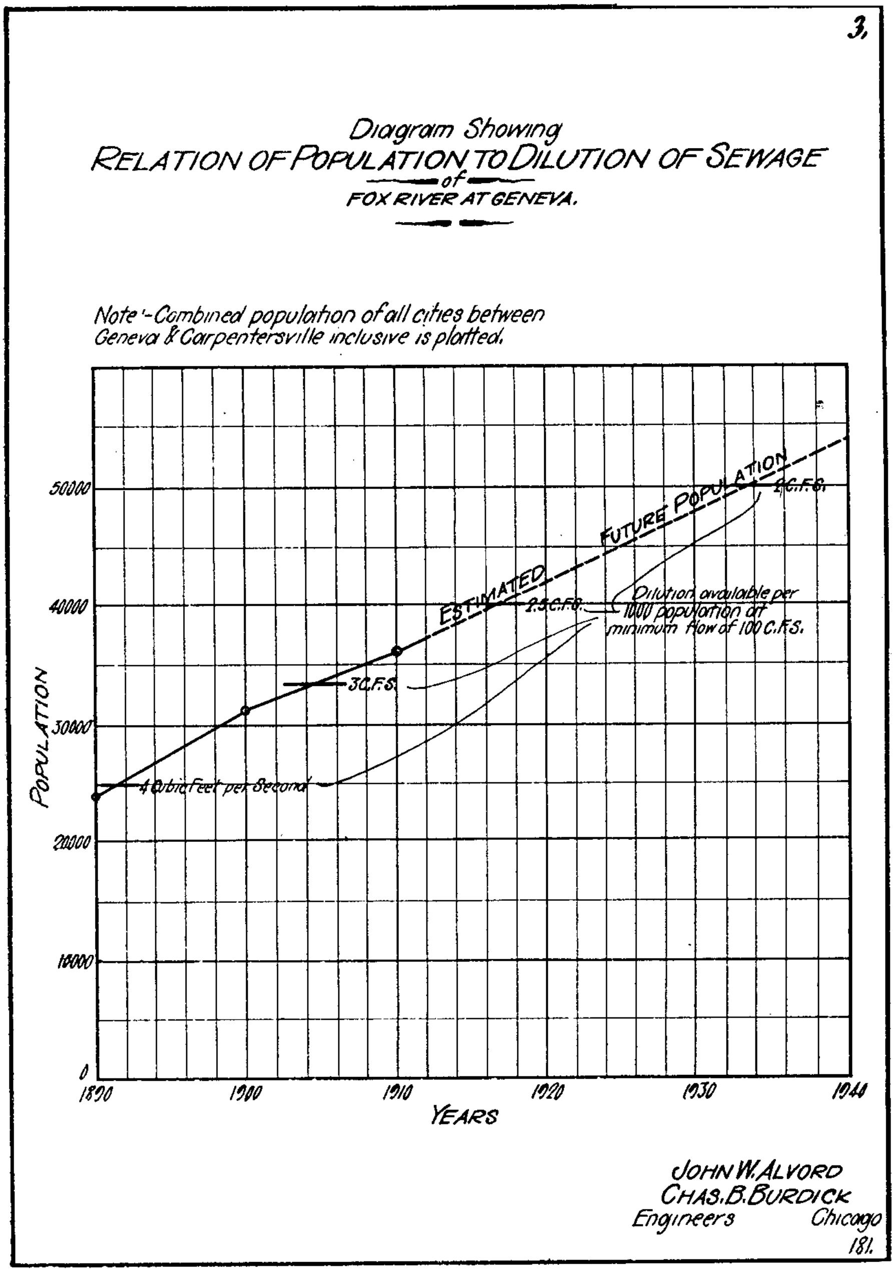


Diagram Showing Relation of Population to Dilution of Sewage of Fox River at Geneva.

District recently recommended that the City of Chicago adopt the policy of purifying all additional sewage to be discharged into the drainage canal on this account.

We believe that it will be wise to limit the discharge of sewage into the Fox River to a ratio of four cubic feet of flowing water for each 1,000 tributary persons, as being a conservative ratio, if satisfactory conditions are to be maintained.

This ratio will be materially exceeded if the various sewer systems and additions to systems now contemplated are constructed in the next year or two.

SEWAGE DISPOSAL BY DILUTION.

It is well understood that if the proper ratios of raw or untreated sewage be emptied into a sufficient quantity of fresh flowing water, that efficient and satisfactory purification will take place within a reasonable distance without offensive conditions being created. This comes about by reason of the fact that what is commonly known as "fresh water" contains a considerable proportion of dissolved oxygen, which unites with the organic matter of the sewage in such a way as to reduce its more complex compounds into simpler and harmless forms. Where such dissolved oxygen is in sufficient quantities, the polluting matter is readily oxidized and reduced to an innocuous and unobjectionable form so far as odors or offense is concerned. This process, however, is not one which would promptly or readily destroy the vast quantities of bacterial life that always accompany—in fact, initiate—the dissolution of organic matter. These bacteria, accompanied as they may be by pathogenic organisms of the disease-producing variety, may persist in such waters for many days, rendering them dangerous to use for domestic purposes or human consumption.

If, however, the dissolved oxygen of a stream be exhausted by the repeated introduction of gross pollution, or if the quantity of organic matter emptied into a stream at any one point is greater than the quantities with which it can properly deal, the exhaustion of the oxygen is followed by intensely disagreeable odors, blackened and objectionable appearance of the river, and general nuisance to the immediate vicinity. This condition may, in a short time, effect a complete transformation of a beautiful and attractive river which is a delight to all its surrounding residents, and an attractive feature to all seeking suburban or country homes, to a foul and unsightly carrier of sewage, which would not be meekly endured by the most tolerant population without emphatic protest. It is important, therefore, even if the waters of such streams are not to be used for water supply, that careful study should be made of each individual problem, so that the danger-line of overloading impurities may not be unthinkingly or unknowingly passed, reached, or even approximated.

It would be highly desirable if we could have made some tests to determine the capacity, in its present condition, of the waters of the

Fox River above Geneva, to oxidize sewage, but such tests should preferably be made in midsummer, when the stream flow is at its lowest rate, in order to determine the oxidizing conditions in the crucial period of the year. It is probable that the State Water Survey will be enabled during the next summer to make some examinations of this kind which will throw greater light upon the subject than we are able to do in this preliminary report. It is quite certain, however, that the low ratios of flow which we point out already exist, and await only the completion of sewerage systems for the full population in the near future to overload the river beyond the danger mark and to create obnoxious conditions.

SEWAGE DISPOSAL BY ARTIFICIAL METHODS.

The development of the art of purifying sewage received great impetus of late years, and we are now in possession of means, well known and fairly well understood, by which without great expense the oxidation of sewage-laden waters can be effected, or partially effected, as the case may demand, by comparatively simple methods and with satistactory economy.

Where a considerable stream of water like the Fox River is available, and especially where it is not used for domestic water supply, or is not likely to be so used in the immediate future, it is evidently the part of wisdom and economy to limit such artificial methods to the supplementing of the natural means of purification effected by the flowing river itself. Such methods should, however, be introduced before the natural resources for purification are exhausted, so that the danger point of nuisance may not be unexpectedly developed to the detriment of adjacent property and the proper enjoyment of such naturally beautiful streams.

The methods of artificial purification are, in brief, the preliminary separation, as far as possible, of the solids of the sewage from the liquids, at or near the outfall of sewer systems, and the detention of such solids in a way that they may be harmlessly and inoffensively modified and partially, or even largely consumed. The liquid remainder, thus clarified, may then either be purified by oxidation in the natural flowing waters in the stream, provided the proper proportions are not exceeded, or where there is danger that the proportions of oxygen will be exceeded, it may be further oxidized by artificial means, either by filtration through carefully prepared beds of sand, or by sprinkling and percolation through beds of broken stone, or by repeated fillings or emptyings of the system of the so-called "contact filters."

SEPARATE SYSTEM OF SEWERS.

It is highly desirable, where works of artificial purification are likely to become a necessity, either at the present time or in the near future, that wherever possible there should be a separation of the sewage proper from the storm water of the district. In cases situated like those of the cities lying along the Fox River, where this storm water can be readily and easily led to the main stream through the ordinary and natural side channels, tributary ravines, and other minor water courses, this is especially desirable, as it would leave only the household wastes and sewage proper of the community to be collected by the artificial sewer systems, and thence led to the purification site.

The economies effected in this way are two-fold:

1st. The sewer systems themselves are less expensive than those which are of necessity designed to convey both the water of storms and household wastes; and

2nd. The works for artificial purification are much less extensive and difficult to construct than they would be otherwise.

It is highly desirable, therefore, that all sewer systems of cities along such a stream as the Fox River should keep prominently in view the possibilities of overloading that river with organic waste and rendering it a foul and unsightly stream by providing, at least in the design of their sanitary works, for the proper collection of the sewage wastes only, with opportunity at their outlets for the necessary head and fall, and available space for the introduction of such artificial sewage purification works as may be now necessary, or early required, from time to time to prevent undue pollution from reaching the river.

CONCLUSION.

We feel, in the light of this information, that the City of Geneva, would be making a grave mistake if, in the contemplated sewerage system which it is proposing to build in the near future provision is not made for separating the storm water from the sewage, and at least partially purifying its sewage by settling or semi-septic tanks, to detain and reduce the coarser solids of the sewage before discharging the liquid into the river. By semi-septic tanks, we mean tanks well baffled to detain the solids, but with brief detention of the liquids, which may be aerobic, and the effluent from which may even contain dissolved oxygen in small amount.

We feel, further, that the outlets of all sewer systems could be so elevated that at some future time additional means of purification, such as percolating filters or sand beds, may be added without undue expense, by reason of want of precautions in the original construction.

The construction of settling or semi-septic tanks in connection with the separate system, if adopted by all the cities along the Fox River, will insure the river from becoming foul for a much longer time to come than if raw sewage should be emptied into the river. The cost of a suitable settling or semi-septic tank for a district the size of the proposed west side district at Geneva, would probably not exceed $3,000.00 or $4,000.00, which cost for the City of Geneva may be much more than saved by the adoption of the separate system of sewers, in place of the partially combined sewers now proposed.

In conclusion, therefore, we would suggest that the City of Geneva in constructing this important sanitary improvement, would do well to anticipate conditions which will be certain to arise in the very near future by adopting the policy of avoiding any greater pollution of the Fox River than is absolutely necessary. A separate sewerage system, with settling or semi-septic tanks carefully designed to meet these future conditions at this time, will save the city considerable money in the future, as well as a large amount of discontent and possible litigation.

SUPPLEMENTARY REPORT ON SOURCES OF POLLUTION ON WATERSHED OF FOX RIVER.*

As an outcome of threatened litigation involving the city of Geneva, Illinois, because that city proposed to further pollute the Fox River by discharging its raw sewage into that stream an association of citizens employed the firm of Alvord & Burdick, consulting engineers of Chicago, to investigate the situation, and render advice relative to the best method of procedure. By request, this firm invited the co-operation of the State Water Survey in making this investigation, and in compliance therewith, Mr. Ralph Hilscher worked in conjunction with Mr. George L. Thon, principal assistant engineer in the office of Alvord & Burdick. This work was begun about the middle of October, 1911. Mr. Thon was in the field about four days obtaining information with special reference to the Geneva situation. Mr. Hilscher, however, stayed in the field for about two weeks visiting all the principal cities on the watershed, obtaining information relative to the pollution of the Fox River as a whole, and, in addition, investigating the sources of water supply.

The foregoing report on the Fox River, signed by Messrs. Bartow and Alvord, was based upon the information gathered by Mr. Thon and Mr. Hilscher. As a supplement thereto, this report has been prepared to set forth additional facts obtained by Mr. Hilscher and contained in a report prepared in the engineering department of the State Water Survey.

GENERAL DESCRIPTION OF RIVER AND WATERSHED.

The Fox River is a stream about 175 miles long which has its source in Waukesha County, Wisconsin, northwest of Milwaukee, and which discharges into the Illinois River at Ottawa, about 75 miles southwest of Chicago. This river has a watershed area of approximately 2,530 square miles, of which about two-thirds lies in the State of Illinois. The country drained is rather rolling in character and increases slightly in roughness from north to south. The glacial drift is heavy in this region and is largely of a coarse, gravelly character. The screening, washing and shipping of gravel and sand is an important industry along the Illinois portion of the Fox River. At the southern end of the watershed much rock formation is to be seen, and steep

*Report by Ralph Hilscher.

bluffs line either side of the river. The St. Peters sandstone outcrops in this section, and is mined for glass making purposes. At Ottawa, a great deal of coal and fire-clay are mined, these materials occurring only a few feet below the surface.

Such flow measurements as have been recorded for the Fox River are included in the foregoing report, together with certain other data on which assumptions as to minimum flow were based. The gagings by the government engineers extended over a period of about one year (September, 1905, to July, 1906), and during that time the minimum flow observed was 240 sec. feet at Sheridan, where the watershed area is about 2,170 square miles. Assuming similar rates of run-off over the entire watershed, it was calculated that the corresponding minimum flow at Geneva, where the watershed area is about 1,580 square miles, was 177 sec. feet. In consideration of other evidence, it was estimated that the minimum flow to be expected at Geneva during dryest years is 100 sec. feet.

It would appear that the period chosen by the government for making the measurements at Sheridan was not a year of extreme minimum flow. Further evidence in this matter is furnished by rainfall data. Records of rainfall at four different points on the watershed of the Fox River have been averaged and these average figures are regarded as the rainfall on the watershed as a whole. These points and the number of years for which we have records are as follows:

Antioch, Lake County, six years.

Aurora, Kane County, thirty-four years.

Ottawa, LaSalle County, thirty-one years.

Sycamore, DeKalb County, twenty-seven years.

The accompanying Table No. 1, contains the total yearly precipitations at each of the stations together with yearly averages for the water shed. In Table No. 2, the rainfall for the period over which the government's measurements of river flow were made in considered. In this the average monthly rainfalls for all four stations are averaged, and the resulting figures regarded as the normal monthly rainfall for the watershed. By reference to Table No. 1, it will be seen that 1901 was the dryest year for which we have complete rainfall data. For comparison, the monthly records of that year are also included in Table No. 2. Of the forty different years for which the yearly watershed rainfall is given in Table No. 1, it will be observed that six, or 15%, had less rainfall than had the year during which the government gagings were made—that is, less than 29.21 inches.

TABLE I.

YEARLY RAINFALL IN INCHES ON FOX RIVER WATERSHED.

Year.	Antioch.	Aurora.	Ottawa.	Sycamore.	Average for Watershed.
1856	....	....	30.09	....	30.09
1857	....	....	34.70	....	34.70
1858	....	47.50	46.87	....	47.18
1859	....	30.45	27.89	....	29.17
1860	....	....	27.07	....	27.07
1861	....	....	38.89	....	38.89
1862	....	....	55.71	....	55.71
1864	....	....	29.53	....	29.53
1866	....	30.24	32.76	....	31.50
1867	....	21.26	....	....	21.26
1870	....	34.36	....	....	34.36
1880	....	44.49	....	....	44.49
1881	....	45.75	....	....	45.75
1882	....	43.03	....	43.54	43.28
1883	....	46.51	....	50.91	48.71
1884	....	36.76	....	44.86	40.81
1885	....	39.50	....	48.50	44.00
1886	....	32.46	....	34.40	33.43
1887	....	36.16	23.60	29.78	29.85
1888	....	34.10	30.27	28.13	30.83
1889	....	32.30	34.27	25.26	30.61
1890	....	32.61	31.16	29.35	31.04
1891	....	31.09	35.37	28.36	31.61
1892	....	44.45	45.52	45.64	45.20
1893	....	29.10	27.72	33.05	29.96
1894	....	29.25	29.72	29.75	29.57
1895	....	31.86	27.56	23.19	27.54
1896	....	35.66	38.50	27.36	33.84
1897	....	33.63	34.12	30.28	32.68
1898	....	42.14	29.01	39.36	36.84
1899	....	28.32	30.83	21.91	27.02
1900	....	30.18	37.87	37.38	35.14
1901	....	22.21	26.77	21.35	23.44
1902	38.77	50.89	55.45	48.08	48.30
1903	36.15	41.54	36.30	42.50	39.12
1904	26.75	35.05	32.22	35.28	32.33
1905	....	35.50	31.05	38.21	34.92
1906	32.75	35.68	29.18	36.50	33.53
1907	33.22	40.15	29.08	37.00	34.86
1908	33.52	34.43	28.54	34.69	32.80
Yearly Normal for Watershed					35.27

Of those six years, four were but little dryer than the year in question, having had rainfalls of 29.17, 27.07, 27.54 and 27.02 inches respectively, but the two years 1867 and 1901 were abnormally dry, and repetitions of rainfall conditions in those years cannot be expected to occur except at very rare intervals.

TABLE II.
MONTHLY RAINFALL IN INCHES ON THE FOX RIVER WATERSHED.

Month.	Normal for Watershed.	Records from Sept. 1905 to Aug. 1906, inc.	Records for 1901. Dryest Year Record.
September	3.75	2.09	2.57
October	2.23	2.93	0.96
November	2.26	2.03	1.34
December	1.83	1.57	1.60
January	2.06	2.84	1.47
February	2.01	2.55	1.67
March	2.75	1.95	3.83
April	2.82	1.74	0.48
May	4.27	2.99	1.50
June	3.88	2.61	2.12
July	3.96	1.65	4.92
August	3.45	4.26	0.98
Yearly	35.27	29.21	23.44

In consideration of the evidence furnished by rainfall data it seems probable that the flow in the Fox River is not liable to fall materially below the minimum figure obtained by the government in 1905–1906, namely, 240 sec. feet at Sheridan, or 177 sec. feet at Geneva. On very rare occasions, like the years 1867 and 1901, the flow may be expected to fall much below these figures, possibly as low as 135 sec. feet at Sheridan or 100 sec. feet at Geneva, as assumed in the foregoing report.

SOURCES OF POLLUTION ON FOX RIVER.

The various cities and villages on the watershed where pollution of the river to any material extent prevails, or is anticipated for the near future, are here listed with a few remarks as to the extent of the pollution.

WAUKESHA, WISCONSIN: Population 8,740. Municipal sewage and brewery waste discharged into river. In 1900, suit was brought against the city of Waukesha by the owner of property on the river below, asking for an injunction against the further discharge of sewage into the river, and for damages on account of pollution already suffered. The injunction was granted by the county court, and sustained by the Supreme Court, the outcome of which was the installation of a septic tank through which the city's sewage is now passed previous to its entering the river.

BURLINGTON, WISCONSIN: Population 3,212. Complete system of sanitary sewers since 1907, designed with the object in view of future treatment of sewage. A plant of the Borden Condensed Milk Company is located here and discharges its waste into the Fox River. Factories of this kind, produce a large amount of highly putrescible waste.

LAKE GENEVA, WISCONSIN: Population 3,079. This city has no sewers or industries producing objectionable wastes. The proposition of installing a sewerage system has, however, recently received considerable agitation.

WOODSTOCK, ILLINOIS: Population 4,331. This city is completely served by a system of sanitary sewers which conveys the city's sewage to a treatment plant on Nappersink Creek north of town. The treatment given the sewage consists of passing it through settling tanks, and then onto intermittent sand filters. The effluent, which is discharged into the creek, is said to be of excellent appearance at all times. There is one important industry at Woodstock, namely, the Oliver Typewriter Company. This concern produces no wastes of consequence except sanitary sewage, which is collected by the city sewers.

McHENRY: Population 1,031. The first town on the river below Pistokee Lake. McHenry has a municipal water supply but no sewers, and there seems to be no immediate prospect of sewers being installed.

BARRINGTON: Population 1,444. This city has only a few sewers, and these discharge into a small tributary of the Fox River. There is a milk and cream bottling works which produces some putrescible wastes in the process of washing bottles, cans, etc.

WEST DUNDEE: Population 1,380. Work on a sewerage system here was begun early in 1911, and practically the whole population is, or soon will be, connected. There is one outlet to the Fox River in the lower part of town.

EAST DUNDEE: Population 1,405. There is a public water supply here, but no sewers, and sewerage has not as yet been seriously considered. There are no factory wastes produced at either East or West Dundee.

ELGIN: Population 25,976. Elgin is served by a combined system of sewers which discharge to the Fox River at various points. There are a number of short private sewers in the business district that were put in before the general sewerage system was designed and regarding which information is very incomplete. The main outlets of the municipal sewerage system are three in number, all located below a power dam which is built in the river above the center of the city. Considerable extension of the sewers is contemplated, but the number of outlets will remain the same. It is said that at times during the summer, there is so little water flowing in the river below the dam in Elgin that it is possible to walk across in many places without wetting the feet. At such times the sewers discharge onto dry ground and deltas of settled material are said to form below the outlets causing extremely objectionable conditions. The most conspicuous of these outlets is located about 200 feet below a highway bridge in the business section. The other two are at a distance of half a mile or so farther south.

There are several industries at Elgin discharging wastes into the river, but none of these is said to be complained of for badly polluting the river at present. There are two breweries whose wastes consist of rather large amounts of water which has been used for washing bottles, vats and various utensils. Brewery waste is ordinarily of a highly putrescible character, and these discharges at Elgin undoubtedly have deleterious effects upon the quality of the river water.

The gas works, located in the south part of the city, at one time, caused a great deal of complaint as it was then the practice of this concern to empty all waste products resulting from the water-gas process onto the river bank. A few years ago this practice was discontinued, and at present all material that was formerly wasted is either recovered as a by-product or used over and over in the process. The objection to gas waste is due to the large amount of tar and oils contained in it. The banks and bed of a stream receiving it soon become heavily coated with a sticky deposit of tar and the oil floats for long distances, making the stream very unsightly. The bed of the Fox River below Elgin is still coated with considerable tar, deposited several years ago, and this is claimed by the Gas Company to be the source of a small amount of oil that now floats on the river.

ST. CHARLES: Population 4,046. This city is not sewered, but plans for a sewerage system have been prepared and the assessment will be spread this year. There are three small factories in St. Charles, but none of these produces any wastes that enter the river.

GENEVA: Population 2,451. Geneva, at present, has no sewerage system, but a system has been designed and will be built as soon as certain legal difficulties can be overcome. Some private parties owning estates on the river below Geneva raised strenuous objections to the discharging of the city's raw sewage into the stream and suits were threatened if such means of disposal should be employed. The city has agreed to treat its sewage in a septic tank, and this, it is said by the Geneva authorities, is a satisfactory solution of the disposal problem from the objector's standpoint.

On the east side of the river, just below Geneva, is a state school for girls with a population of about 600. The sewage from this institution is discharged into the river in its raw state.

BATAVIA: Population 4,436. A little over half of Batavia's population is on the west side of the river, and that side is wholly sewered. There are no sewers on the east side. The sewage is discharged into the river through three outlets, all of which are below a power dam across the river at this point.

AURORA: Population 29,807. Aurora is served throughout by a system of about 65 miles of combined sewers having five points of discharge to the Fox River. A dam is built across the river just above a highway bridge in the center of town. Two outlets to about six miles of sewers, one on each side, discharge into the river half a mile above this dam. The Knickerbocker Ice Company harvests ice just above this dam and when these two points of sewage discharge were decided upon, the ice company made objections. This action resulted in extending the outlets well out into the river channel. Ice is still harvested here, but is said to be used only for cold storage purposes. The remaining 59 miles of sewers have their outlets below the dam. On the east side there are two, one about 400 feet below the bridge and one about half a mile below. On the west side, there is one outlet between the bridge and the dam. All outlets have been extended well into the stream so that they always discharge into running water. There are said to have been few, if any, complaints of nuisance caused by the sewage in the river.

There is more manufacturing at Aurora than at any other point on the Fox River. But few of the factories, however, produce wastes that are in any way objectionable. The gas works, as at Elgin, has been the cause of complaint by persons living on the river below. It is said that at Yorkville, fifteen miles down stream, there was a time when, by scraping the bed of the river, with a pole, large amounts of oil could be made to rise to the surface, the oil having come from the Aurora Gas Works. Conditions are not as bad now as formerly, because the company in recent years has separated a large part of the tar by passing its waste through a baffled settling tank before allowing it to enter the river. Nevertheless, there is a considerable quantity of oil still to be seen on the water.

On the east bank of the river about three miles above Aurora, there is located the plant of the Aurora Packing Company. This is a small concern that slaughters hogs and cattle, and its waste consists of the water used in washing meat, instruments, floors, etc. An effort is made here to save as much material as possible that can be made up into fertilizer and, with this end in view, a settling tank is being constructed to remove suspended material from the wash water. The effluent from this tank, amounting to about 25,000 gallons per day, will be discharged into the river.

All material from the packing plant that is not either disposed of to meat dealers or to tanneries is sold to the Rogers Rendering Company, which has a plant only a short distance below the packing plant. This company, in addition to the above, procures from other sources about four tons per day of scrap meat, bones, etc., and all dead animals from the city of Aurora. All this material is boiled in large closed vats and then allowed to stand for a time. To the surface there rises most of the fat originally contained in the raw material, and this is skimmed off and sold for soap making purposes, To the bottom there settles the greater part of the heavier undissolved material and this is removed and made into fertilizer. The balance of the contents of these vats is discharged into the Fox River through a submerged outlet placed well out in the current. This waste is extremely objectionable in character, being very highly charged with nitrogenous organic matter. A large amount of suspended matter can be seen in the river below this outlet, making the water very unsightly.

On the west side of the river, about a mile and a half above the center of Aurora, is the plant of a company which manufactures glycerine by some secret process. It is claimed that no wastes other than condenser water are emptied in the river.

Half a mile below the glycerine works is a plant at which white cotton cloth is bleached and starched. About ninety pounds per day of bleaching powder is used at this plant, but this is practically spent in strength before it is wasted to the river. About 700 pounds of starch per week is used. Although the greater part of the starch is retained by the cloth, there is enough waste to make it pay, in large plants of this character, to recover the starch as glucose. The Aurora plant, however, is thought to be too small to economically recover this by-product, so the starch waste passes to the river. There is probably no serious objection to any of the wastes at this place.

A factory for the manufacture of heavy pasteboard is now being built in Aurora. It is understood that waste paper and rags will be the raw material used; also that a large amount of water will be consumed. One brewery in Aurora discharges its waste to the Fox River.

Between Aurora and Ottawa, there are no municipal sewers or factories emptying wastes into the Fox River or its tributaries. At Plano, population 1,627, sewerage is being strongly agitated; and definite action will be taken next spring if not sooner. Its outlet would probably be Big Rock Creek, about two miles above the point where it empties into the Fox. Sandwich is a city of 2,557 population, situated near Somenauk Creek, about ten miles above the point where it empties into the Fox. The matter of sewers is to be considered by the City Council in the near future and it is expected that, a system will soon be installed. At Earlville, there is some talk of sewering the town. It is a city of 1,059 population, and would probably have its outlet in the Big Indian River about twenty miles above its confluence with the Fox.

OTTAWA: Population 9,535. Ottawa is situated at the junction of the Illinois and Fox Rivers. The Illinois and Michigan Canal crosses the north end of the city, and all that portion of Ottawa south of this canal is sewered on the combined plan. That portion north of the canal is very sparsely populated. The sewers west of the Fox River and north of the Illinois, have five outlets. Three of these are outlets from small districts and [discharge, at distances of about 500 feet apart, into ,the Fox River.

The outlet discharging the greatest amount of sewage of all is located on the Illinois River about one mile below the point at which the Fox enters. East of the Fox and north of the Illinois is a residence district having an outlet for its sewage in the Fox River about a quarter of a mile from the mouth. South of the Illinois River all sewers have their outlet at a point about half a mile below the mouth of the FOX. There are in all about twenty-five miles of sewers.

The principal industries at Ottawa are coal mining and brick and tile manufacturing. There are no factories producing objectionable wastes.

SUMMARY OF PRESENT SITUATION AS REGARDS POLLUTION OF RIVER.

From the foregoing account of the various sources of pollution, it will be seen that the sewage from a population of approximately 75,000 people is now discharged into the Fox River or its tributaries.

That sewage which enters the Fox River in Wisconsin probably has a negligible effect upon the Illinois portion of the stream. The distances over which that sewage is carried before reaching Illinois, the preliminary treatment received by the larger part of it at Waukesha, and the long storage given by Grass, Fox and Pistokee Lakes is probably sufficient to remove all traces of Wisconsin pollution from the water entering the Illinois portion of the river. The effects of the Woodstock sewage on the main stream are, for similar reasons, probably of no consequence. In fact, as far down as Dundee the stream may be considered as being in a very well preserved state.

Between and including Dundee and Aurora, in a distance of about thirty miles, there is now discharged into the river sewage from a total of about 59,000 people in addition to an appreciable amount of putrescible trade wastes. It is this portion of the river that is now approaching the danger line as regards pollution. Below Aurora there is no appreciable pollution entering the stream until Ottawa is reached, and at that point there seems to be no immediate danger of overloading the river with polluting material. Two or three small towns on tributaries which are contemplating sewerage will hardly have any effect upon the main stream, although there may be some question as to the ability of these tributaries to provide sufficient dilution.

On the assumption that the minimum allowable dilution of sewage in the Fox River, as assumed in the foregoing report, is 4 cubic feet, per second of river water to each one thousand persons tributary, and assuming the minimum flow in the river at Geneva to be 100 cubic feet per second, the following Table No. 3 has been compiled to give an approximate idea of the river's capacity for receiving sewage and of its present state of preservation.

TABLE III.

1 Points on River below.	2 Area of watershed square miles.	3 Minimum flow in river sec. ft.	4 Population to be permitted sewage disposal by dilution.	5 Population below Pistokee Lake having sewerage above point. 1910.
Aurora (30,000 pop.)..........	1,640	104	26,000	59,000
Elgin (26,000 pop.)...............	1,430	90	22,500	27,000

The figures in columns 4 and 5 are not strictly comparable, for it is to be remembered that in column 4 each number represents the population which may safely discharge sewage into the stream at a particular point, assuming the river water reaches that point in an unpolluted condition. On the other hand, the figures in column 5 represent the total populations now discharging sewage above the respective points, and represent people scattered along the river over a distance of about thirty miles. In the case of both Elgin and Aurora it will be seen, however, that the local population exceeds the theoretical maximum to be allowed sewage disposal as computed in column 4.

All the foregoing conclusions relative to the pollution of the Fox River have been based on certain minimum run-off figures for this watershed. One condition that has not been considered, and which may or may not affect the influence of sewage on the quality of the river water, is the presence of a number of dams. Between Lake Pistokee and Ottawa there are fourteen dams across the river that have an average height of perhaps 6 feet. Most of these are power dams, and their effect on the river is to make the flow quite irregular during the low stages, the mills operating a few hours then stopping to allow the ponds to fill up. As already noted, at Elgin this practice has tended to aggravate conditions below the dam and sewer outlets. The net effect, however, on the river as a whole may be for the better, on account of additional aeration afforded by the spillways and millraces at these dams.

IMPROVEMENT OF STREAM.

It seems evident from the information available that pollution of the Fox River is approaching the limit of that stream's capacity as a purifying agent along a portion of its course. The region between Dundee and Aurora is rapidly developing, and a very material increase in the amount of pollution may be confidently expected within the next few years. The stream is one of many natural beauties, rather extensively used for recreative purposes, and it is eminently desirable that steps should be taken looking toward maintenance of the water in a reasonably pure condition and protection of it against future increase in pollution. Artificial methods, as indicated in the preceding report, could be made to effectually bring about this condition.

At the outlet of Pistokee Lake, an association of summer residents has constructed a dam about 3 feet high for the purpose of maintaining the water in the lakes at a constant height during the summer outing season. The lakes above act now in no sense as a reservoir for equalizing the flow in the river below, as there is always a rate of outflow from them approximately equal to the prevailing rate of inflow, but this suggests a possibiltiy of improving the river conditions by equalization of flow.

The various lakes in Illinois tributary to the Fox River have a combined area of about 15 square miles. By building a dam at the outlet of each of these lakes high enough to raise the water 2 feet, a storage of about 840,000,000 cubic feet might be made available for purposes of equalizing the flow in the river. Such a supply of water, if judiciously released, would be capable of increasing the flow in the river by about 160 sec. feet for a period of two months. There are other tributary lakes in Wisconsin having a combined area even greater than those in Illinois. A more careful investigation of these possibilities would, of course, be necessary before anything definite could be said as to the practicability of the suggestion, but the value of such equalization of flow in the river is apparent, so far as both the solution of sewage disposal problems and the improvement of power development conditions is concerned.

INDEX.

PUBLICATIONS OF THE STATE WATER SURVEY.

No. 1. Chemical Survey of the Waters of Illinois. Preliminary Report. 98 pp., 3 pl., 1 map. 1897. (Out of print.)

No. 2. Chemical Survey of the Waters of Illinois. Report for the years 1897–1903. XVI+254 pp., 44 pl. 1904. (Out of print .)

No. 3. Chemical and Biological Survey of the Waters of Illinois. Report for year ending August 31, 1906. 30 pp., 5 cuts. 1906.

No. 4. Mineral Content of Illinois Waters. VIII+192 pp. 1908.

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No. 6. Chemical and Biological Survey of the Waters of Illinois. Report, September 1, 1906, to December 31, 1907. 88 pp., 3 cuts, 9 pl. 1908.

No. 7. Chemical and Biological Survey of the Waters of Illinois. Report for 1908. 204 pp., 4 cuts. 1909.

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No. 9. Chemical and Biological Survey of the Waters of Illinois. Report for 1911. 171 pp., 20 cuts. 1913. Price 85 cents, cloth one dollar.

NOTE—For copies of these reports or information, address Director, State Water Survey, University of Illinois, Urbana, Illinois.