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CHEMICAL AND BIOLOGICAL SURVEY OF THE WATERS OF ILLINOIS

REPORT FOR YEAR ENDING DECEMBER 31, 1915

EDWARD BARTOW

DIRECTOR

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[1]To May. [2]To August. [3]To July. [4]From July. [5]From December.

LETTER OF TRANSMITTAL

Illinois State Water Survey.

University of Illinois,
Urbana, Illinois, October 1, 1916.

Edmund J. James, Ph.D., LL.D.,
President, University of Illinois.

Sir: Herewith I submit a report of the work of the State Water Survey, for the year ending December 31, 1915, and request that it be printed as a bulletin of the University of Illinois, State Water Survey Series No. 13.

The report contains an account of the work done by the State Water Survey in accordance with the laws creating the State Water Survey and imposing upon it new and additional duties (Laws of Illinois, 40th General. Assembly, 1897, 12; 47th General Assembly, 1911,43. Bull. State Water Survey Series 9, 7-8).

Summaries of the chemical, biological, and engineering work are given, together with more complete reports on certain special investigations conducted during the year.

Several epidemics of typhoid fever have been investigated and recommendations have been made for the prevention of the spread of the disease.

Thanks are due the regular staff and graduate students for the interest they have shown in the work. Credit has been given in appropriate places in the bulletin. Thanks are also due R. B. Dole who edited the Engineering Report and the article on Manganese in Illinois Waters and S. D. Kirkpatrick who assisted in editing the remainder of the bulletin.

Respectfully submitted,

EDWARD BARTOW, *Director.*

CHEMICAL AND BIOLOGICAL SURVEY OF THE WATERS OF ILLINOIS

REPORT FOR THE YEAR ENDING DECEMBER 31, 1915

EDWARD BARTOW
Director

GENERAL REPORT

ADMINISTRATION

By authority of the 40th General Assembly of Illinois[1] the Board of Trustees of the University of Illinois in 1897 created the Illinois State Water Survey and made it a division of the Department of Chemistry. The work was extended by the 47th General Assembly in 1911.[2] The State Water Survey is empowered to visit municipal water supplies, to inspect watersheds, to make such field studies and to collect such samples as are necessary, to analyze and test the 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. Sanitary water analyses are made free of charge when samples are collected according to the directions of the Survey.

During 1915 the laboratory and field work of the State Water Survey was continued along the lines inaugurated late in 1911 and described in Bulletins 9-12. The scope of the work was somewhat extended because the 49th General Assembly increased the appropriation from $21,500 per annum to $23,500 per annum, and made special appropriation of $5,000 to establish a sewage experiment station. The Trustees of the University of Illinois continued the allotment of $7,500 per annum for the educational and scientific work carried on by the Survey and by the Sanitary Division of the Department of Chemistry.

The staff has been slightly changed during the year. The Survey

[1]Laws of the State of Illinois 40th General Assembly, 1897, 12.
[2]Laws of the State of Illinois 47th General Assembly, 43.

has been deprived of the advice of Dr. Otto Eahn, consulting bacteriologist, because of his absence in Germany. Mr. Milford Everett Hinds, assistant chemist, resigned to become chemist with the State Food Commission of Tennessee, Nashville, Tennessee. Mr. Fred Wilbur Tanner, assistant bacteriologist, resigned to become instructor in Bacteriology in the University of Illinois. Mr. Henry Lawrence Huenink, assistant chemist, resigned to become chemist for the Dutch Canning and Pickling Co., at Cedar Grove, Wisconsin. Mr. Maurice Charles Sjoblom, engineering assistant, resigned to become assistant engineer with the Illinois State Board of Health. Mr. William Durrell Hatfield, B.S., Illinois College, Jacksonville, Illinois, was appointed assistant bacteriologist and Mr. Friend Lee Mickle, A.B., Allegheny College, Meadville, Pennsylvania, was appointed assistant chemist.

Instruction in the analysis and purification of water and sewage has been given by members of the Water Survey staff. There is one course for undergraduates, Chemistry 10, one course for graduates, Chemistry 110, and both undergraduates and graduates registered in Chemistry 11 or Chemistry 111 may prepare theses on subjects connected with the chemistry of water and sewage. Many of the theses thus prepared have been published in the scientific and technical press and in bulletins of the State Water Survey. The Engineer has assisted in Municipal and Sanitary Engineering 6a-6b by giving lectures and conducting class work on purification of water and sewage.

The Water Survey has always occupied quarters in the Chemistry Building and during 1915 used nine rooms in the Chemistry Building and two in Engineering Hall. New quarters in the addition to the Chemistry Building are nearly ready for occupancy. (The offices were occupied in April, 1916). It is expected that the present laboratories will be remodeled for instructional work in chemistry of water and sewage.

ENGINEERING WORK

Members of the staff of the Engineering Division, which was established in 1911, have visited nearly all the cities in the State. Conferences have been held with local authorities regarding the construction of new water and sewerage systems or the improvement of old ones. Reports describing public water supplies, sewerage systems and sewage-disposal works have been prepared. Abstracts of these reports may be found in Bulletins, **9**, 15-33; **10**, 89-185; **11**, 28-141; 12, 28-147, and in this bulletin, pages 30-143. The work from 1912 to 1915 is briefly summarized in Table 1.

TABLE 1.—NUMBER OF ENGINEERING INVESTIGATIONS, CONFERENCES, INSPECTIONS, AND REPORTS PREPARED, 1912-1915.

Nature of work.	1912	1913	1914	1915	Total.
Inspections of public water supplies	60	101	101	117	379
Conferences concerning the installation and extension of public water supplies	1	59	34	19	113
Inspections of sewerage systems	25	28	34	20	107
Conferences concerning proposed sewerage systems	3	24	8	11	46
Special investigations	18	41	26	25	110
Reports prepared on public water supplies	60	85	82	96	323
Reports prepared on proposed water supplies and extensions	19	34	28	18	99
Reports prepared on sewerage systems	11	6	22	17	56
Reports prepared on proposed sewerage systems	14	10	5	11	40

The State Water Survey believes that every municipality should have a public water supply of good quality. A good water supply is in a great measure insurance against water-borne diseases. Special efforts have been made to see that all municipalities whose population is 1,000 or greater should have good public water supplies. Many smaller communities might economically install public water supplies. There are 107 municipalities whose population is less than 1,000 that now have public water supplies.

Waterworks were installed during 1915 at Ashton, Carpentersville, Cuba, Leland, Matteson, Eed Bud, Roanoke, Rockdale, Stronghurst, and Winchester.

Water-purification plants installed before the end of 1913 are named in Bulletin **11**, 170. During 1914 plants were installed at Harrisburg and Centralia (see Bull. **12**,) and during 1915 at Herrin and Sparta.

The State Water Survey believes that all surface-water supplies should be purified by filtration or disinfection before they are used for drinking purposes. It has, therefore, promoted the installation of filtration and disinfection plants. At the end of 1915 46 public water supplies were being treated. Of these 34 were filtered for purification, 2 were filtered for removal of iron, 2 were treated by coagulation and sedimentation without filtration, and 8 were treated only by disinfection.

The State Water Survey has facilities for making examinations of public water. supplies only at infrequent intervals. The daily control of surface supplies is valuable and almost necessary for the control of purification plants. Twenty-four local control laboratories have been installed. Many of these have been installed at the suggestion of and often under the supervision of the State Water Survey.

LABORATORY WORK

From the time of its foundation, September, 1895, to December 31, 1915, 32,510 samples of water (see Table 2) have been received by the State Water Survey. Of these 19,917 were collected and sent to the laboratory by private citizens, health officers, or waterworks officials. The remaining samples, including 2,800 collected in 1899 and 1900 in connection with a study of the Chicago Drainage Canal, have been collected either by members of the staff or under their direction for the study of special problems.

The greatest number of samples from one type of source, 7,598, have been taken from shallow wells in drift, naturally enough, since such wells furnish by far the greatest number of private supplies. Only 476 samples of water from shallow wells in rock have been received, undoubtedly because the greater part of the State is covered by 50 to 300 feet of glacial drift.

Deep wells in rock have furnished 2,869 samples and deep wells in drift 1,763 samples. Satisfactory water can be obtained from the deep wells in rock in the northern part of the State and from deep wells in drift in the east-central part of the State. Many surface waters (4,977) have been received because of the installation of filter plants and the additional monthly control tests which are made. The number of samples of ice has increased during the past two years because of the requirement of the U. S. Public Health Service that samples of all ice used by the railroads must be examined and approved before it can be used on railway trains.

During 1915, 3,009 samples of water were received. (See Table 3). This is the largest number that has been received in any year since the foundation of the Survey and is an increase of 8.6 per cent over the number received during 1914. Of these samples 1,732 were sent to the laboratory by health officers or private citizens. The greatest number of samples were sent in during August, September, October, and November. More than 40 samples per week were received during this period. The fewest samples, less than 100 per month, were sent in during January and April. For special study 283 samples were collected on railway trains, and 31 samples were collected from swimming pools.

Well waters sent to the Survey for examination from 1907 to 1915 have been classified in Table 4 according to the depth of wells. The number condemned decreases as the depth of the wells increases. The waters have been condemned from data afforded by analyses and from information concerning the surroundings of the well. The

TABLE 2.—NUMBER OF WATER SAMPLES EXAMINED AT THE DIRECT REQUEST OF PRIVATE CITIZENS OR LOCAL HEALTH OFFICERS, CLASSIFIED BY YEARS AND BY SOURCE.

SOURCES.	October 1895, to Dec. 31 1896.	YEARS.																			Total from each source.
		1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	
Surface waters, rivers, lakes and ponds	69	72	102	54	59	61	97	75	80	107	304	336	356	372	428	196	398	640	599	577	4977
Springs	16	21	34	23	22	35	28	18	28	41	63	52	68	62	41	29	73	50	53	80	787
Cisterns	12	19	17	7	7	3	10	6	7	5	13	29	28	31	21	25	27	25	46	37	375
Natural ice	4	12	1	11	9	4	9	3	12	6	....	1	5	1	12	9	10	19	21	5	154
Artificial ice	......	1	....	2	1	....	1	1	1	....	4	....	....	0	0	1	0	....	2	12	26
Water for artificial ice	3	....	....	8	....	1	1	....	5	2	1	....	1	2	0	2	0	....	....	....	21
Water for natural ice	......	2	....	....	....	3	1	1	2	....	6	....	....	3	0	3	0	....	....	....	21
Mine water	......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	11	10	4	30
Shallow wells in rock	28	16	8	22	12	22	10	17	25	25	19	45	32	53	43	29	31	20	11	8	476
Deep wells in rock	58	48	34	26	36	56	59	23	28	66	170	159	258	345	207	119	299	320	326	232	2869
Flowing wells in rock	45	8	16	12	13	14	3	8	9	11	22	17	43	3	2	2	9	6	....	....	243
Shallow wells in drift	500	245	168	243	274	209	243	245	270	292	442	514	683	614	344	256	436	435	563	622	7598
Deep wells in drift	64	68	43	80	24	36	63	54	51	40	114	154	160	159	95	103	138	152	28	187	1763
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	5	33	46	5	1	1	6	3	4	3	216
Distilled water	......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	2	5	10
Miscellaneous	......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	53	....	....	....	53
Unknown	......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	30	72	2	10	134
Total samples from citizens	899	517	448	467	471	444	529	463	525	613	1182	1365	1682	1651	1201	795	1510	1756	1667	1732	19917
Other samples	888	811	988	1579	1866	778	147	419	555	466	445	55	87	73	101	279	214	460	1105	1277	12593
Total for year	1787	1328	1436	2046	2337	1222	676	882	1080	1079	1627	1420	1769	1724	1302	1074	1724	2216	2772	3009	32510

TABLE 3.—NUMBER OF WATER SAMPLES EXAMINED DURING THE YEAR ENDING DEC. 31, 1915, CLASSIFIED BY MONTHS AND BY SOURCE.

SAMPLES BY REQUEST.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
Surface waters, rivers, lakes, and ponds	59	61	57	15	53	54	46	43	40	34	63	52	577
Springs	1	2	4	1	2	1	3	4	6	2	1	3	30
Cisterns	1	6	0	0	2	2	1	0	0	7	15	3	37
Natural ice	0	0	1	1	1	0	2	0	0	0	0	0	5
Artificial ice	0	0	0	2	0	0	2	4	1	2	1	0	12
Shallow wells in rock	3	1	1	2	1	0	0	0	0	0	0	0	8
Deep wells in rock	12	16	20	12	17	21	14	21	28	32	25	14	232
Shallow wells in drift	23	34	13	86	44	39	48	66	70	98	90	61	622
Deep wells in drift	1	8	9	6	14	5	20	61	23	22	9	9	187
Sewage	0	3	0	0	0	0	0	0	0	0	0	0	3
Distilled water	0	0	0	0	0	0	0	3	0	2	0	0	5
Mine water	0	1	0	0	0	3	0	0	0	0	0	0	4
Unknown source	0	1	1	0	0	0	1	1	3	1	2	0	10
Total	100	133	106	75	134	125	137	203	171	200	206	142	1732
MADE ON INITIATIVE OF WATER SURVEY.													
Surface water, rivers, lakes, and ponds	19	2	8	47	3	4	3	6	2	18	0	2	109
Springs	0	0	0	0	0	0	0	0	0	0	0	12	12
Cisterns	0	0	0	0	0	0	0	0	0	0	0	1	1
Deep wells in rock	10	3	3	0	2	21	12	3	14	19	2	1	90
Shallow wells in rock	0	0	0	0	0	1	0	0	0	0	0	0	1
Shallow wells in drift	8	3	3	0	2	5	4	2	7	1	0	4	39
Deep wells in drift	6	0	1	7	0	4	9	5	9	5	2	0	46
Mine water	1	0	0	0	0	0	2	0	0	0	0	0	3
Unknown source	0	0	0	0	0	0	0	0	0	0	0	1	1
Stagnant water	0	0	0	0	0	0	0	0	1	0	0	0	1
Specials													
Illinois River	24	22	4	0	0	0	0	0	0	0	0	0	50
Railway trains	29	47	32	37	16	44	31	23	18	0	3	3	283
Ice	7	0	2	1	0	0	0	0	0	1	0	0	11
Chicago deep wells	0	0	0	0	0	0	36	4	25	18	0	0	83
Swimming pools	0	4	0	0	0	8	6	5	4	4	3	2	31
Boiler waters	0	0	6	44	59	79	28	30	56	56	72	86	516
Total	104	81	54	136	82	161	131	76	136	122	82	112	1277
Grand total of samples by request and those on initiative of Water Survey	204	214	160	211	216	286	268	279	307	822	288	254	3009

TABLE 4.—PERCENTAGE OF WELL WATERS CONDEMNED BY THE WATER SURVEY CLASSIFIED BY DEPTH, 1907-1915.

	1907	1908	1909	1910	1911	1912	1913	1914	1915	Total
DEPTH LESS THAN 25 FEET										
Number examined..........	284	254	242	148	118	168	230	235	269	1943
Number condemned........	240	192	183	118	74	113	155	189	176	1440
Percentage condemned......	85	75	75	79	65	67	67	81	65	74
DEPTH 25 TO 50 FEET										
Number examined..........	224	395	354	201	196	353	262	331	391	2707
Number condemned........	173	250	226	137	122	185	166	206	236	1701
Percentage condemned......	77	63	63	68	62	52	63	62	60	63
DEPTH 50 TO 100 FEET										
Number examined..........	111	192	161	90	89	129	164	158	239	1333
Number condemned........	42	66	54	46	8	28	54	47	80	425
Percentage condemned......	37	34	53	51	9	22	33	29	33	32
DEPTH MORE THAN 100 FEET										
Number examined..........	161	312	376	205	171	339	603	633	428	3228
Number condemned........	22	31	62	43	30	49	59	51	65	412
Percentage condemned......	13	9	16	20	17	14	10	8	15	13
DEPTH UNKNOWN.										
Number examined..........	88	46	72	67	19	27	83	65	66	533
Number condemned........	34	22	38	35	9	6	21	24	29	218
Percentage condemned......	38	47	65	52	47	22	25	37	44	41
Total number examined...	868	1199	1205	711	593	1016	1342	1422	1393	9744
Total number condemned..	511	561	563	379	243	381	455	517	586	4196
Percentage of total condemned...........	60	46	47	53	41	38	34	36	42	43

waters have been condemned because of presence of filth which suggests the present or future presence of disease germs. During the 9 years mentioned 74 per cent of the samples from wells less than 25 feet deep were condemned, whereas only 13 per cent of those from wells more than 100 feet deep were condemned and many samples of water from the deepest wells were condemned not because of contamination but because of excess of the mineral content. Of all the well waters 43 per cent were condemned. An improvement in the quality of the waters received for analysis during the latter part of the period has been observed, possibly because people are now sending in a supposedly good water in order to confirm their opinion of its character. The character of the water in the wells examined does not give a true idea of the character of all the well water in the State for by far the greater number of samples are sent because of suspected contamination. The true condition of well water throughout the State can only be obtained by analyzing many representative samples from all parts of the State.

SCIENTIFIC AND SPECIAL STUDIES

The routine analyses made in the laboratory of the Water Survey and inspections of private and municipal water supplies bring to the attention of the Water Survey many special problems relating to water, water supplies, sewage, and sewerage. The members of the staff are, therefore, called upon to study special problems. The following summary indicates the special work which has been completed during 1915, the results of which are published elsewhere in this report. The regular staff has at times been assisted by instructors and graduate students in the University. Assistance in the preparation of material presented in this bulletin has been given by J. F. Garrett, C. S. McKellogg, Robbins Russel, C. Scholl, J. D. Snook, and H. J. Weiland.

Manganese in water supplies. The colorimetric persulfate and the colorimetric bismuthate methods were found best for the determination of manganese in water. Practically no manganese is present in Illinois water supplies from the Potsdam and St. Peter sandstones, the limestones, Lake Michigan, and the large streams. Manganese is present in many Illinois water supplies from the drift, especially near the large rivers, and from impounding reservoirs in the southern part of the State. Coal-mine drainage often contains manganese in, very large amounts, 56 parts per million having been found. The content of manganese bears no relation to the amount of other mineral matter in natural waters, except that mine drainage always contains iron with the manganese.

The reaction between manganese salts and manganese dioxide is the basis for all processes for removal of the manganese, except those in which a chemical precipitant is used. In an experimental plant practically no removal of manganese was obtained by filtration through sand until the sand was artificially coated with manganese dioxide. In two water supplies in the State manganese is now efficiently removed by filtration through sand on which a coating of manganese dioxide has developed.

Organisms which deposit manganese were not found in water pipes stopped by manganese incrustations. This precipitation is probably caused by catalytic separation of manganese by manganese dioxide in the presence of dissolved oxygen.

The arsenic content of sulfate of aluminium used for water purification. Because of European specifications requiring absence of arsenic in sulfate of aluminium used for water purification 41 samples were collected and analyzed. Samples obtained within the State of Illinois contained negligible amounts of arsenic. In some of the samples from outside the State larger amounts of arsenic were found.

Most of the arsenic is precipitated with the aluminium hydroxide so that only a small percentage of the amount originally present is found in the filtered water. There is a strong probability that the quantity of arsenic added to the filtered water by treatment with sulfate of aluminium would never be sufficient to have therapeutic significance. However, since it is possible to obtain sulfate of aluminium with a very low amount of arsenic, waterworks officials should demand such a product.

Bacteria in deep wells. Few bacteria but of harmless varieties were found in deep wells. B. coli were found in wells in alluvial drift in a city. Salt placed in near-by privies did not appear in the wells.

The factors which influence the longevity of B. coli and B. typhosus in waters. The lack of food in pure water caused death of the two organisms at a rate similar to a chemical reaction following the monomolecular law. Oxygen under starvation conditions seems to be harmful to B. coli and beneficial to B. typhosus.

Pollution of Vermilion River at and below Streator. During much of the year sewage and mine water make up the flow of the river below Streator. In warm weather, conditions are bad just below the city. In winter, bad conditions were noted 23 miles downstream. Low water and cold weather and a coating of ice prevented self-purification and caused the water to have a bad odor making it objectionable for use by manufacturing plants at Portland.

Investigation of destruction of fish in Sangamon River below Springfield. Large numbers of dead fish were noticed from January 1-12 for 30 miles downstream. Death was undoubtedly caused by (1) low water in the river, (2) sewage from Springfield, and (3) cold weather which froze the river and prevented access of air to oxidize the organic matter of the sewage.

Quality of drinking water obtained in Illinois by common carriers. Samples of water from 99 sources of supply have been collected and analyzed and limits of chemical impurities suggested. Of 94 samples examined bacteriologically 47 per cent did not conform to the standards of the U. S. Treasury Department. All of 16 samples of ice examined were satisfactory. Twenty-one of the 26 purification plants examined furnished a satisfactory effluent at the time of the examination.

Epidemic of typhoid fever caused by polluted water supply at Old Salem Chautauqua. The investigation, made by the State Board of Health, of an epidemic of typhoid fever involving 201 cases preceded by a larger but non-fatal epidemic of diarrhea is described in a paper read before the Illinois State Medical Society. The epidemic was caused by the use of a polluted water supply at the Old Salem Chautauqua grounds. This water supply, on the basis of analyses, had been condemned at three different times by the Survey. Twenty-six incorporated communities were affected and 1.2 per cent of the entire population of Menard County were victims of the epidemic.

Epidemic of typhoid fever at Park Ridge. An epidemic of typhoid fever at Park Ridge was traced to infection of milk by milk cans contaminated by water from Des Plaines River.

The significance of chemistry in water purification. In a paper read before the Second Pan-American Scientific Congress at Washington, D. C., it was pointed out that chemistry and chemical methods were of vital significance in the treatment of water for drinking purposes, for domestic uses, for the production of steam, and for manufacturing purposes. The applications of water chemistry were summarized as follows: It assists in and supplements bacteriological tests. By determining the mineral constituents of a water, it shows the therapeutic character; it shows the presence or absence of troublesome metals, iron and manganese; it shows the presence or absence of poisonous metals, copper, lead, and zinc. It controls water purification, filtration for use as drinking water and softening for industrial uses. It formulates standards of purity and improves methods of purification. Finally, its fundamental purpose is to help furnish and conserve pure water for all purposes.

The use of barium salts in water treatment. Experiments confirm statements of others concerning the efficiency of barium salts in removing sulfates from water. The cost is high and other methods are to be preferred when practicable.

The use of Permutit in water softening. The Permutit method of water softening was tested and found satisfactory for softening University water to zero hardness. A well water containing sulfates could also be efficiently softened.

The English incubation test for the purification of sewage and sewage effluents. The test was carefully tried with specimens of raw sewage and of effluent from a septic tank. The test should be carried for at least three days at 20°C. Variations in the dilutions give variable results.

Purification of sewage by aeration in the presence of activated sludge. Experiments on the purification of sewage by aeration in the presence of activated sludge have been conducted on a small scale in the laboratory and on a larger scale in four concrete tanks of 600-gallon capacity each, and, located in the boiler house of the University of Illinois. This process was discovered by Ardern and Lockett, of Manchester, England, working under the direction of Professor Gilbert J. Fowler, of the University of Manchester. Results have shown that the process will produce a stable effluent from Champaign sewage with four hours' aeration at the rate of 2 cubic feet of air per gallon of sewage. Sludge of good quality can be built up without aerating each portion of sewage until the oxidation of the ammonia nitrogen is complete. The diffusion area providing Filtros plates are used should be between one-third and one-tenth of the total floor area. Experiments on a larger scale are to follow.

The value of activated sludge as a fertilizer. Activated sludge was analyzed and found to contain greater; quantities of nitrogen and phosphorous than other sewage sludges. The best evidence of its value was the greater growth of wheat, lettuce, and radishes when the sludge was used as a fertilizer.

Biological studies of sewage purification by aeration. A large consistent reduction of the number of bacteria in sewage is obtained by the activated-sludge process. Purification is accomplished by typical aerobic bacteria which break down the organic matter into substances which can be oxidized by two typical known nitrifiers called Nitrosomonas and Nitrobacter.

Hydrogen sulfide in well waters of Chicago and vicinity. Hydrogen sulfide occurs in waters from the Niagara limestones or, in the territory southwest of Chicago, in waters from the "Coal Measures". The amount present in a water varies with the rate of pumping especially when waters from different sources enter the well. The amount of hydrogen sulfide retained by the water is greater when the water is pumped by deep-well pumps than when air lift is used.

ASSOCIATIONS AND COMMISSIONS

Certain phases of Illinois water problems are of interest to several State, interstate, national, and international associations and commissions, which have been cooperating as far as possible in order to prevent duplication of work. In order to place before the citizens interested in the water supplies of the State information concerning the activity of these associations, it has been customary to publish a list of the organizations with abstracts of articles pertaining to the water supplies of Illinois. The organizations are noted below together with.

statements in regard to their work on water supplies in 1915. Titles and abstracts of articles published by these associations during the year are given elsewhere.

Illinois State Board of Health. (1877.) John A. Eobison, M. D., Chicago, president; C. St. Clair Drake, M. D., Springfield, secretary and executive officer. By mutual consent the care of the water supplies of the State is in the hands of the State Water Survey. Water analyses have been made for the State Board of Health when requested. The State Board of Health and the State Water Survey have cooperated in the investigation of several typhoid-fever epidemics.

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.

State Public Utilities Commission of Illinois. (1913.) William L. O'Connell, 714 Insurance Exchange Bldg., Chicago, chairman. The commission, as an administrative body, has jurisdiction over all private corporations and individuals, as public utilities, owning or operating water or power plants, but its powers do not extend to municipally-owned plants. It has extensive authority over reports, accounts, capitalization, mergers, intercorporate contracts, rates, services, and facilities. A certificate of convenience and necessity from the commission is necessary to authorize a new enterprise by a public utility, and the operation of the undertaking is brought under its active control and regulation. Under the present law a public utility must be incorporated by the Secretary of State, before receiving a certificate of convenience and necessity from the Utilities Commission. No fees are charged by the commission in any action, except authorization of security issues. Much of the commission's work consists of the adjudication of complaints concerning the practices of public utilities.

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 aquatic life. A special study is being made to determine the effect of Chicago sewage on the plankton and food fishes in Illinois River, the chemical work of which has been done under the direction of the State Water Survey.

Illinois Academy of Science. (1907.) The functions of the academy are the promotion of scientific research, the diffusion of scientific knowledge, and the unification of the scientific interests in the State. All residents of the State who are interested in scientific work are eligible to membership. Transactions have been published annually since 1907. The officers for 1915 were A. R. Crook, Springfield, president; E. N. Transeau, Charleston, secretary.

Illinois Society of Engineers and Surveyors. (1885.) W. S. Shields, consulting engineer, Chicago, 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 1915 proceedings contained four papers and reports relating to water and sewage.

Illinois Water Supply Association. (1909.) Illinois Section, American Water Works Association. W. J. Spaulding, Commissioner of Public Property, Springfield, president; Dr. Edward Bartow, Director State Water Survey, University of Illinois, Urbana, secretary-treasurer. The Illinois Water Supply Association became a section of the American Water Works Association in 1915. It is composed of persons interested in the waterworks and water supplies of Illinois. Papers dealing with topics of interest to waterworks men are read at the annual meetings, which are held at the University of Illinois in February or March. A second meeting is held elsewhere in the fall.

Sanitary District of Chicago. (1890.) Thomas A. Smyth, president; George M. Wisner, chief engineer, Karpen Bldg., Chicago. The Sanitary District of Chicago has continued its investigations of sewage disposal for Chicago during 1915.

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 pure supply for cities and towns that depend on Lake Michigan for water. The commission comprises representatives from the United States Army and the United States Public Health Service and members, usually officials, are appointed by the governors of the States and the mayors of several cities which border the lake. No special appropriations are made for this commission. The eighth meeting was held March 19, 1915.

Lake Michigan Sanitary Association. (1908.) A. J. Horlick, Racine, Wisconsin, president. This association, whose object is the protection of water supplies, is composed of representatives of city councils, health departments, and engineering departments of cities in Lake Michigan drainage basin.

North Shore Sanitary Association. (1908.) James O. Heyworth, Lake Forest, president; James F. King, Lake Forest, secretary. This association advocates proper sewage disposal and water supply for municipalities on the "north shore" of Lake Michigan, and its work until recently has consisted mainly in accumulating necessary data and promoting a campaign of education. A bill passed in 1913 by the State Legislature granted permission to organize a sanitary district in Lake County, and on April 7, 1914, the North Shore Sanitary District, extending as far north as the north limits of Waukegan, was formally organized by a vote of the people.

North Shore Sanitary District. (1914.) W. J. Allen, Waukegan, president. Territory along Lake Michigan in Lake County from the Cook County line to the northern boundary of Waukegan. It is the duty of the trustees of the district to prevent pollution of Lake Michigan by sewage.

Rivers and Lakes Commission. (1909.) A. W. Charles, Carmi, chairman; Leroy K. Sherman, Chicago, and Thomas J. Healy, Chicago, members; Charles Christmann, State Bldg., Chicago, secretary.

Western Society of Engineers. (1895.) W. B. Jackson, Chicago, president; E. N. Layfield, 1735 Monadnock Bldg., Chicago, secretary. The annual meeting is held in Chicago.

International Joint Commission of the United States and Canada. For the United States, Obadiah Gardner, Chairman; Whitehead Kluttz, Southern Bldg., Washington, D. C., Secretary. For Canada Charles A. Magrath, Chairman; Lawrence J. Burpee, Secretary. The sanitary condition of the boundary waters between Canada and the United States was referred to this commission.

United States Geological Survey. George Otis Smith, Washington, D. C., Director. The Survey has charge of stream measurements and other investigations of water resources of the country. Water-Supply Papers are issued at frequent intervals.

United States Public Health Service. Dr. Rupert Blue, Washington, D. C, Surgeon-General. The Public Health Service publishes bulletins and a weekly journal entitled "Public Health Reports," containing current information regarding the prevalence of disease, the occurrence of epidemics, sanitary legislation, and related subjects.

American Water Works Association. (1880.) Nicholas S. Hill, New York City, president; J. M. Diven, Troy, N. Y., secretary. The 1915 annual meeting was held at Cincinnati, Ohio. In 1914 the association began the publication of a quarterly journal which takes the place of the annual proceedings heretofore issued.

American Public Health Association. (1872.) W. T. Sedgewick, Boston, Mass., president; Selskar M. Gunn, 755 Boylston St., Boston, Mass., secretary. The 1915 annual meeting was held at Rochester, N. Y. The official publication of this association is the American Journal of Public Health, a monthly magazine. "Standard Methods of Water Analysis" is also published by the association.

ENGINEERING REPORT

GENERAL SCOPE OF WOEK

The work of the Engineering Division may be classed broadly as investigations of water supply, of sewage and trade-waste disposal, and of epidemics of typhoid fever. Investigations of water supplies have been considered of most importance, but the close relationship in many places between the water supply and sewage disposal, and several complaints of stream pollution have rendered necessary the investigation also of sewage disposal. The investigations of epidemics of typhoid fever have been undertaken at the request of the State Board of Health. The studies of sewage disposal have been materially aided by the cooperative agreement with the Rivers and Lakes Commission (see Bull. 11, 22-3).

PUBLIC WATER SUPPLIES

The examination of the public water supplies of the State was continued in 1915, but owing to a decrease in the staff of the Engineering Division and the numerous calls for special investigations there remained a number of communities not visited at the end of the year. The increase in the number of supplies on our records, is because during the year 13 communities installed public water supplies, and by special inquiry several communities already having supplies have been found. A list of the water supplies visited and described to the end of 1915 is given in Table 5. The waterworks of places whose names are printed in roman type are described hi this bulletin, and those of places whose names are printed in italic type have been described in preceding bulletins.

TABLE 5.—WATER SUPPLIES VISITED AND DESCRIBED BY THE ENGINEERING DIVISION, TO DEC. 31, 1915.

Abingdon	*Arlington Heights*	*Barrington*
Aledo	*Arthur*	*Barry*
Alexis	Ashton	*Batavia*
Algonquin	*Assumption*	*Beardstown*
Alton	*Astoria*	*Belleville*
Amboy	*Atlanta*	*Bellwood*
Anna	*Aurora*	*Belvidere*
Anna, State Hospital	*Aviston*	*Bement*
Arcola	Avon	Benson

Benton
Berwyn
Bloomington
Blue Island
Blue Mound
Braceville
Braidwood
Breese
Brookfield
Brookport
Buckley
Buda
Bureau
Bushnell
Byron
Cairo
Cambridge
Canton
Carbondale
Carbon Hill
Carlinville
Carlyle
Carmi
Carpentersville
Carrollton
Cedar Point
Centralia
Cerro Gordo
Chadwick
Charleston
Chatsworth
Chenoa
Cherry
Chester
Chicago Heights
Chillicothe
Cissna Park
Clinton
Coal City
Collinsville
Creal Springs
Crescent City
Crete
Crystal Lake
Cuba
Danvers
Danville
Decatur
Deer Creek
Dekalb
Delavan
Depue
Des Plaines
Dixon
Downers Grove
Duquoin
Dwight
Earlville
East Dubuque
East Dundee
East St. Louis
East Wenona
Edwardsville
Effingham
Elgin
Elgin, State Hospital
Elmhurst
Elmwood
El Paso
Eureka
Evanston
Fairbury
Fairfield
Farmer City
Farmington
Flora
Forest Park
Forreston
Fort Sheridan
Freeburg
Freeport
Fulton
Galena
Galesburg
Galva
Geneseo
Geneva
Genoa
Gibson City
Gilman
Glencoe
Glen Ellyn
Grand Ridge
Granite City
Granville
Grayville
Great Lakes, U. S. Naval Training Station
Greenup
Greenview
Hamilton
Harrisburg
Harvard
Harvey
Havana
Henry
Herrin
Highland Park
Hillsboro
Hinckley
Hinsdale
Hollywood
Homewood
Hoopeston
Ipava
Jacksonville
Jacksonville, Illinois school for the deaf
Jerseyville
Johnston City
Joliet
Joliet, Illinois State Penitentiary
Kankakee
Keithsburg
Kenilworth
Kewanee
Kirkwood
Knoxville
Lacon
Ladd
Lagrange
Lagrange Park
La Harpe
Lake Bluff
Lake Forest
Lake Zurich
Lanark
La Salle
Lawrenceville
Leland
Lena
Le Roy
Lewistown
Lexington
Libertyville
Lincoln
Lincoln, State School and Colony
Litchfield
Little York
Lockport
London Mills
Lostant
Lovington
Lyons
McHenry
McLeansboro
Mackinaw
Macomb
Manteno
Maple Park
Marengo
Marion
Mark
Maroa
Marseilles
Marshall
Mascoutah
Mason City
Mattoon
Maywood
Melrose Park
Melvin
Menard, Southern Illinois Penitentiary
Mendota
Metamora
Metropolis
Milford
Minonk
Minooka
Mokena
Moline
Momence
Monea

Monmouth
Monticello
Morris
Morrison
Morrisonville
Morton
Mound City
Mounds
Mount Carmel
Mount Carroll
Mount Morris
Mount Olive
Mount Pulaski
Mount Sterling
Mount Vernon
Moweaqua
Murphysboro
Naperville
Nauvoo
Newton
Nokomis
Normal
North Chicago
North Crystal Lake
Oakland
Odell
Olney
Onarga
Oregon
Ottawa
Palatine
Pana
Paris
Paxton
Pearl
Pecatonica
Pekin
Peoria
Peoria, State Hospital
Peotone
Peru
Petersburg
Pinckneyville
Piper City
Pittsfield
Plainfield
Plano
Polo
Pontiac
Portland
Princeton
Quincy
Rantoul
Red Bud
River Forest
Riverdale
Riverside
Roanoke
Roberts
Robinson
Rochelle
Rock Falls
Rock Island
Rock Island, Arsenal
Rockdale
Rockford
Roodhouse
Rossville
Rushville
St. Anne
St. Charles
St. Elmo
Salem
San Jose
Sandwich
Savanna
Secor
Sheffield
Shelbyville
Sheldon
Silvis
Somonauk
Springfield
Spring Valley
Stanford
Staunton
Steger
Sterling
Stockton
Stonington
Strawn
Streator
Sullivan
Sycamore
Taylorville
Tinley Park
Tiskilwa
Tolono
Toluca
Toulon
Tremont
Trenton
Tuscola
Utica
Warren
Warsaw
Waterloo
Watseka
Waukegan
Wenona
West Chicago
West Dundee
West Hammond
Western Springs
Whitehall
Wilmette
Winnetka
Woodstock
Wyoming
Zion City

REGULATIVE INSPECTION

The Engineering Division makes preliminary investigations and examination of local conditions in relation to proposed installations, improvements or additions to waterworks, filtration plants, sewerage, and sewage-treatment plants. The preliminary investigations and examinations of local conditions, in connection with new water-supply projects, forestall the selection of inadequate or unsuitable sources of supply and the installation of improper equipment. The investigation of local conditions in connection with sewerage projects determines what degree of sewage treatment is necessary in order to protect the streams of the State against unreasonable or dangerous pollution.

In its work the State Water Survey does not attempt to act as consulting engineer, but, on the contrary, advises employment of competent consulting engineers by local officials. The Survey tries to serve as an unprejudiced advisory board and as a clearing house for information relative to water resources and stream sanitation. Though the work of the Engineering Division touches that of other State organizations duplication is avoided by close cooperation. Reference has already been made to the cooperation with the Rivers and Lakes Commission. The State Board of Health has requested assistance during 1915 in the study of the occurrence of typhoid fever at Gibson City, Money Creek Township, Oak Park, and Park Ridge. The State Game and Fish Conservation Commission have referred through the Rivers and Lakes Commission to the Survey for investigation and report complaints of gross pollution of streams causing the death of fish. Studies of this nature were made during the year of Kishwaukee River below Belvidere, Kishwaukee River below Dekalb, Sangamon River below Springfield, Stony Creek near Blue Island, and Turtle Creek at South Beloit.

Places that have been visited by members of the Engineering Division for the purpose of inspecting special conditions of waterworks or sewerage or places for which plans of proposed waterworks or sewerage have been examined are named in Table 6. The names of places visited or for which plans were examined in 1915 are printed in roman type. The names of places visited or for which plans were examined during previous years are printed in italic type.

TABLE 6.—PLACES VISITED OR PLANS EXAMINED FOR PROPOSED INSTALLATIONS OR IMPROVEMENTS OF WATERWORKS OR SEWERAGE, TO DEC. 31, 1915.

Albion	*Bradley*	*Decatur*
Altamont	*Breese*	*Deer Creek*
Alton	Bunker Hill	Deland
Anna	*Cairo*	Depue
Anna, State Hospital	*Camp Point*	*Duquoin*
Arthur	*Canton*	*East Peoria*
Ashton	Carlyle	*Edwardsville*
Assumption	*Carterville*	*Effingham*
Astoria	Casey	*Eldorado*
Atkinson	*Centralia*	*Elgin*
Aurora	*Charleston*	*Elmhurst*
Averyville	*Chester*	Eureka
Barrington	Chrisman	*Evanston*
Barry	*Clinton*	*Fairfield*
Belleville	*Colfax*	*Farmington*
Bellwood	*Collinsville*	*Flora*
Benld	Columbia	*Galena*
Benton	*Creal Springs*	*Galesburg*
Bloomington	Crete	*Geneseo*
Blue Island	Cuba	*Geneva*

Geneva, Illinois State Training School for Girls
Genoa
Georgetown
Gillespie
Girard
Glen Ellyn
Grand Ridge
Granite City
Grayslake
Greenville
Hamilton
Harmon
Harrisburg
Herrin
High Lake
Highland
Hillsboro
Jacksonville
Kansas
Keithsburg
Knoxville
La Rose
Lawrenceville
Leaf River
Leland
Lincoln, State School and Colony
Litchfield
McLean
Macon County Almshouse
Mansfield
Marion
Marissa
Matteson
Mattoon
Maywood
Melrose Park
Minonk
Moline
Monticello
Mound City
Mounds
Mount Pulaski
Mount Sterling
Mount Vernon
Neoga
New Athens
Nokomis
North Chicago
Oblong
Oglesby (See Portland)
Olney
Onarga
Palatine
Pana
Peoria Heights
Peoria, State Hospital
Petersburg
Piper City
Portland
Princeville
Rankin
Red Bud
Reddick
Roanoke
Roseville
Rushville
St. Anne
Salem
Sears
Sparta
Staunton
Stronghurst
Sullivan
Tinley Park
Tiskilwa
Toledo
Toulon
Tuscola
Villa Grove
Virden
Warsaw
Watseka, Iroquois County poor farm
Wenona
West Frankfort
Westville
Wheaton
Whitehall
Winchester
Witt
Yorkville

SPECIAL INVESTIGATIONS

Among the special investigations conducted in 1915, the most important of which were undertaken at the instance of the Rivers and Lakes Commission, the State Game and Fish Conservation Commission, or the State Board of Health, may be enumerated the following:

Ashley, Public wells. (p. 32).

Belleville, Nuisance by sewage disposal. (p. 34).

Belvidere, Alleged pollution of Kishwaukee River by gas-house wastes. (p. 34).

Blue Island, Pollution of Stony Creek and Calumet Lake. (p. 37).

Collinsville, Nuisance by sewage disposal. (p. 45).

Dekalb, Pollution of Kishwaukee River below Dekalb. (p. 57).

Bast St. Louis, Pollution of Cahokia Creek. (p. 63).

El Paso, Disposal of corn-canning wastes. (p. 66).

Galesburg, Pollution of Cedar Creek. (p. 72).

Gibson City, Typhoid fever. (p. 73).

Harrisburg, Pollution of public water supply by improper sewage disposal. (p. 79).

Homer, Pollution of private wells. (p. 86).
Lockport, Inspection of a private well. (p. 93).
Mendota, Treatment of gas-house wastes. (p. 97).
Minonk, Nuisance by disposal of sewage. (p. 100).
Money Creek Township, Typhoid fever. (p. 104).
Oak Park, Typhoid fever. (p. 112).
Oregon, Pollution of creek by wastes from a silica sand-washing plant. (p. 113).
Pana, Pollution of a tributary of Beck Creek. (p. 115).
Park Eidge, Epidemic of typhoid fever. (p. 287).
Pittsfield, Disposal of sewage at the high school. (p. 117).
Rock Island, Disposal of gas wastes. (p. 124).
Salem, Disposal of sewage from high school. (p. 128).
Somonauk, Stream pollution. (p. 130).
South Beloit, Pollution of Turtle Creek. (p. 130).
Springfield, Pollution of Sangamon River. (p. 251).
Streator, Pollution of Vermilion River. (p. 234).

EDUCATIONAL WORK

Educational work has included courses and lectures, by the Engineer, during the second semester of the school year to senior students on purification of water and treatment of sewage. Public addresses, by the Director, the Engineer, and Assistant Engineers were delivered in several cities and conferences were held with public officials.

ABSTRACTS OF ENGINEERING REPORTS

The following pages contain abstracts of detailed reports of various investigations made by the Engineering Division during 1915 and references by number and page to abstracts of reports made prior to 1915 and printed in preceding bulletins of the State Water Survey. These abstracts are arranged in alphabetical order by name of city, village, or town. References to abstracts in previous reports are given in parentheses after the title of each investigation. The abstracts have been prepared from the original reports by H. F. Ferguson, Assistant Engineer, and have been edited by R. B. Dole. Capacities of pumps, yields of wells, and consumptions of water are stated in gallons per 24 hours unless otherwise specified. Depths of wells are given in feet from the surface of the ground unless otherwise specified. It should be understood that estimates of capacity, yield, daily consumption, consumption per capita, discharge of sewage, and similar amounts are rounded off to avoid expression of fictitious accuracy.

ABINGDON. Water supply.—Bull. **11**, 28.)

ALBION. Proposed water supply.—(Bull. **10**, 89.)

ALEDO (2,144). Sewage disposal.—(Bull. **10**, 90.) Aledo was visited June 2 to inspect the sewage-disposal plant.

A sludge-drying bed, built during the spring, is about 30 feet square and has a layer of sand 6 inches thick on 3 feet of cinders underdrained with 6-inch tile. It had been used only once and has proved inefficient as the water failed to drain out readily. The cinders were probably too fine or contained ashes which compacted into a nearly impervious layer. The bed will probably be refilled with coarser material.

The mechanical parts of the plant were working satisfactorily. The siphons were discharging regularly and the distributors were applying sewage fairly uniformly to the filters. Because of frost the walls of the filters had bulged. They were supported temporarily by wooden props, which were later replaced by I-beams driven into the ground around the outside and against the walls of the filter with their tops tied together by rods across the filter. Frequent rains during the spring kept the stream below the outlet thoroughly flushed and there were no objectionable odors at the plant except over the filters. The effluent was only slightly turbid and the water in the stream was sufficient to dilute it to several times its volume. Men working in a near-by field stated that the stream at times became foul and was disagreeable to people living near it. No complaints have been made to the city officials.

ALEXIS (829). Water supply.—Visited October 26. Alexis is located near the northern border of Warren County in the drainage basin of Middle Henderson Creek. The village does not have sewerage, but a drainage system of open-joint tile, which has been installed primarily for ground-water drainage, has connected to it several overflows from cesspools.

Waterworks installed in 1895 consisted of a 100-foot drilled well, a steam pump, an elevated wooden tank, and a few mains. When the well proved inadequate a 1,204-foot well was drilled and this well is now in use. It is 10 inches in diameter at the top and terminates in a 4-inch bore in St. Peter sandstone. It is cased to 600 feet. The static level is about 70 feet below the surface. The steam pump was replaced in 1914 by a 100,000-gallon electrically driven deep-well pump, whose working barrel is about 140 feet below the surface. The pump discharges directly into the distribution system, and its operation is electrically controlled by a float in the elevated tank. The 47,000-gallon wooden tank is 20 feet high and is elevated on an 80-foot steel tower. The distribution system comprises 1,500 feet of 6-inch and 1,200 feet of 4-inch pipe. There are about 95 service connections, most of which are metered. No estimate of the consumption of water can be made as the pump is automatically controlled and no records are kept.

The only analysis of the water supply shows evidence of slight contamination, which may have taken place in collecting the sample as it was collected under difficulty. Nothing in the inspection of the plant showed that the water is contaminated. The total mineral content is 965 parts per million, and the total hardness is 295 parts per million. The content of iron is high, namely, 7.0 parts per million.

ALGONQUIN (642). Water supply.—Visited June 1. The water supply, which was installed about 1895, is obtained from rows of tile about one-fourth mile long laid at a depth of 4 or 5 feet in a hillside overlooking Fox River about one-half mile northeast of town. The black loam soil is underlain by a water-bearing gravel. The land directly over-lying and in the vicinity of the collecting tile is cultivated and used for pasturage. The water flows from the system of tiles into a 9,000-gallon concrete collecting reservoir 15 feet by 20 feet by 4 feet deep. It flows by gravity from the reservoir into the distribution system affording a pressure of 30 pounds in lower parts, but a much lower pressure in the higher parts, of the village. A 100,000-gallon reservoir 36 feet in diameter and 14 feet deep was built on a hill near the waterworks to furnish greater pressure for fires. It has a concrete bottom, cemented brick walls, and a conical wooden roof. The water is pumped into it from the collecting reservoir by a 144,000-gallon triplex pump. A pressure of 50 pounds is produced throughout most of the village. The distribution system, including the mains from the collecting reservoir, comprises 3.54 miles of 4-inch, 6-inch, and 8-inch pipe. A measurement made some years ago indicated an available supply of 700,000 gallons a day from the present source.

The water is of good sanitary quality. It has a mineral content of 329 parts per million, a total hardness of 292 parts per million, and contains only 0.07 part of iron.

ALGONQUIN. Sewerage.—Visited June 1. A sanitary sewerage system was installed in 1913 at a cost of $11,000. It serves the greater part of the village and contains 11,400 feet of 8-inch, 10-inch, and 12-inch vitrified pipe. The sewage is discharged into Pox River just below the village and no nuisance has thus far resulted.

ALTAMONT. Proposed water supply.—(Bull. **11**, 28.)

ALTON (17,528). Water supply.—(Bull. **9**, 15; **10**, 90; **11**, 29; **12**, 28.) Alton was visited April 6 to note the modifications and improvements in the purification plant then under way and to collect samples of water for analysis. As new parts were being constructed the regular chemical-feeding devises were out of commission, but temporary devices were being used with reasonably satisfactory results. The improvements consist of 2 new filter units, each having a daily capacity of 1,150,000 gallons. These are being built at the east end of the filter house in accordance with plans on file in the office of the Survey.

ALTON. Proposed additional sewers.—(Bull. **12**, 30.)
Nuisance complaint.—(Bull. **12**, 30.)

AMBOY. Water supply.—(Bull. **11**, 29.)

ANNA. Water supply.—(Bull. **9**, 15; **11**, 30.)
Sewerage.—(Bull. **9**, 15; **11**, 30.).

ANNA, State Hospital. Water supply.—(Bull. **9**, 15; **10**, 91; **12**, 30.) Visited April 8 and May 3-4. The filters had been gradually increasing in efficiency and no trouble was being experienced with discoloration of the filtered water by manganese. The grains of sand in the filter were becoming more heavily coated with manganese dioxide. Daily determinations of the manganese and bacterial content in the raw and filtered waters were being made. Complete details of the operation and efficiency of the filters are given on pages 193-9.

ANNA, State Hospital. Proposed sewage treatment.—(Bull. **12**, 32.)

ARCOLA. Water supply.—(Bull. **10**, 91.)

ARLINGTON HEIGHTS. Water supply.—(Bull. **12**, 32.)

ARLINGTON HEIGHTS (1,943). Sewage disposal.—(Bull. **10**, 91; **12**, 32.) Visited October 13. The sewage-treatment plant comprises a grit chamber, settling tank, a dosing chamber, and 6 intermittent sand filters. The settling tank has a total capacity of about 42,000 gallons. The dosing chamber discharges about 7,700 gallons at every dose and the filter beds have a combined area of 0.57 acre. Local officials estimate the flow of sewage at considerably more than 100,000 gallons a day, but the daily pumpage at the waterworks is only about 45,000 gallons. It is understood that there are certain overflow provisions between the storm-water and sanitary sewers and that storm water can enter the sanitary sewers during heavy rains. This has been detrimental to the sewage-treatment plant as this storm water carries with it oil used on the roads and tends to clog the filters. Until shortly before this visit the filter beds had not been in

Figure 1.—Waterworks pumping station, Arlington Heights.

service for several months because cracks had developed in the walls of the dosing chamber which prevented proper operation of the automatic siphons. The filter beds were free from vegetation and had the appearance of being well tended. The men working at the plant had been employed only a short time and were not entirely familiar with results of previous operation. The advisability of mounding or furrowing the surface of the beds to prevent trouble with ice during winter was pointed out to them.

ARTHUR. Water supply.—(Bull. **10**, 94; **12**, 33.)

ASHLEY (913). Public wells.—Visited July 7 at the request of the State Board of Health.

Ashley has no public water supply and private dug wells are generally used. One well, from which water is used by the public is about 50 feet from a privy. Examination of this water showed it to be contaminated. Another much-used well was satisfactorily situated and examination showed that water from it is safe. Both waters contained, however, about 2,000 parts per million of mineral matter. The curbings of the wells should be kept water-tight and the upper parts of the brick walls should be cemented.

ASHTON (779). Water supply.—Visited June 30.

Waterworks were installed in the fall of 1914 and the spring of 1915 at a cost of about $20,000. The supply is obtained from a 545-foot well, which enters St. Peter sandstone at 415 feet. The well is cased with 12-inch pipe to rock, into which it is drilled 8 inches in diameter. The static level is about 16 feet below the surface. The yield is not known, but when the pump is working 30 strokes a minute the water level is lowered below the working barrel, which is at 85 feet. Water is pumped from the well into the distribution system by a 400,000-gallon deep-well pump. A 50,000-gallon elevated steel tank is connected with the distribution system. The maximum lift of the pump is about 250 feet. The distribution system contains 2.84 miles of 4-ineh and 6-inch cast-iron pipe. About one-fourth of the population were using the supply and all services were metered.

The water is of excellent sanitary quality. It contains 423 parts per million of mineral matter and 0.3 part of iron, and it has a total hardness of 372 parts per million.

ASHTON. Sewage-treatment plant.—In response to a request November 1 an informal report was sent to the consulting engineers approving changes in the design of the settling tanks and filter beds for a proposed sewage-treatment plant at Ashton, but requesting that final plans and specifications including the proposed changes be submitted to the State Water Survey for approval before construction was started.

ASSUMPTION. Water supply.—(Bull. **11**, 31; **12**, 33.)
Sewerage.—(Bull. **11**, 32.)

ASTORIA. Water supply.—(Bull. **11**, 32.)

ATKINSON (805). Proposed water supply.—Visited May 20 at the request of the consulting engineer.

Atkinson owns an electric lighting plant, but has no waterworks or sewerage system. Shallow dug wells are used many of which may be polluted by privies or cesspools. A 180-foot well at the light plant, which enters rock at about 50 feet and is eased to 70 feet, is available as a supply. The yield of the well is not known. Its water is softer than that from the shallow wells. Its mineral content is 525 parts per million, its hardness only 75 parts, and its content of iron 0.6 part per million. If the citizens approve the water-supply project a test will be made to ascertain the yield of the well.

ATLANTA. Water supply.—(Bull. **11**, 33.)

AURORA. Water supply.—(Bull. **9**, 16; **11**, 34; **12**, 33.)

AVERYVILLE. Proposed sewerage.—(Bull. **12**, 34.)

AVISTON. Copper-sulfate treatment of reservoir.—(Bull. **11**, 34.)

AVON (865). Water supply.—Visited October 25. Avon is in the northwest part of Fulton County on Swan Creek, a tributary of Spoon River. Drinking water is obtained almost entirely from wells 14 to 50 feet deep. The village has no sanitary sewerage, but has an inadequate drainage system.

Waterworks were installed about 1890, the source of water being dug wells near the center of the village. A supply was later developed in the south part of town by damming a small slough. The reservoir thus formed has a storage of about 1,000,000 gallons and its drainage area is only one square mile. The village has several fire hydrants on a 6-inch pipe of the Chicago, Burlington & Quincy Railroad, which is supplied with water pumped from a ravine east of the village.

The public water supply now used is obtained from 2 dug wells in the northwest part of the village; one, 8 feet in diameter and 38 feet deep, is equipped with a 25,000-gallon single-acting pump with the working barrel at 15 feet; the other, 10 feet in diameter at the top, 8 feet in diameter at the bottom, and 52 feet deep, is equipped with a 2-cylinder single-acting 42,000-gallon pump. The wells arc walled with brick with lime-plaster joints, and they are 100 feet from each other. The water is pumped into a brick reservoir 26 by 22 feet and 10 feet deep, which has a capacity of 43,000 gallons. The pumping equipment at the electric light plant comprises a 360,000-gallon rotary pump belt-connected to a steam engine. At the pond a 360,000-gallon horizontal 2-stage centrifugal pump is belt-connected to an 18-horsepower electric motor. When the waterworks were installed 0.5 mile of 3-inch black iron pipe was laid, and a 6-inch cast-iron pipe now leads from the pond to the pumping station. There are 11 hydrants and 10 service connections. No record of consumption is kept. A 1,700-gallon wooden tank located in the pumping station is connected with the mains. It is 4 feet in diameter, 18 feet high, and elevated 12 feet above the ground.

No analyses of the waters have been made. The water supply is only used for fire protection and street sprinkling.

BABBINGTON. Water supply.—(Bull. **12**, 34.)
Proposed sewerage.—(Bull. **10**, 94.)

BARRY. Water supply.—(Bull. **12**, 35.)

BATAVIA. Water supply.—(Bull. **9**, 16.)

BEABD8TOWN. Water supply.—(Bull. **11**, 35.)
Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **11**, 35.)

BELLEVILLE. Water supply.—(Bull. **11**, 36.)

BELLEVILLE (21,122). Sewage disposal.—(Bull. **12**, 35.) Belleville was visited July 10 to testify before the Rivers and Lakes Commission regarding a complaint by a resident of Hecker against the city of Belleville on the pollution of Bichland Creek. The hearing was continued until additional data might be obtained, and Belleville was again visited October 11-12 and December 6-7 to make detailed inspections of Bichland Creek and to ascertain the nature of the different wastes that might pollute the stream.

The greatest pollution entering the creek is sewage from Belleville. There are 3 sewer outlets, one south and one east of the city into tributaries of Bichland Creek, and one northwest into a branch of Prairie du Pont Creek. A septic tank at each outlet removea part of the suspended solids. At the time of inspection pollution by sewage was noticeable in Bichland Creek for 6 miles below the city. Objectionable conditionsl in the creek at Hecker, 16 miles below Belleville, occur only occasionally during high-water stages because of movement downstream of sludge deposited a mile or so below the outlets of the sewers. Investigation of other sources of pollution, such as water pumped from coal mines and wastes from rendering establishments and breweries indicated that they are relatively unimportant in comparison with the city sewage. The water from the mines that actually reaches the creek was small in amount and unobjectionable in character. The wastes from the rendering plants are strong and objectionable, but amount to only 100 to 200 gallons a day. The wastes from the breweries, which are discharged into the city sowers, are weak and consist largely of wash water.

BELLWOOD. Water supply.—(Bull. **12**, 36.)

BELVIDEEE. Water supply.—(Bull. **11**, 36.)

BELVIDEBE. Alleged pollution of Kishwaukce Bivor by gas-house wastes.—(Bull. **11**, 36.) Belvidere was visited June 1-2 at the request of the Game and Fish Conservation Commission to determine whether the gas-house waste which emptied into Kishwaukee River caused objectionable conditions. The gas plant has an outlet into the city sewer, through which waste waters are sometimes discharged. This sewer empties into Kishwaukee River by a submerged outlet a few hundred feet above a dam which impounds water to a depth of 8 feet.

It was claimed that tar and oil could be seen in the river water at low stage and that although fish were not killed their meat acquired an objectionable taste and was unfit to eat. The river was considerably above normal on June 1, and inspection revealed no visible traces of objectionable pollution of water or banks. In July, 1914, however, the Survey made a sanitary survey of Eock River drainage basin, and observations were then made above and below Belvidere when the stream was comparatively low. A distinct odor of gas-house waste was noticed in the vicinity of the dam, and some oil was observed on the water. At two other points, three eighths and one-half mile below the dam, oil was seen, but 4 miles below there was no trace of it.

BEMENT. Water supply.—(Bull. 10, 95.)

BENLD. Proposed water supply.—(Bull. 12, 36.)

BENSON (362). Water supply.—Visited September 16. Benson is located in the north-central part of Woodford County in the drainage basin of Mackinaw River.

Waterworks, installed in 1889, comprised a dug and bored well 50 feet deep, a steam pump, a wooden tank on a brick tower, and a few mains. This well was abandoned about 1900 as its yield was inadequate. The well now used was then sunk. It is dug 20 feet in diameter to 20 feet, then 14 feet in diameter to 50 feet; then 2 holes, each 30 feet deep and cased with 2-inch pipe tipped with gauze strainers, were bored in the bottom. The wall of the dug portion is 13 inches thick; it is made of brick laid in lime plaster and is not water-tight. The well is in the east end of the pumping station and it is uncovered except for a few planks laid across for a passageway. A feed lot and a privy are within 150 feet and several privies are within 250 feet of the well. The static level during wet weather is 6 feet below the surface and during dry weather about 44 feet below the surface. The working barrel of the pump is placed at 48 feet. The yield thus far has been sufficient to meet the rather small demand. The steam pump was replaced after a few years by a pump driven by a gasoline engine. When the new well was put down this pump was replaced by the present deep-well pump and gasoline engine. The distribution system comprises about 4,800 feet of 4-inch and 6-inch cast-iron pipe. There are 30 service connections, all of which are metered. A 47,000-gallon wooden tank, 20 feet in diameter and 20 feet high on a brick tower 65 feet high, is connected to the distribution system. The average daily consumption of water is about 4,800 gallons. The public supply is used by about one-third of the population.

The supply is subject to contamination and the single analysis made by the Survey showed that the water at that time was grossly contaminated. It has a mineral content of 397 parts per million and a total hardness of 323 parts per million. There is only a traee of iron.

BENTON. Proposed improvement of water supply.—(Bull. 9, 16; 10, 95; 11, 38; 12, 36.)
Sewage treatment.—(Bull. 10, 96; 12, 37.)

BEEWYN. (Est. 9,000 in 1915). Water supply.—Visited October 14. Berwyn is in Cook County west of Chicago, of which it is a rapidly growing suburb. It has natural drainage westward and southward into Des Plaines River about one mile distant, but the city was recently brought into the Sanitary District and its sewage is now diverted into the Sanitary Canal.

Waterworks were installed about 1893 to serve the south end of the suburb. The north end of Berwyn a few years ago was made a separate water district and is supplied with water from Chicago. The population of the north end of Berwyn is about two-thirds that of the south end. Until 1912 the south end was supplied by a drilled well 1,605 feet deep near the center of the city. To meet increasing demand a second well was drilled 1,600 feet deep and 100 feet from the first well, but its yield was less than that of the first well. Both wells are 16 inches in diameter at the top and 5 and 8 inches in diameter, respectively, at the bottom and terminate in St. Peter sandstone. The yields of the wells have decreased during the past 3 years while the demands have increased. The static level, which was 113 feet below the surface in 1912, has gradually fallen to approximately 186 feet. Similar wells at Riverside have experienced similar drops in static level. In view of the shortage it has been recently decided to make another connection to the supply of Chicago to serve the south end. A 16-inch connection serves the north end and another main of the same size will be laid to the pumping station in the south end of Berwyn.

The older well is pumped by air lift and the nozzle is placed 297 feet below the surface, which gives a submergence of only 37 per cent. The new well is equipped with an 8-inch by 36-inch single-acting deep-well steam pump, and the water is pumped from both wells into a collecting reservoir. The head of more than 200 feet under which the deep-well pump works subjects it to severe strains that have frequently resulted in breakdowns. The 100,000-gallon reservoir is 35 feet in diameter and 14 feet deep, the walls extending 5 feet above the surrounding ground. It has a conical concrete roof. The high-service equipment comprises one 18½-inch by 9¼-inch by 10-inch duplex pump and a 12-inch by 17-inch by 10-inch by 15-inch tandem compound duplex pump. The combined capacity of the 2 pumps is about 2,000,000 gallons a day. The proposed main to the south end of Berwyn will end at the pumping station and arrangements will be made whereby the water delivered by it can be discharged either into the collecting reservoir, the suction of the high-lift pumps or the distribution system. For ordinary domestic service the Chicago pressure will probably be sufficient, but the collecting reservoir will be kept full and the high-service pumps will be held in reserve for fire service.

The distribution system comprises about 33 miles, about 20 miles of which is in the south end and 13 miles in the north end. The south-end system is entirely of 6-inch pipe with the exception of a 10-inch feeder from the pumping station through the central part of the city. The mains in the north end are also 6 inches in diameter with the exception of one mile of 12-inch feeder and the 16-inch connection with the Chicago system. There are, respectively, about 1,100 and 800 service connections in the south and north ends of Berwyn. Practically all services are metered. A 150,000-gallon steel standpipe 16 feet in diameter and 100 feet high is connected to the south-end system. This tank when full would maintain a pressure of 43 pounds at its base, but it is not kept full because of present shortage of water and a pressure of only 10 pounds was maintained during the summer at the pumping station in order to restrict consumption. The average daily pumpage in the south end is about 300,000 gallons, and the maximum is about 500,000 gallons. The north end of Berwyn now uses about 200,000 gallons a day.

The system in the south end has cost approximately $125,000, and that in the north end has cost about $55,000. The north end of Berwyn pays Chicago about 6 cents a 1,000 gallons for lake water.

One analysis of a sample collected in 1904 from the wells of Berwyn shows a total residue of 730 parts per million. The water is of good sanitary quality.

BLOOMINGTON. Proposed increase in water supply.—(Bull. **10**, 96; **12**, 37.)

BLUE ISLAND (8,043). "Water supply.—(Bull. **12**, 37.) Visited August 12. As the water supply of Blue Island, which is taken from deep wells, contains some gas the city has decided to abandon it and buy water from Chicago. A 16-inch line has been laid from Chicago to the boundary of Blue Island and attached to 10-inch and 8-inch distributing pipes. It is planned eventually to extend the 16-inch line to the center of the city. As the pressure from Chicago will probably not be more than 30 pounds, it is planned to install centrifugal booster pumps to increase the pressure when necessary. The cost of pumping the well water is said to be 5.9 cents per 1,000 gallons; Chicago water will cost 6¼ cents per 1,000 gallons beside the additional expense of operating the booster pumps.

BLUE ISLAND. Pollution of Stony Creek and Calumet Lake.—Visited February 3. Blue Island, a suburban district of Chicago, is in Cook County on the city line about 9 miles southwest of the entrance of Grand Calumet River into Lake Michigan.

Stony Creek, a small stream entering Little Calumet River just east of Blue Island, has two main branches. The south branch, on which the factories producing the objectionable wastes are located, has a drainage area of 22 square miles above its junction with the north branch. The wastes from the wire-netting factory of the Gilbert Bennett Manufacturing Co. consist mostly of wash waters containing iron and lime and sulfuric acid. The spenti acid pickle, which is the most objectionable waste, is neutralized with scrap iron to produce copperas in sufficient quantity to pay the cost of recovery. The lime solution, used to neutralize the acid left on the iron after the acid pickle, is discharged on the ground about once a month, where it mixes with the waste wash water, which is discharged daily. This waste amounts to about 400 to 600 gallons of liquid made by treating 3 to 5 barrels of lime with water. The wastes from the crude-oil refinery of the Consumers Mutual Oil Co. comprise chiefly wash water containing some oil. The condensing water used to cool the distillates is detained in a settling tank about 14 feet by 8 feet by 5 feet deep, from which the oil that rises is irregularly pumped. Some oil, however, is not recovered and runs into the creek. The most objectionable wastes are those from the caustic soda scrubbers. This waste is yellowish brown, is coated with brown and black scum and has a thick oily consistency. The sulfuric acid wash waters are discharged into 2 wooden tanks in the ground. What eventually becomes of this waste could not be ascertained. The wastes from this plant are not large in volume but they are very objectionable.

At the time of inspection the creek was covered with ice except near the outlets of the drains. Any pollution from the wire factory was covered by the spreading oil wastes. The water could not have been made very acid by the wire-factory wastes for the condensers in the oil refinery are not pitted though the water forms hard scale in the boilers. Installation of a settling tank large enough to hold 2 days' waste from the wire plant would be beneficial in reducing any hardness from that factory as it would provide a place in which the acid wash waters and the pickling wastes could be neutralized by the lime wastes.

The oil-refinery wastes produce an objectionable pollution that coats the water with oil and fringes the banks a mile downstream with a thick brownish oily waste. More attention should be given to the settling tank, and the caustic wash waters should not be discharged into the creek.

Pollution entering Calumet Lake at 115th Street from a paint factory was claimed to have caused the death of fish. The wastes at one outlet from the plant are greenish when they enter the lake, but they produce a brownish-red coloration by mixing with the lake water and other pollution. The lake had been frozen over except near the outlets of the drains, and fish have sought these open places for air. The undiluted or only slightly diluted wastes there have killed the fish. The banks were covered with small dead fish and those observed swimming were partly overcome.

These objectionable pollutions could undoubtedly be prevented by suitable settling tanks, and filters. The Survey is prepared to assist the factories in devising means for rendering the wastes unobjectionable.

BLUE MOUND. Water supply.—(Bull. **12**, 38.)

BEACEVILLE. Water supply.—(Bull. **12**, 39.)

BRADLEY. Proposed sewerage.—(Bull. **11**, 38.)

BEAIDWOOD. Water supply—(Bull. **12**, 39.)

BEEESE (2,128). Water supply.—(Bull. **9**, 16; **11**, 39; **12**, 40.) Visited April 2 and 15. Breese has been visited several times principally to inspect the water-purification plant and to encourage the city to improve it. The purification comprises only coagulation and sedimentation. Lime and iron are used as coagulants, but the dissolving tanks are dilapidated, and satisfactory equipment for applying the chemicals to the raw water has never been installed.

The plant is not only inadequate to yield satisfactory water but the method of operation does not produce the best water obtainable under the circumstances. It was suggested that new solution tanks and satisfactory feeding devices be installed and that alum be tried as a coagulant instead of lime and iron. The present operator of the plant does not favor alum as he fears that it makes the water hard. As a matter of fact proper use of alum does not increase the total hardness but merely converts part of the carbonate hardness into sulfate hardness. Sulfate hardness is, of course, more objectionable than carbonate hardness in waters used in steam boilers, but the slight change in this water would be negligible.

The city recently installed a service connection leading from the raw-water main at the water-treatment plant to the pipe supplying the tank of the Baltimore & Ohio Eailroad. This diverts raw water directly to the tank of the railroad and thus reduces the burden on the settling basin by approximately 100,000 gallons a day as heretofore the railroad has been supplied with settled water. During spring and autumn, when the water is most likely to be muddy, the plant will be required to purify as much as 150,000 gallons a day. The period of sedimentation afforded by the settling basin for this quantity is 35 hours. During summer consumption is greater but the raw water is less turbid and more readily clarified. A clear safe water, however, cannot be obtained with the present equipment and the city should plan to improve the plant and especially to install sand filters.

BROOKFIELD (2,186). Water supply.—Brookfield derives its water supply from Lagrange.

BROOKPOET (1,443). Water supply.—(Bull. **11**, 40.) Visited July 12. Brookport is located on Ohio River at the southern edge of Massac County. In the spring of 1913 when the river reached the highest stage ever recorded a small portion of the city was inundated. About two-thirds of the population still depends for water supply on private wells and cisterns. Such wells are generally dug 30 feet deep into a vein of sand below clay. There is no public sewerage but a few private drains have been installed.

Waterworks were installed in 1907 mainly for fire protection at a cost of about $8,000. Electric light equipment was added at the station in 1911. The water is obtained from a drilled well 226 feet deep and 8 inches in diameter near the center of the city. The last 60 feet of the well is in fine white sand and a Cook screen 18 feet long has been installed. Sand is occasionally raised with the water. The static level is 18 to 20 feet below the surface and is not lowered much, by prevailing rates of pumpage. Water is pumped directly from the well into the distribution system by a steam-driven deep-well pump of unknown capacity. The pump is operated 7 to 14 hours a day. The distribution system installed consists of one line of pipe, 6, 8, and 10 inches in diameter, laid in a centrally located street east and west to the city limits. , Groups of citizens tapped the city main and have installed laterals of ½-inch and 2-inch galvanized-iron pipe in several streets. A serious defect in the distribution system is absence of cut-off valves. A 60,000-gallon hemispherical-bottomed elevated steel tank serves as an equalizer and furnishes pressure when the pumps are not being operated. The bottom and top of the tank are, respectively, 90 and 130 feet above the ground. A wide variation in water level is permitted and there are at times only 5 feet of water in the tank. About one-third of the population use the public supply. Many houses have only yard hydrants, some of which serve two or more dwellings though each user pays the regular flat rate of $6.00 a year. The average daily consumption is estimated at 30,000 gallons.

The water is of good sanitary quality and comparatively soft. It has a mineral content of 257 parts per million and a total hardness of 223 parts. The iron content is 0.4 part per million.

BUCKLEY (495). Water supply.—Visited June 1. Buckley is in the southwest part of Iroquois County in the drainage basin of Spring Creek, a tributary of Iroquois River. The city has no sewerage system, but overflows from cesspools reach several ground-water drains.

Waterworks, first installed about 1889, comprised a dug well 35 feet deep, a pump operated by a windmill, a small wooden tank and tower, and about 800 feet of 3-inch galvanized-iron pipe. In 1893 a 147-foot well 4 inches in diameter was drilled into sand and gravel above a thin layer of hardpan in the drift. It was cased to 142 feet, and a Cook screen 5 feet long was placed at the bottom. The water flowing from this well was collected in a brick reservoir made from the old dug well. The windmill was replaced by a gasoline engine in 1894 and a deep-well pump was installed in the drilled well and a wooden tank erected on a steel tower in 1907. A second well similar to the first was drilled about 1912. When the Central Illinois Utilities Co. purchased the village electric plant in 1913 and entered into a 10-year contract for pumping the water supply, an electric motor was installed to operate the pumps. The present pumping equipment comprises two 45,000-gallon deep-well pumps. The static level is now about 10 feet below the surface, and the working barrels of the pumps are placed at 25 feet. The water is pumped from both wells directly into the distribution system, which comprises 2 miles of 6-inch and 4-inch cast-iron pipe and 800 feet of 3-inch galvanized pipe. There are about 100 service connections, all of which are metered. A 34,000-gallbn wooden tank, 18 feet in diameter and 18 feet high elevated on a steel tower to a total height of 80 feet, is connected to the distribution system. The pumpage, which is measured by 2 meters, one on the discharge from each pump, averages 7,500 gallons a day with a maximum of about 20,000 gallons a day. The supply is used by approximately one-third of the population.

The water is of good sanitary quality. It has a total mineral content of 1,092 parts per million and a total hardness of 748 parts per million. The content of iron, 1.4 parts per million, is sufficient to cause stains on plumbing fixtures and fabrics laundered in the water.

BUDA (887). Water supply.—Visited August 31. Buda is situated in the southwest part of Bureau County in the drainage basin of Coal Creek, a tributary of Green River. There is no sewerage system and leaching cesspools are generally used.

Waterworks were installed in 1896. The supply is obtained from a well 1,612 feet deep, the lower 140 feet being in St. Peter sandstone. The well is 8 inches in diameter for the first 336 feet, below which it is 6 inches in diameter; it is cased for 483 feet. The static level in 1899 was 125 feet below the top[1]; the superintendent gave the present static level as about 160 feet. This drop is equivalent to 2.2 feet a year. The pumping station is erected over the well on the same lot with the standpipe and the reservoir. A 360,000-gallon double-acting deep-well pump with a lift of about 160 feet and its working barrel at 212 feet is operated in the well. A 500,000-gallon triplex pump serves the high service. Both pumps are belt-connected to a horizontal single-cylinder 22-horsepower gasoline engine. The deep-well pump discharges into a 28,000-gallon covered concrete collecting reservoir, 20 feet in diameter and 12 feet deep, built partly in excavation and partly in embankment, the walls being sufficiently high to exclude surface water. A steel standpipe 10 feet in diameter and 100 feet high is connected with the distribution system. Practically the entire population is said to use the supply, and 4-inch, 6-inch, and 8-inch mains extend throughout the built-up portions of the village; a few wrought-iron pipes provide domestic service for small isolated neighborhoods.

The water has not been analyzed, though unsuccessful efforts to obtain samples have been made.

BUNKER HILL (1,046). Proposed water supply.—Visited September 25-26. Bunker Hill is in the southern part of Macoupin County in the catchment area of Sweet Creek, a tributary of Mississippi River. Its prosperity depends on coal mining. A manufacturing company in search of a site agreed to locate in Bunker Hill if an adequate supply of water was available, and prospecting for a water supply was, therefore, begun near a coal mine one mile east of town.

Two wells 8 inches in diameter were sunk. Rock was encountered at 50 feet, and water was obtained after penetrating this rock a few feet and shooting the wells. A short test with a pump of small capacity indicated that a well might yield 50,000 gallons a day. A larger pump had just been received at the time of inspection and a longer test pumping at a greater rate is to be made. The Survey agreed to send containers for the collection of samples for mineral analysis when the second test is made. In a third well sunk about one-half mile south of the other two wells rock was encountered at 25 feet, but the well yielded no water. A few feet from the third well the rock formation forms the bed of a creek.

[1]Leverett, Frank, The Illinois glacial lobe: U. S. Geol. Survey Mon. 38, 628 (1899).

BUREAU (534). Water supply.—Visited September 2. Bureau is in the southeast corner of Bureau County in the valley of Illinois River about a mile west of the stream. The town has no sewerage system.

Waterworks were installed in 1899. One drilled well flowed directly into a system of 3-inch wrought-iron pipe under a pressure of about 30 pounds, or sufficient to supply the lower district. A second well was connected in 1910 and the distribution system was rebuilt with 4-inch cast-iron pipe. The wells are about 305 feet deep and 4 and 5 inches, respectively, in diameter. They penetrate 135 feet of drift, enter the Coal Measures, and probably derive their supply from limestone. The natural pressure of about 30 pounds has decreased apparently but little since the wells were first drilled. A single-cylinder 57,000-gallon double-acting pump delivers water to the higher districts. This pump is belt-connected to a 3-horsepower motor and is controlled by an automatic switch which starts and stops the motor at 20- and 50-pound pressures, respectively. A steel air-pressure tank 42 inches in diameter and 14 feet long in the pumping station is connected with the high-district mains. It has a capacity of about 1,000 gallons, of which approximately 430 gallons is used between the pressures of 30 and 50 pounds. Practically the entire population is served by the system. The system of mains includes about 5,000 feet of 4-inch cast-iron pipe. There was practically no cost of operation before installation of the high-district pumping station. Water is supplied free of charge to anyone making the necessary connections to the mains and it is understood that there is no intention of changing this policy.

The water is of good sanitary quality. It contains, however, 2,026 parts per million of mineral matter and 1.2 parts per million of iron. Though the total hardness is only 75 parts per million the content of chloride is great enough to give the water a distinctly brackish taste.

BUSHNELL. Water supply.—(Bull. **12**, 40.)
Sewerage.—(Bull. **9**, 17; **12**, 41.)

BYRON. Water supply.—(Bull. **11**, 40.)

CAIRO (14,548). Water supply.—(Bull. **10**, 96; **11**, 40; **12**, 42.) Cairo was visited April 8 to inspect the operation of the water-purification plant and to collect samples of water for analysis. The analyses indicated very satisfactory bacterial reduction. The general appearance of the waterworks has been greatly improved by the removal of near-by unsightly shacks. The low-lift pumping equipment has been improved by installation of a 5,000,000-gallon centrifugal pump.

CALUMET RIVER. Pollution of Grand Calumet River and Calumet Lake.—(Bull. 12, 42.)

CAMBRIDGE. Water supply.—(Bull. **10**, 96.)

CAMP POINT. Proposed water supply.—(Bull. **11**, 41.)

CANTON. Proposed improved water supply.—(Bull. **11**, 41; **12**, 43.)
Sewage-disposal nuisance.—(Bull. **9**, 17.)

CARBON HILL. Water supply.—(Bull. **12**, 44.)

CARBONDALE. Water supply.—(Bull. **11**, 42.)

CARLINVILLE. Water purification.—(Bull. **10**, 97; **12**, 44.)

CARLYLE (1,982). Proposed water-purification plant.—(Bull. **9**, 17; **11**, 43.) Carlyle was visited April 2 for a conference with the city officials. The water-purification plant will probably not be installed in the near future as a $10,000 bond issue for a filter plant failed to pass last year. More recently a

$5,000 issue has been authorized for extension of water mains and a new pump. Extension of sewers at a cost of $21,000 is under way, and the city still has a bonding capacity of $10,000. The distribution system includes 5.65 miles of 4-inch, 6-inch, and 8-inch pipe. The estimated value of the waterworks is $35,400. The average daily consumption in 1915 was 280,000 gallons.

CABLYLE. Sewerage.—(Bull. **12**, 45.)

CAEMI. Water supply.—(Bull. **11**, 44.)

CARPENTEBSVILLE (1,128). Water supply.—Visited June 2. Carpentersville is on Fox River in the northeast part of Kane County. There is no sewerage system.

Waterworks were installed in 1914. The supply is obtained from a well 19 feet in diameter and 17 feet deep which taps coarse water-bearing gravel overlying limestone. The water level is kept 6 feet below the surface by an overflow

Figure 2.—Well house and pumping station, Carpentersville.

to Fox River. It is understood that the level was lowered to 13 feet when the well was pumped at the rate of 250 gallons a minute, but that it could not be drawn below that point. The well has a conical roof and an 8-inch concrete wall, extending from 16 inches above ground to the bottom of the well, surface drainage being thus excluded. One 500,000-gallon triplex pump, direct-connected to a 25-horsepower motor and drawing against a suction lift of 7 to 14 feet, delivers the water into the mains against a pressure of 68 pounds per square inch. A 30-horsepower 2-cycle gas engine is also direct-connected to the pump. The distribution system includes 5.45 miles of 4-inch, 6-inch, 8-inch, and 10-inch cast-iron pipe. A 60,000-gallon steel tank on a 75-foot steel tower, erected on a hill, affords a pressure of 68 pounds at the pumping station and 38 pounds at one of the highest points in town. Only 70 services have yet been installed and the pump is operated only about one hour a day, which indicates a daily consumption not exceeding 15,000 gallons. All services are metered. The waterworks cost $36,000.

Analysis indicates that the supply is safe for drinking. It was stated that the water contained large quantities of air when first drawn. The rather high turbidity of tho sample suggests the presence of iron. The total residue on evaporation was 460 parts per million.

CARROLLTON. Water supply.—(Bull. **11**, 44.)

CAETEEVILLE. Proposed water supply.—(Bull. **12**, 45.)

CARTHAGE. Sewage disposal.—(Bull. **10**, 99.)

CASEY (2,157). Proposed water supply.—(Bull. **10**, 100.) Visited January 21. Casey voted to issue $60,000 in 6 per cent bonds for development of a new water supply. Two shallow 15-ineh wells are to be sunk beside Embarrass River 10½ miles southwest of Casey and 2 miles north of Greenup. A 6-inch test well is said to have penetrated limestone between 41.5 and 47.5 feet and to have entered 5 feet of gravel. The entrance of gravel below limestone is improbable and the well is doubtless entirely in drift. A 3-inch centrifugal pump throwing 50 gallons a minute did not lower the water level in this well during a 5½-hour test. The existing waterworks had not been in operation since August, 1914, because of shortage of water and water was being shipped into town.

CEDAR POINT. Water supply.—(Bull. **11**, 45.)

CENTRALIA (9,680). Water supply.—(Bull. **10**, 102; **11**, 45; **12**, 46.) Centralia was visited April 14 to inspect the operation of a hypochlorite plant which had been installed as a result of recommendations by the State Water Survey. A small steam-driven pump had been installed to pump the solution of hypochlorite in place of the water motor formerly used. It was suggested that a proper container for the chloride of lime be installed in order to prevent deterioration, and that the dosage be increased to a minimum of 10 pounds per 1,000,000 gallons. The sterilization plant was in good working order, but the raw water was very turbid and showed the need of filtration.

CENTRALIA. Sewerage.—(Bull. **10**, 102; **12**, 46.)

CERRO GORDO. Water supply.—(Bull. **12**, 46.)

CHADWICK. Water supply.—(Bull. **11**, 46.)

CHARLESTON (5,884). Water supply.—(Bull. **10**, 103; **11**, 46,; **12**, 47.) Charleston was visited April 16 to inspect the operation of the filtration plant and to collect samples of water for analysis. The raw water was comparatively clear and the chemical tanks had been allowed to run dry and no chemical was being applied. The general appearance of the plant showed neglect. A disinfecting agent such as hypochlorite is not used, and it was said that there was even strong local sentiment in favor of shutting down the filter plant entirely during periods of low turbidity of the raw water.

CHATSWORTH. Water supply.—(Bull. **9**, 17.)

CHENOA. Water supply.—(Bull. **9**, 17; **12**, 48.)

CHERRY (1,048). Water supply.—Visited September 1. Cherry is in the east part of Bureau County in the catchment area of Negro Creek, a tributary of Illinois River.

Waterworks were installed about 1911. The supply is obtained from a well 6 inches in diameter and 98 feet deep, terminating in a bed of sand and gravel just above bedrock. The yield is not known, but it has been sufficient to meet the small demand. Water and oil that is allowed to accumulate in a concrete pit about 5 feet deep around the top of the well, produces an objectionable condition. The water is pumped from the well directly into the distribution system by an electrically driven 140,000-gallon deep-well pump. Frequent breakdowns in the machinery have cut off the supply at times. The distribution system comprises about 3 miles of 4-inch and 6-inch cast-iron pipe, which covers nearly all the built-up section of the village; only about 20 per cent of the population, however, use the public supply. All the services are metered. A 100,000-gallon elevated steel tank having a total height of 115 feet is connected to the distribution system. The waterworks cost about $16,000.

The water is of good sanitary quality. It has a mineral content of 700 parts per million, a total hardness of 395 parts per million, and contains 2 parts per million of iron. The iron is sufficient to stain plumbing fixtures and laundered fabrics.

CHESTER. Water supply.—(Bull. **9**, 18; **11**, 47.)

CHICAGO HEIGHTS. Water supply.—(Bull. **11**, 47.)
Sewerage.—(Bull. **11**, 48.)

CHILLICOTHE. Water supply.—(Bull. **12**, 49.)
Pollution of Illinois River by Chicago Drainage Canal.—(Bull. 9, 19; **11**, 50.)

CHRISMAN (1,193). Proposed sewerage.—(Bull. **11**, 50.) Chrisman was visited May 14 at the request of the city officials for advice relative to proposed sewerage and drainage.

Chrisman has had a water supply since 1905, but no sewerage has yet been installed though private and city storm drains have been used. The city officials desired to install necessary drains and sewers in several streets before paving them, and they were undecided whether to build combined or separate sewerage.

The city drains into small branches of Brouilett Creek, which in turn is tributary to Wabash River. The watercourse into which sewage would be discharged has a very small catchment area and has no flow during prolonged dry weather. Treatment of the sewage will, therefore, be necessary in order to prevent nuisances; on this account it waB recommended that separate systems of sanitary sewers and surface drains be installed. Surface drains can discharge into the watercourses at the most convenient points, and the sanitary sewer can be constructed with one outlet at a site suitable for a treatment plant on the bank of the creek northeast of the city.

CISSNA PARK (652). Water supply.—Visited June 5. Cissna Park is in the extreme southern part of Iroquois County in the drainage basin of Spring Creek, a tributary of Iroquois River.

Waterworks, installed in 1894, comprised a flowing well, a collecting reservoir, an elevated tank, and a plunger pump driven by a gasoline engine. A second well was drilled in 1906 because of decreased flow of the well and increased demand for water. A concrete collecting reservoir was built in 1907 and a triplex pump was installed to replace the old pump. A new wooden tank was placed on the old brick tower in 1911. The 2 wells are both 5 inches in diameter, 150 feet and 237 feet deep, respectively, and are cased to the bottom without screens. They are about 25 feet apart and derive their supplies from different strata of sand and gravel. The older and shallower well is in the bottom of a 14,000-gallon brick collecting reservoir, 15 feet in diameter and 11 feet deep, whose walls extend about 18 inches above the ground and are surmounted by a conical shingled roof. The newer reservoir, of reinforced concrete with a flat concrete roof, is 28 feet 10 inches in diameter and 9 feet deep and its walls extend about 2 feet above the level of the ground. The capacity to the flow line is 41,500 gallons. The deeper well discharges into this reservoir, but both reservoirs are connected by a 6-inch pipe and the suction from the pumps extends into the older reservoir. The pressure in the wells is sufficient to fill the reservoirs to within a few inches of the tops and the flow normally exceeds the consumption. The water is pumped from the reservoirs into the distribution system by a 250,000-gallon triplex pump driven by a gasoline engine operated 4 to 6 hours a day. The distribution system comprises 3.5 miles of 4-inch, 6-inch, and 8-inch cast-iron pipe. There are 113 service connections, three-fourths of which are metered. A 47,000-gallon wooden tank, 20 feet in diameter and 20 feet high, elevated on an 82-foot brick tower is connected to the distribution system. The daily consumption ranges between 40,000 and 65,000 gallons.

Analyses show that the water is of good sanitary quality. It has a mineral content of 442 parts per million and a total hardness of 364 parts per million. The content of iron is 0.5 part per million.

CLINTON. Contamination of water supply.—(Bull. **12**, 50.)

COAL CITY. Water supply.—(Bull. **12**, 50.)

COLFAX. Proposed sewerage.—(Bull. **11**, 51.)

COLLINSVILLE. Water supply.—(Bull. **10**, 104.)
Typhoid fever.—(Bull. **12**, 51.)

COLLINSVILLE (7,478). Sewage disposal.—(Bull. **10**, 104; **11**, 51; **12**, 50.) Collinsville was visited May 10 at the request of the Rivers and Lakes Commission to investigate a complaint of a nuisance caused by the discharge of the city's sewage into a small stream and on July 9 to testify at a hearing held by the commission.

The disposal of sewage from Collinsville had previously been studied by the Survey, and the city officials had been advised as to the steps necessary to eliminate the existing objectionable conditions. At present there are 2 sewer districts. The first district, built in 1907 and serving the business district and part of the residential district, has an outlet northwest of the city into a small creek tributary to Schoolhouse Branch, which is tributary to Cahokia Creek. The second district, built in 1910 and serving the south-side residential district, has an outlet southwest into a tributary of Canteen Creek which is also tributary to Cahokia Creek. Another district with an outlet east of town has been proposed, but construction of it has not been commenced. A septic tank at each outlet removes only part of the suspended matter, and the effluents are highly putrescible. The flow from the second district has been small and has caused little complaint; The sewage from the first district has been the cause of considerable complaint and on two different occasions the city in trying to remedy the conditions has extended the outlet further downstream at a cost of about $2,000. This extension was disapproved by the Survey as it fails to remedy the actual conditions, merely transferring the nuisance downstream. The city has also paid $400 in damages to a complainant and is now threatened with a suit by a second complainant farther downstream.

No stream in the vicinity of Collinsville can permanently and successfully care for the sewage by dilution. The makeshift relief heretofore employed in extension of outlets has proved ineffective and uneconomical. Collinsville is having a substantial growth and it should study and solve its sewerage and sewage-disposal problems on a comprehensive basis.

COLUMBIA (2,076). Proposed water supply.—(Bull. **10**, 105; **11**, 51; **12**, 51.) Visited April 5 and June 5. Conferences were held with city officials and with the engineers for the city. Plans of proposed improvements at Columbia were received March 29. It is proposed to make a $10,000 bond issue this spring to cover the cost of a well, pumping equipment, and elevated tank and to levy a special assessment for laying water mains. The estimated cost of waterworks is $28,000.

It is proposed to obtain water from a well near the shaft of an old coal mine in the southwest part of town. The top of a 40-foot test well is on a hill 20 feet from the bottom of the slope. The mine shaft is 10 feet by 50 feet deep. The engineers proposed to increase the hole to a diameter of 12 feet and to sink a masonry wall on a steel shoe into the water-bearing stratum. The hole now probably extends nearly to bedrock. The ground around the well will be cut down 12 feet and leveled so that the depth of the well from that elevation will be 38 feet. A platform in the well at 21 feet will support two 290,000-gallon triplex pumps operated by extension rods from motor-driven power heads at the surface. The water-bearing stratum consists of drift ranging in size from fine sand to large boulders. If the finer sand is removed this material should; constitute an ideal strainer. The sand tended to drift to the bottom during a pumping test of the old shaft; this should improve the yield of water if it is allowed to continue as it would reduce friction head. It would be well, therefore, to leave a few large openings in the bottom of the wall in order that the finer sand can drift into the well. The proposed distribution system includes 5.7 miles of 2-inch to 8-inch pipe and a 75,000-gallon elevated tank near the business section. In approving the plans April 13 attention was called to the possible inadequacy of the supply, but it was suggested that the supply be augmented by gravity, if necessary, by water from Hill Spring.

The water from the 40-foot test well contains 675 parts per million of mineral matter and 1.5 parts of iron; the water from Hill Spring contains only 422 parts per million of mineral matter and 0.2 part of iron.

COLUMBIA. Proposed sewerage and sewage treatment.—Visited April 5. The proposed sewerage includes 5.2 miles of 6-inch to 12-inch tile. The sewers are planned to converge to one outlet in the west end of the village, where a deep ravine and natural watercourse leads westward three-fourths mile to Carr Creek, a tributary of Mississippi River. Foul conditions would doubtless arise if the sewage were not first purified as the ravine would afford no dilution during most of the year. The site chosen for the treatment plant can be seen from a public highway only 300 feet away and it was, therefore, advised that a more secluded site about 100 yards farther down the ravine be secured.

The plans provide for a settling tank and contact beds. A 12,600-gallon tank, 7 by 40 feet by 6 feet deep, is proposed. The average flow of sewage should not exceed 100,000 gallons a day for several years at which rate this tank will afford a detention period of about 3 hours. The plans show a horizontal-flow coke filter at the outlet end of the tank, but specifications regarding it have not been submitted. The bed of coke is about 3½ feet deep and is contained between 2 vertical ½-inch mesh screens, 7 feet apart. Four contact beds, each about 0.03 acre in area and 4 feet deep, are to be arranged around a central dosing chamber; this gives almost one-half acre-foot of contact material. These contact beds are inadequate for reasonable growth, and the arrangement does not provide for future extension, though the plans are not sufficiently detailed to show exactly the intentions of the engineers.

The proposed sewerage was approved, but the proposed sewage-treatment works were not approved. The septic tank would probably produce a satisfactory effluent for contact treatment at most times, but it will promote a septic condition of the sewage unfavorable to proper nitrification. It was recommended that installation of a 2-story Imhoff tank be considered. Investigation indicates that it would be permissible at present to locate the outlet 100 yards farther downstream and to discharge the sewage into the stream after passing it through a well-constructed sedimentation tank, but it should be clearly borne in mind that this will not prevent objectionable conditions in the stream and that the city must adopt more complete purification when the pollution becomes objectionable to riparian owners downstream.

COOK, County poor farm. Sewage disposal.—(Bull. **11**, 52.)

CEEAL SPRINGS. Water supply.—(Bull. **11**, 52.)

CRESCENT CITY (341). Water supply.—Visited June 3. Crescent City is in the center of Iroquois County in the drainage basin of Spring Creek, a tributary of Iroquois River. The glacial drift in this vicinity is somewhat more than 150 feet thick and consists mostly of alternate layers of clayey till and beds of sand. There are about 90 flowing wells 90 to 150 feet deep in the village. In the lower parts of the village the head of these wells is 4 feet above the surface. A very complete drainage system for surface and ground water has been built but house connections to it are permitted.

Waterworks were installed about 1892 and comprised 2 flowing wells 1¼ inches in diameter, a wooden collecting reservoir, a pump operated by a windmill, a wooden elevated tank, and a few hundred feet of mains. About 1903 a 4-inch well was sunk, a steel tank and tower were erected, and a new wooden collecting reservoir and a gasoline-driven pump were installed. As the new well did not yield enough water another 4-inch well, from which the supply is now obtained, was drilled in 1908. It is 120 feet deep and derives its supply from strata of sand and gravel in the drift. The water flows into a wooden collecting reservoir built in excavation outside the pumping station. The flow has decreased slightly since the well was put down, but it still exceeds the requirements of the village, and the excess is allowed to waste. The reservoir, built of cypress, is 15 feet in diameter and 8 feet deep, and has a capacity to the flow line of 10,000 gallons. The side walls are only a few inches above the ground and are surmounted by a dilapidated conical shingle roof. The water is pumped from the reservoir into the distribution system by a 152,000-gallon single-cylinder double-acting pump belt-connected to a gasoline engine. The distribution system comprises about 7,000 feet of 4-inch cast-iron pipe and 80 feet of 6-inch pipe extending to the elevated tank. There are 32 service connections, all of which are metered. The elevated tank has a capacity of 50,000' gallons and the height to the top is 100 feet. The estimated average daily consumption is 3,600 gallons. The estimated cost of the waterworks is $11,000 and the annual cost of operation is about $162.

Analysis of the water showed it to be of good sanitary quality at the time of collection. The covering of the collecting reservoir, however, is in a poor state of repair and its walls have probably deteriorated as it has been in service for 12 years. The water has a mineral content of 490 parts per million, a total hardness of 367 parts per million, and a content of iron of 1.5 parts per million.

CEETE (840). Water supply.—Visited June 29. Crete is in the east part of Will County on Thorn Creek, a tributary of Little Calumet River. The drift is generally about 100 feet thick, though in the lower parts of the village roek is encountered at 60 feet.

Waterworks were installed in 1903. The supply is derived from a drilled well 10 inches in diameter and 192 feet deep terminating in limestone. Eock was encountered at 100 feet and the well is cased to 150 feet. The static level is about 30 feet below the surface. The yield is not known, but it is sufficient to meet demands. The water is pumped from the well into the distribution system by a 134,000-gallon deep-well pump, whose working barrel is placed at 80 feet. The pump is driven by current obtained from the Public Service Company of Northern Illinois. The distribution system comprises 2.65 miles of 4-inch, 6-inch, and 8-inch cast-iron pipe. There are only 32 service connections, all of which are metered. About one-fifth of the population uses the public supply. A 60,000-gallon elevated steel tank 22 feet high is connected to the distribution system. The height to the top of the tank is 120 feet. The average daily consumption is about 11,000 gallons. The total cost of the waterworks was about $15,000 and it costs about $180 a year to operate the plant.

The water is of good sanitary quality. It has a mineral content of 434 parts per million, ai total hardness of 400 parts per million, and a content of iron of 0.9 part per million.

CRETE. Proposed sewerage.—Visited June 29. At present there is no public drainage system, but several private drains discharge into Goose Creek, a small watercourse, and some of these drains receive overflow from cesspools. The foul conditions thus produced in the watercourse have been made the subject of complaints to the Rivers and Lakes Commission. The commission held a hearing and advised the village to consider the installation of a sewerage system and a sewage-treatment plant. The village thereupon engaged the services of a consulting engineer who prepared plans and specifications for such a system to cost about $45,000. These plans provide for 34,000 feet of 6-inch to 20-inch vitrified pipe, and a treatment plant comprising a 2-story settling tank, a dosing chamber, either intermittent sand or contact filters, and a sludge bed. The proposed location of the plant is remote from dwellings and on Goose Creek at the northeast edge of town outside the corporation limits.

CRYSTAL LAKE. Water supply.—(Bull. **9**, 19; **11**, 52.)
Typhoid fever.—(Bull. **9**, 19.)

CUBA (2,019). Water supply.—(Bull. **12**, 51.) Visited April 16 and December 28. Cuba is in the central part of Fulton County in the catchment area of Spoon River, a tributary of Illinois River. The prosperity of the community is dependent on agricultural interests and coal mining.

Waterworks were completed early in 1915. The supply is obtained from a well 1,768 feet deep, 16 inches in diameter at the top, 10 inches in diameter at the bottom, and ending in St. Peter sandstone. Rock was entered at 34 feet and a casing extends to 317 feet. The static head is 103 feet below the surface and recedes 39 feet when the well is pumped at a rate of 164 gallons a minute. On completion the well was pumped continuously for 34½ hours at an average rate of 118 gallons a minute Water is pumped from the well directly into the distribution system by an electrically driven 220,000-gallon double-acting deep-well pump. The distribution system comprises 6.62 miles of 4-inch, 6-inch, and 8-inch cast-iron pipe. A 74,000-gallon elevated steel tank having a total height of 119 feet is connected to the distribution system. Before the time of inspection only 15 service connections had been made, and the consumption was, therefore, very small. A 2-inch meter has been placed on the discharge from the pump, but no readings had been recorded. The total cost of the waterworks including the distribution system was $28,794.

The water is of good sanitary quality. It is very highly mineralized and very hard, having a mineral content of 2,400 parts per million and a total hardness of 745 parts per million. It contains 360 parts of chloride, 1,120 parts of sulfate, and 0.4 part per million of iron and has a distinct mineral taste.

CUBA. Proposed sewerage.—On April 7 plans and specifications for proposed sewerage and sewage-treatment works were submitted by the city's consulting engineers. These plans were reviewed and a report thereon was made. Cuba is in the central part of Pulton County in the drainage basin of Spoon River, a tributary of Illinois River. The city drains into a small tributary of Big Creek, which discharges into Spoon River about 8 miles south. The rapid growth of the city during the last decade has been caused by the coal industry, but as little further growth is anticipated sewerage and sewage-treatment works sufficient to treat the sewage from a population of 2,000 will doubtless be adequate for many years. The city this year completed a public water supply, and the need of a sewer system will be felt more and more as the number of consumers increases.

The proposed sewers are designed to carry only sanitary sewage. It is assumed that storm-water drains will be laid from time to time as needed and will discharge into the nearest watercourse. The sanitary system will comprise about 33,000 feet of 8-inch, 10-inch, and 12-inch vitrified pipe. Sufficient manholes will be provided so that the distance between two manholes will not exceed 450 feet. No profiles were presented, but it is assumed that the local topography will permit suitable grades. The system will have one outlet through a 12-inch outfall sewer entering a small branch of Big Creek about one mile south of the central part of the city. There are no houses close to the branch below the proposed outlet, and land suitable for treatment works is available. The branch winds slightly through moderately hilly and woody country used for pasture and for farming, and it has no normal dry-weather flow. Water from a mine is discharged into it shortly below the proposed location of the sewage-treatment plant, but this mine water is negligible in amount during dry weather and cannot be relied on to dilute the sewage. The current in the stream is rapid because of a fall of about one foot per 100 feet.

The plans for the sewage-treatment plant call for a valve chamber, 2 primary sedimentation tanks, one secondary sedimentation tank, and a filter of coke. The valve chamber is a small concrete structure fitted with valves that permit passing the sewage through either or both tanks or by-passing them entirely. Two manholes make the chamber readily accessible. Each of the primary sedimentation tanks is to be 45 feet long and 7 feet deep to the flow line. One is 10 feet and the other is 6 feet wide, and their respective capacities are thus 23,500 gallons and 14,200 gallons, equivalent to a total capacity of 37,700 gallons. Based on an average daily sewage flow of 200,000 gallons the combined detention period is 4% hours. With care in operation it would be practicable to obtain a well-settled effluent but with lack of care septic conditions developing in the sludge will cause ebullition and the escape of large quantities of suspended matter with the effluent. The plans do not show any means of removing sludge. In order to facilitate the removal of sludge it was advised that a greater slope be given to the bottoms of the tanks. The sewage is admitted to and drawn from the primary sedimentation tanks through down-turned 10-inch cast-iron pipes reaching to about mid depth. This arrangement is not conducive to producing the best distribution of flow across the width of the tank, but in view of the length of the tanks as compared with their width this is not serious. Two hanging baffles in each tank reach somewhat lower than mid depth. These baffles will be serviceable in holding back scum, but they will prevent in a measure proper sedimentation of the sewage. Each chamber has manholes at inlet and outlet which, however, do not provide sufficient accessibility for observing the operation of the tanks. The sewage passes from the primary sedimentation tanks into a secondary tank, which extends across the outlet of the primary tanks. This tank is 4½ feet in the direction of flow, 17 feet at right angles to the flow, and 7 feet deep to the flow line. In the middle there is a hanging baffle, and single manholes are placed on either side of the. baffles. The secondary sedimentation tank, like the primary tanks, is not provided with moans for drawing off sludge. From the secondary tanks the sewage flows laterally through a bod of coke about 2½ feet deep and 8 feet thick in the direction of flow. The width is the same as that of the tanks. The filter as designed is very inaccessible, there being but a single manhole. The filter can be regarded only as a strainer, and as such it will have to operate at a rate far beyond that which roughing filters have ever been successfully operated.

When the sewerage system is generally used the effluent from the sewage-treatment works will be a putrescible liquid though materially clarified by sedimentation. As the creek falls rapidly it is not anticipated that objectionable accumulations of solid matter will occur, and no offensive conditions will result as long as the discharge of the creek is about 5 second-feet. The discharge will not always be so great, and it may be anticipated that the water of the creek will be rendered unfit for watering cattle and offensive to riparian owners. The sewerage system as designed was approved, but approval of the treatment works was withheld partly on account of imperfections in design and partly on account of the inadequacy of the proposed method for producing an. effluent that will not prove offensive to sight and smell.

DANVERS (593). Water supply.—(Bull. **12**, 51.) Visited September 13. Danvers is in the northwest part of McLean County in the drainage basin of West Fork, a tributary of Sangamon River. There is no sanitary sewerage, but tiles that have been installed for ground-water drainage receive overflow from cesspools. In 1914 the village planned to install at an estimated cost of $4,500 about 5,500 feet of sanitary sewers 12 to 8 inches in diameter with an outlet directly into West Fork, but the proposition was defeated by popular vote.

Waterworks were installed about 1892 and the supply was obtained from a deep well in drift. A second well drilled in 1900 was so crooked that it could not be used. Another attempt was made about 1905 when a well 10 inches in diameter was drilled to 218 feet about 25 feet east of the original well, but it was almost a dry hole. Another well 8 inches in diameter was put down in 1906 about 6 feet south of the first well; it furnished an abundant supply and has been used continually since its completion. In May, 1915, a fifth well was drilled 15 feet from the fourth well as the yield of the first well had become too small to warrant pumping. This well ia the same size and depth as the fourth well, and the supply is now obtained from these two wells. Both are equipped with 10-foot Cook screens and derive their supply from sand and gravel. The static level is about 60 feet below the surface. The water is pumped from the wells directly into the distribution system by 2 single-acting deep-well steam-head pumps. One has a 6-inch by 24-inch working barrel at 205 feet and the other an 8-inch by 36-inch working barrel at 208 feet; at 30 strokes per minute the displacements are, respectively, 130,000 gallons and 225,000 gallons a day. The distribution system comprises about one mile of 4-inch, 6-inch, and 8-inch cast-iron pipe. There are 61 service connections, all of which are metered. A 54,000-gallon steel tank 18 feet in diameter and 25 feet high on an 80-foot brick tower is connected to the distribution system. The daily consumption is about 8,000 gallons. Slightly less than one-half the population use the public supply. The estimated cost of the waterworks was $14,000 and the cost of operating during 1914 was $341, the revenue from water rates amounting to $410 for the same period.

The water is of good sanitary quality. It has a mineral content of 569 parts per million, a total hardness of 362 parts per million, and a content of iron of 1.6 parts per million.

DANVILLE. Water supply.—(Bull. **9**, 19; **12**, 52.)

DECATUR (31,140). Water supply.—(Bull. **10**, 106; **11,** 53; **12**, 55.) Visited March 2-3 and 30. Decatur, the county seat of Macon County, is bordered on the south by Sangamon River. It is the location of many industrial establishments.

Waterworks were started in December, 1870, when Decatur had a population of 7,161. A well was drilled near the center of the business district, and a 500,000-gallon pump was installed. In order to sell large quantities of water to railroads and factories the mains were laid along the most direct line to supply these consumers. As the supply was inadequate from the start it was unanimously voted at a mass meeting one month after the completion of the system to issue $100,000 worth of bonds to increase the supply. A site for a pumping station on the north bank of Sangamon River was purchased in May, 1871, and this has since been the location of the station, though material additions to the area have been made. A contract was awarded in June, 1871, for an intake from the river, a pumping station equipped with a 1,000,000-gallon reciprocating steam pump, 2 electrically driven rotary pumps for fire use, and mains. As the river water was turbid an infiltration gallery to improve the supply was built parallel to the river in 1874. It was 100 feet long, 10 feet wide, and 6 feet deep with its top 4 feet below the bed of the river; the sides and the bottom were timber and the top was arched with brick. Water from this gallery was clear and satisfactory, but the supply soon became inadequate, and the length of the gallery was increased to 500 feet in 1877. A valve-controlled connection also was made between the river and the upstream end of the gallery for use in emergencies. This supply in turn became inadequate in about a year, after which the available; quantity was increased by constructing across the river a wooden dam which created a head of about 8½ feet over the top of the gallery. In 1882 the pumping equipment was increased by 1,000,000 gallons a day and in 1884 two 2,000,000-gallon pumps were added. At that time the emergency intake drawing water directly from the river had to be regularly used. This produced unsatisfactory conditions and so much mud accumulated in the mains that hydrants sometimes had to be flushed as frequently as every 15 days. A 3,000,000-gallon rapid-filtration plant of the Warren type, consisting of coagulaing basins, 16 wooden filters, a clear-water reservoir, and raw-water pumps was installed in 1894 for about $60,000. The system was overhauled in 1896 at a cost of $35,000. During the next 14 years the waterworks were operated with little change except extension of mains. All large consumers were metered in 1895 and universal metering, adopted in 1905, served materially to reduce consumption. Extensive improvements were made in 1910 and 1911 comprising a new pumping station, additional high-service and low-service pumps, a concrete dam to replace the wooden dam, and new duplicate intakes from the river. Plans and specifications for a purification plant of greater capacity and up-to-date type were prepared, but this improvement was not then undertaken.

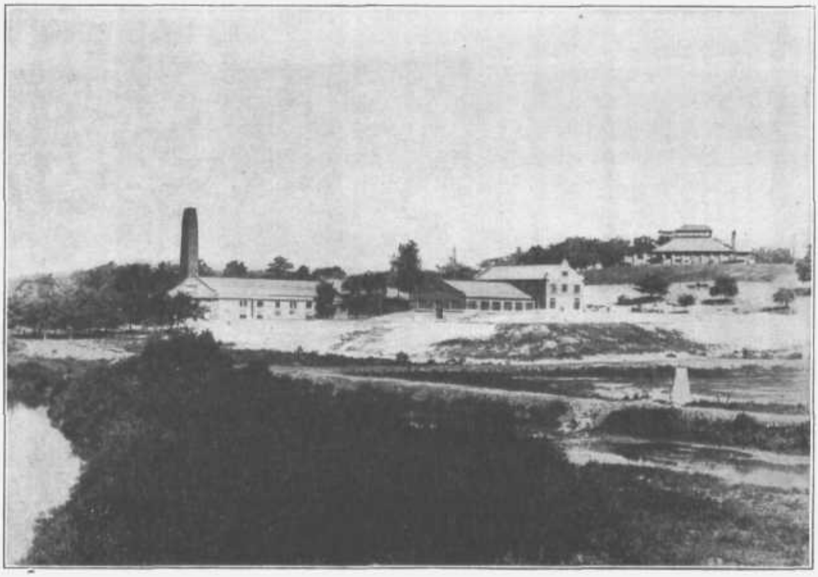


Figure 3.—Pumping station, new filtration plant, and old filtration plant, Decatur.

The Survey made its first detailed investigation of the water supply at Decatur in 1912, and then urged the city to install a new filter plant to replace the inadequate inferior old plant and immediately to treat the supply with calcium hypochlorite. This advice was followed, and the present treatment plant was put into operation in September, 1914. This improvement cost about $135,000; the waterworks now represent an investment of $1,135,000, and has been brought to a high state of efficiency.

The waterworks are located on a 20-acre tract on the north bank of Sangamon River. The pumping station and the new filter plant are within 200 feet of the river on relatively low land, and the old filter house stands at the top of the bluff 75 feet above the river. A concrete dam of the gravity-section overflow type, approximately 200 feet long and 10 feet high above the foundation, is about 1,000 feet below the pumping station. The low-stage flow may be passed if desired through a sluice gate in the center. The impounding capacity afforded by this dam has not been ascertained, but it is probably at least 30,000,000 gallons. Sangamon River above Decatur drains an area of 862 square miles of flat or slightly rolling country with loose loamy soil devoted almost entirely to agriculture. Drainage has been greatly improved in recent years by open ditches and tile drains, whose ready removal of water makes the stream subject to large rapid fluctuations in discharge. According to records at gaging stations maintained on this river above and below Decatur by the U. S. Geological Survey the average discharge at Decatur during August, 1911, the month of least flow, was about 8 second-feet and the mean daily discharge for 18 days during that month was less than 3 second-feet. There is now an average pumpage during the summer of 6.5 second-feet and at times as much as 9.5 second-feet. No shortage has occurred thus far, but the water was drawn down below the crest of the dam during 1913 and 1914; it is apparent that additional storage facilities will be required properly to meet future demands, and the city is seeking increased storage. The total population in the catchment area, based on the United States Census for 1910, is about 65,000, or 67 per square mile. There are 15 incorporated communities in the catchment area ranging in population from 81 to 2,086 and located 8 to 80 miles by river above Decatur. Monticello (population 1,981), 30 miles by river above Decatur, is the only one of these municipalities that has sewerage, but 3 others have public water supplies and probably will soon install sewerage. The probability that any municipality nearer Decatur than 20 miles by river will install sewerage is remote. The sewage of Decatur is discharged into the river below the waterworks dam. The shops of the Wabash Railroad, where about 600 men are employed, and the country club are 2 sources of local pollution above the dam. The waste from the railroad shops, which is passed through a septic tank and discharged into the river about 1½ miles above the intake is offensive and usually carries an oily film. The small volume of sewage from the country club is passed through a tank, filtered through gravel, and discharged into the river about 1½ miles above the intake.

The water is drawn from the impounding reservoir through 2 reinforced concrete cribs about 150 feet apart near the center of the river opposite the pumping station. Each crib is 20 feet long and 10 feet wide and the tops are 4 feet below the crest of the dam. Water, entering the cribs through iron gratings on the sides opposite the pumping station, flows through 30-inch cast-iron pipes to a roofed concrete suction well 200 feet from the river, 20 feet in diameter and 22 feet deep. The purification plant has a rated daily capacity of 9,000,000 gallons. The principal structures are concrete with an attractively designed brick superstructure harmonizing with the pumping station. It is proposed eventually to develop the city property around the waterworks into a park. The purification process involves coagulation with alum, sedimentation, filtration, and sterilization with hypochlorite. The raw water is pumped from the intake well into a basin at the purification plant, 9 feet by 20½ feet in plan, and 18½ feet deep, into which the solution of alum is introduced. The solution, having a strength of 5 per cent, is prepared in 2 rectangular 6,000-gallon concrete tanks provided with suitable dissolving racks and motor-driven agitating propellors. The solution is introduced through 2 float-controlled orifice boxes, either of which may be used with either solution tank. Since the new plant has been in operation the dose of alum has ranged from 0.56 to 3.37 grains per gallon according to the condition of the raw water. The water flows from the basin in which the alum is added into 2 mixing chambers, which may bo used singly, in parallel, or in series. A longitudinal baffle in each mixing chamber causes the water to flow forward and backward through channels 4 feet wide; in one chamber vertical transverse alternate hanging and upright baffles at 3-foot intervals along the channel cause the water to take a continual up-and-down course; in the other mixing chamber vertical walls placed at intervals of 6½ feet transverse to the flow with their bottoms and tops 3½ feet and 12 feet, respectively, above the bottom of the channel, aid in mixing. The mixing chambers are now operated in series, the water entering the one having the alternate hanging and upright baffles. If the plant were run at its rated capacity the detention period in the mixing chambers in series would be about 25 minutes, but at the present rate of 3,700,000 gallons the water is detained more than an hour in the mixing chambers.

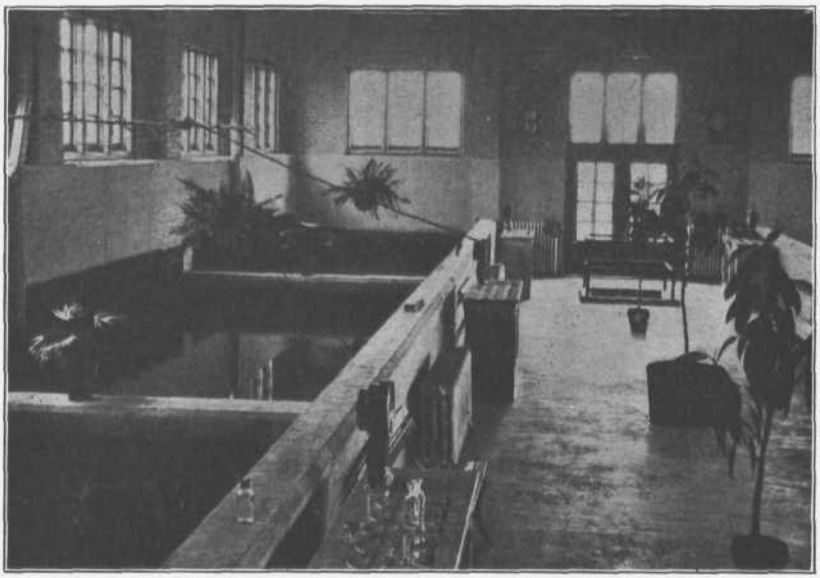


Figure 4.—Operating floor and filters, Decatur.

The coagulated water flows from the mixing chambers into 2 settling basins which are so arranged that they may be used singly or in parallel. The basins have a combined capacity of 1,370,000 gallons, equivalent to 3.6 hours' detention with the rated capacity and to 8.9 hours' detention with the present consumption. One basin is 66½ feet by 100½ feet and the other is 49½ feet by 100½ feet and both are 15.7 feet deep to the flow line. The basins are constructed of reinforced concrete and are covered with a slab roof supported by columns about 17 feet apart, over which is placed 18 inches of earth. A driveway to the filter building passes over the basins. Grooves moulded in the 4 sides of each column and in the walls opposite the columns are provided for stop planks. By the present arrangement of the planks the water is diverted the length of the narrow basin twice and the length of the wider basin 4 times. An 18-inch valve-controlled waste outlet is provided in each basin.

The 6 filter units have rated daily capacities of 1,500,000 gallons each, and they are arranged on either side of an operating floor, beneath which is a pipe gallery 14 feet wide with 11 feet 9 inches head room. All the principal valves are hydraulically operated from a marble-topped operating table in front of each unit. Each filter is 25½ and 21¼ feet in plan. A 2-foot concrete channel at the operating-floor end of each filter serves as an influent and wash-water channel. Seven steel wash-water troughs extend longitudinally across each filter about 20 inches above the top of the sand and open into the concrete channel at the operating end. The strainer system consists of small perforated brass strainers spaced 6 inches apart and connected to a grid of piping embedded in the concrete bottom of the filter boxes. The filtering medium consists of 10 inches of gravel and 30 inches of St. Peter sand from Ottawa. Its effective size is 0.32 mm. and its uniformity coefficient 1.81. Both water and air are used in. washing the filters. The filters are usually agitated with air about 3 minutes and are then washed with water 3 to 4 minutes. The air pressure at the blower during washing is 2½ pounds, and 3 cubic feet per minute per square foot is the estimated amount used in washing. The centrifugal wash-water pump has a capacity of 4,600 gallons a minute, and the vertical rise of water in the filters during washing is about 13 inches a minute. Each filter is equipped with a recording loss-of-head gage, and the filters are washed when this registers about 8 feet. The rate of filtration is governed by a rate controller of the Venturi meter type.

The 3 filtered-water reservoirs have a combined capacity of 3,144,000 gallons, equivalent to 20 hours' supply at the present rate of consumption and 8.4 hours' supply at the rated capacity of the plant. One reservoir beneath the pipe gallery has a capacity of 46,000 gallons. The other two reservoirs, adjoining this reservoir on either side, have capacities of 1,706,000 and 1,392,000 gallons, respectively, and are connected to the smaller reservoir by 3-foot gate-controlled openings in the dividing walls. The filters discharge into the smallest reservoir, and the outflow to the suction well of the high-service pump discharges from this reservoir. Hypochlorite of lime is applied to the filtered water in the smallest filtered-water reservoir at the inlet of the pipe leading to the suction well of the high-service pump. The solution of hypochlorite is prepared in 2 circular iron tanks, each of which has a capacity of 1,445 gallons and motor-driven revolving agitators. The solution flows from the tanks through 2 adjustable float-controlled orifice boxes. The quantity of hypochlorite used since the installation of the new plant has ranged from 7.5 to 9.5 pounds per 1,000,000 gallons.

Two 5,400,000-gallon pumping units raise water from the intake well into the filtration plant. Bach consists of 2 single-stage centrifugal pumps operated in series gear-connected to a steam turbine on the same base. Two 2,500,000-gallon tandem-compound flywheel pumps with single water cylinders and a 6,000,000-gallon cross-compound flywheel pump draw from a suction well fed from the clear-water reservoir and pump into the distribution system. As the suction well also has a valve-controlled connection to the intake well it would be possible to pump untreated water directly into the distribution system.

The distribution system to April 30, 1914, comprised 63.5 miles of 4-inch to 24-ineh cast-iron pipe. The number of service connections in use at the time of the visit was 6,267. The number of service connections in the decade 1904 to 1914 increased 181 per cent while the population increased 42 per cent and the pumpage only 31 per cent. The small increase of pumpage in relation to the increase in population and service connections is caused by installation of meters.

There is no elevated tank or equalizing reservoir in the distribution system. The average daily consumption during 1914 was 3,700,000 gallons, of which the industrial consumption is 1,000,000 gallons. The pumpage is determined by a Venturi meter on the discharge from the low-lift pumps and from readings of revolution counters on the high-service pumps without allowance for slippage. The difference between the two amounts, about 3.5 per cent of the low-lift pumpage, represents roughly the water used in washing the filters. The maximum daily pumpage thus far has been 6,000,000 gallons.

All the samples of the water furnished by the new purification plant analyzed by the Survey have been of good sanitary quality. Though a well-equipped laboratory has been installed at the plant it has not thus far been regularly used, and analytical control of the purification has not been attempted. It is planned, however, to undertake daily analytical control at an early date.

DECATUR. Sewage disposal.—(Bull. **10**, 107; **11**, 253; **12**, 55.)

DEER CREEK. Water supply.—(Bull. **10**, 107; **11**, 53.)

DEKALB (8,102). Water supply.—Visited June 3. Dekalb is in the central part of Dekalb County in the catchment area of Kishwaukee River.

Waterworks were installed about 1875, when 3 deep wells were put down in the southern part of the city, one to a depth of 2,400 feet. After 20 years this supply was abandoned and a well was sunk just west of the business district. Two more deep wells in the same locality have since been added to the supply. Two of the wells are in the pumping station and the third one-half block away. The oldest well, 800 feet deep, is lined with 12-inch casing to rock at about 150 feet and ends with a 6-inch bore in St. Peter sandstone. As this well is crooked and can be pumped only by air lift it is rarely used. The second well, outside the pumping station, was drilled originally to St. Peter sandstone, but it was later reamed out and drilled to 1,300 feet into Potsdam sandstone. It has 15-inch casing to rock at 150 feet and is 6 inches in diameter at the bottom. The third well, 1,300 feet deep and ending in Potsdam sandstone, is cased to rock with 15-inch pipe, and ends in an 8-inch bore. The static level is 104 feet below the surface. The yield of the wells is unknown. When the newest well is pumped at 500 gallons a minute the water level is drawn down to the working barrel at a depth of 160 feet. Water is pumped from the wells into a 550,000-gallon brick collecting reservoir 65 feet in diameter and 22 feet deep built in excavation with the wall rising above ground and surmounted by a substantial conical roof. A dividing wall through the center permits cleaning one-half of it at a time. The old well is pumped by air lift with the discharge nozzle 300 feet below the surface, thus affording an initial submergenco of 65 per cent. The other wells are pumped with electrically driven 700,000-gallon deep-well pumps with the working barrels at 160 feet. Two 700,000-gallon motor-driven triplex pumps regularly pump water from the reservoir into the distribution system, and a motor-driven 2,150,000-gallon 3-stage centrifugal pump is maintained for fire service. The distribution system comprises 22 miles of 4-inch to 12-inch mains. There are 1,765 connections, all of which are metered. A 240,-000-gallon steel standpipe 85 feet high is connected to the distribution system. The connection is provided with a novel shut-off valve. A swinging check valve is closed by a bucket on the end of a lever when the bucket is filled with water that enters it through a small valve operated electrically from the electric plant in case of fire. The extra pressure during fire holds the check valve closed; meanwhile the water escapes front the bucket through a small outlet in the bottom, and thus the check can swing open again when the extra pressure is released. The pumpage is recorded by a Venturi meter except that used for fires as the discharge of the fire pump does not pass through the meter. The average daily pumpage during 1914 was 363,000 gallons. On the basis of service-meter readings the city receives payment for about 61 per cent of the pumpage indicated by the Venturi meter. Metering of the services was started in 1909 and although the number of consumers has increased the per capita consumption has decreased.

The water is of good sanitary quality. It has a total hardness of 200 parts per million, and contains 295 parts per million of mineral matter and 0.1 part per million of iron.

DEKALB. Sewage disposal.—A comprehensive sewer system and sewage-treatment plant started in Dekalb in 1914 were completed during 1915. The sewer system comprises 16.4 miles of 8-inch to 24-inch pipe.

The sewage-treatment plant has been built at the outlet beyond the northwest part of town into Kishwaukee River. It comprises a grit chamber, settling tanks, dosing chambers, trickling filters, and a sludge bed. The outfall sewer from the city discharges into a diversion chamber, from which the sewage will flow under normal conditions into the grit chamber; while the flow is excessive, however, part of it will overtop a weir and pass directly into the river. The grit chamber is a concrete channel 40 feet long having a cross-sectional area below the flow line of 6 square feet. Two valve-controlled outlets lead from the grit chamber to 2 settling tanks, each of which is 60 feet long, 20 feet wide, and has an average depth of 6 feet, equivalent to a capacity of 54,000 gallons. The halves of the tanks nearer the inlet ends have bottoms that slope rapidly to sludge outlets, but the bottoms of the other halves are practically flat; concrete walls with 2 horizontal slots separate the halves of the tanks. Sewage enters through a perforated submerged iron pipe across one end and passes out over a weir at the opposite end. A dosing chamber at the end of each settling tank is 20 feet by 30 feet in plan and is designed to empty at a depth of 2½ feet, equivalent to a dose of 11,250 gallons. There are two 10-inch siphons in each chamber. Two trickling filters, each 160 feet long by 31 feet wide, are underdrained by 6-inch half-tile, which discharge into an open effluent channel 7 feet wide at the top and extending to the bottom of the filters. The filter medium consists of 6% feet of crushed stone and gravel. The sewage is distributed by 2 parallel longitudinal wooden troughs on the surface of each filter. The troughs decrease in size from the inlet ends and each has 9 points of discharge. One siphon discharges into each trough. The sludge bed is 50 feet by 60 feet in plan and is underdrained at a depth of a few inches with 6-inch tile 10 feet apart.

DEKALB. Pollution of Kishwaukee River.—Landowners along Kishwaukee River below Dekalb and residents of Sycamore submitted in April a petition to the State Game and Fish Conservation Commission requesting attention to the periodic dying of fish in that stream. After a brief investigation that commission referred the matter to the Rivers and Lakes Commission which in turn requested the Survey to make a detailed investigation. The condition of Kishwaukee River from Dekalb downstream to a point below Sycamore was inspected June 3.

Kishwaukee River above Dekalb has a catchment area of 85 square miles. Eight miles below Dekalb the area is increased to 178 square miles by a creek draining the country to the eastward around Sycamore. The banks of the stream have been used rather extensively for outings, and the Kishwaukee has been considered a good fishing stream. For several years past, however, the water is said to have had much of the time a distinct reddish color that makes a stream and its banks unsightly; it is further stated that many fish have died when the water haa become low. Farmers state that stock will not drink from the river during much of the summer if any other water is obtainable and that if they are forced to drink it their vitality is lowered.

The only appreciable liquid wastes entering the stream at Dekalb are city sewage and waste from a plant of the American Steel and Wire Co. Though the sanitary sewer system was completed during 1914 comparatively few dwellings have thus far been connected to it and the discharge of sewage is small. Moreover, the sewage before being discharged into the stream north of the city is treated in settling tanks and trickling filters which should purify it sufficiently to prevent any serious pollution in the stream. A small creek called Acid Ditch because it carries wastes from the plant of the American Steel and Wire Co. discharges into the river just above the outlet of the sewer. The wastes from the plant consist chiefly of rinse water into which the iron is dipped after coming from a bath of sulfuric acid and of water used in washing the various vats and floors. The waste flows one-half mile in Acid Ditch before entering the river. The sulfuric acid in which the iron is dipped for cleaning before being galvanized is not discharged as waste but is allowed to stand over scrap iron until practically neutralized, after which it is evaporated to the proper concentration for crystallization of iron sulfate. The supernatant liquid is used again in the acid vats. The quantity of waste water produced could not be definitely ascertained and it doubtless varies both in volume and in character. In the summer of 1914 the waste in Acid Ditch amounted to 118,000 gallons a day. Another measurement in Kishwaukee River just below the mouth of Acid Ditch showed a discharge of 119,000 gallons a day. The waste had practically no dilution at that time. The water in the ditch had a distinct red color and high turbidity. This color was noticeable in the main stream for a distance of 3½ miles, and the investigators were informed at Genoa, about 20 miles below Dekalb, that the red color at times was carried even to that point. At the time of the last inspection the bed and banks of Acid Ditch were deeply stained with deposits of iron and a slight amount of iron was noticeable on the banks of the stream as far downstream as Sycamore.

The deposit of iron is largely the hydrate, which is deposited when ferrous sulfato in the waste becomes oxidized. During periods of small flow most of this red deposit and polluting effect will disappear a few miles below the mouth of Acid Ditch but at flood stages it may be carried many miles downstream. The color of the stream and the red deposits along the bank make the stream unsightly. The dying of the fish may be due to the lack of oxygen in the water brought about by exhaustion of the dissolved oxygen by the iron sulfate. Complete oxidation of the iron would be slow under such conditions and it would be natural to expect the red deposits to appear several miles below Dekalb. Arrangements were made whereby the Survey will be notified when extreme objectionable conditions prevail in order that a further examination may be made.

DELAND (503). Proposed water supply.—(Bull. **12**, 55.) Visited May 19. Several conferences at the office of the engineer and interviews oyer the telephone with the city officials have taken place.

In an effort to obtain a water supply 4 wells hav.e been sunk at Deland. The first 3 were, respectively, 140, 225, and 130 feet deep. Bedrock shale was struck at 160 feet, and the only water encountered was about 15 gallons a minuto in a 2-foot bed of sand at about 80 feet. A fourth well, first ended at 80 feet, was continued to greater depth because data in the Geological Department of the University indicated that water might be secured from Niagara limestone at 800 or 900 feet. It seemed probable that any water encountered above the Niagara would be too highly mineralized for domestic use. This information was referred to the village authorities, who were also advised to make further efforts to procure water from drift wells in an area some distance from that in which the other wells had been bored. The village authorities decided to continue drilling the deep well, and late in July, 1915, the well had reached a depth of 1,085 feet. A little salt water was encountered at 510 and 725 feet. It wad thought that fresh water was encountered before drilling ceased, and according to latest information received by the Survey the village was making an effort to case out the upper salt waters in order to ascertain the quality and quantity of water near the bottom of the well.

DELAVAN. Water supply.—(Bull. **12**, 56.)

DEPUE (1,339). Water supply.—Visited September 1 and 15. Depue is in the southeastern part of Bureau County on the north bank of Depue Lake, an arm of Illinois River, which is connected with the river at all stages about 2 miles below the village and is connected with the river during high water also above the village. From the flat land 10 to 20 feet above the normal level of the river in the south half of the village the ground rises northward rather abruptly to 2 00 feet above the river. The built-up section of the village is principally on the low ground. Depue is the site of a large zinc refinery.

Waterworks were installed about 1909. The supply is obtained from a well 1,278 feet deep terminating in a 6-inch hole in St. Peter sandstone. As the water flows from the well under a natural pressure of 31 pounds pumping was unnecessary for a few years; but increased consumption decreased the pressure in the mains and pumping equipment was finally installed. The services were, however, metered throughout about the same time and this resulted in so reduced consumption that the pumps are now little used except for fire protection. A supply is available in emergency from 4 wells owned by the Mineral Point Zinc Works. Three of these wells are similar to the village well in construction, but the fourth is a large open well about 40 feet deep. A connection between the two systems can be opened when either fails. Though the zinc works also obtain water from Depue Lake for certain uses, it is understood that no connection exists between the lake and the well supplies.

The village supply is of good sanitary quality. It contains 520 parts per million of mineral matter and 2 parts per million of iron, and it has a total hardness of 236. parts per million. The content of iron is sufficient to stain plumbing fixtures and laundered fabrics; and it also causes trouble at several dead ends in the distribution system, which have to be flushed at times as often as once a week.

DEPUE. Proppsed Sewerage.—Plans have been prepared for a complete system of combined sewers fpr Depue estimated tp cost $55,000. The system is designed to carry 2,000 gallpns a minute Qf city sewage from a population of 12,000 and 3,800 gallons a minute of wastes from the refinpry qf the Mineral Point Zinc Works. The outlet is to be 30 inches in diameter and is to discharge into Lake Depue. If the village should ever have the large population used as a basis in designating the system the sewage will undoubtedly cause a grave nuisance in Depue Lake as its water, ordinarily stagnant, would favor rapid accumulation of sludge near the outlet. If objectionable conditions Ehould develop treatment works or an outlet extended to Illinois River might be constructed. Either would be expensive. It would be advisable, therefore, for the village to consider installation of separate systems of sewers, one for house drainage and one for storm water and industrial wastes. Provision of several outlets to the storm-water system would permit use of relatively small outlet pipes that could be laid from time to time as needed. The waste from the zinc works is clear and probably unobjectionable and could be discharged into the lake with the storm water. If house drainage were discharged into the lake the use of the lake as a source of ice supply must be absolutely prohibited.

DES PLAINES (2,348). Water supply.—Visited June 29. Des Plaines is on the west side of Des Plaines River in Cook County about 15 miles northwest of the center of Chicago, of which it is essentially a suburb.

Waterworks were installed in 1895. The supply is obtained from 3 wells on low land on the east side of the river. One well is 10 feet from the river bank; the other 2 are 300 feet from this well and 50 feet apart. All 3 wells are 130 feet deep, 8 inches in diameter and derive their supply from beds of sand. The static level is 15 feet below the surface. The combined yield with present pumping facilities is about 300 gallons a minute. Water raised from the wells by air lift is discharged into a small receiving basin at the top of each well, from which it flows by gravity into a collecting reservoir on the west side of the river. The air nozzles are placed near the bottoms of the wells. A new well about 60 feet from the well nearest the river was being constructed at the time of inspection. It is 4 feet in diameter at the bottom and had reached a depth of 102 feet. The upper 12 feet was a rectangular chamber 8 feet square in which a motor and pumps are to be placed. The circular portion of the well is lined with a steel shell, outside of which is 6 inches of concrete. The contract provided for carrying the well to a 2-foot water-bearing sand stratum at 107 feet. When the well reached 102 feet the contractors bored a small hole in the bottom to the sand bed in order to ascertain how much more digging was necessary. The water encountered under pressure rose to within 15 feet of the surface and caused trouble in continuing the excavation. After unsuccessful efforts to continue the well the job went into the hands of a receiver, and the city at the time of inspection was planning to complete the well. It was proposed either to dredge out clay and fine sand at the bottom and fill with coarse gravel or to sink several tubular wells 8 inches in diameter in the bottom of the 4-foot well. Pumping the 3 existing wells at the rate of 320,000 gallons a day lowers the water in the new well about 4 feet. The concrete collecting reservoir on the west side of the river is 35 feet in diameter and 20 feet deep and has a capacity of 145,000 gallons. It is covered by the concrete floor of the pumping station; a manhole flush with the surface of the floor may admit dirty floor washings into the reservoir. This possibility of contamination was called to the attention of the water committee and is to be remedied. Water is pumped from the collecting reservoir into the distribution system by a 750,000-gallon compound duplex pump. The distribution system comprises 4-inch, 6-inch, and 8-inch cast-iron pipe and covers practically the entire built-up section of the village. All connections are metered. A 150,000-gallon elevated steel tank having a total height of 151 feet is connected to the distribution system.

The water is of good sanitary quality. It has a mineral content of 877 parts per million and a total hardness of 462 parts per million.

DES PLAINES. Sewerage.—(Bull. **10**, 66; **11**, 54.) Visited June 29. The combined sewerage system of Des Plaines discharges into Des Plaines River and creates an. offensive condition in the stream that affects the value of property downstream and within the village itself. Some State authority will sooner or later require treatment of this sewage as the river is used extensively for recreation. The municipal authorities were advised by the Survey to have plans prepared at an early date so that additional sewerage may be properly installed in conformity with a consistent plant for treatment of the dry-weather flow of sewage.

DIXON (7,216). Water supply.—(Bull. **11**, 58.) Visited June 28. Dixon is in the northwest part of Lee County on Bock River and it is the site of several factories.

Waterworks were installed in 1883 when the city granted a 30-year franchise to the Dixon Water Co. At the expiration of this franchise municipal ownership was considered, but a new franchise was granted in consideration for a reduction in rates. The supply is obtained from 4 wells drilled 300 to 400 feet apart in a row parallel to the south bank of Rock River at the east end of the water front. The wells range in depth from 1,637 feet to 1,810 feet and terminate in Potsdam sandstone. The three older wells are cased to 50 feet with 8-inch casing, and the newest well is 10 inches in diameter at the top and 6 inches in diameter at the bottom and is cased to 400 feet. The total natural flow of the wells is estimated at 700,000 gallons a day; they discharge into a stone collecting reservoir built principally in excavation and covered with a conical wooden roof. It is 86 feet in diameter and 18 feet deep with a capacity of 780,000 gallons. Three are equipped with air lift, the nozzles being placed at 107 feet, and it is estimated that a daily yield of 2,000,000 gallons can be obtained by using air. The newest well has a natural flow of 200,000 gallons a day. One high-service unit is a walking-beam pump installed about 27 years ago comprising 2 tandem-compound 1,000,000-gallon pumps side by side and capable of being separately operated. The second unit, installed in 1914, is a 2,500,000-gallon cross-compound flywheel duplex pump. The distribution system comprises about 22 miles of 4-inch to 12-inch cast-iron pipe. There are **1,600** service connections, 22 per cent of which are metered. The system is divided into a high-level and a low-level district. The low-level district comprises the greater part of the city and the mains in it are connected to a 260,000-gallon steel tank 28 feet high on a mound of earth 15 feet high. A 90,000-gallon steel tank 27 feet high on a tower 24 feet high is connected to the mains in the high-level district. When the high-level tank is to be filled a valve on the other tank is closed and the pressure in the entire system is increased until the high-level tank is full. The pressure is then reduced and check valves prevent back flow from the high-level district. The daily pumpage ranges from 600,000 to 1,300,000 gallons and averages about 700,000 gallons.

The water is of good sanitary quality. It has a mineral content of 355 parts per million and a total hardness of 324 parts per million.

DOWNERS GROVE (2,601). Water supply.—Visited June 5. Downers

Grove is in the east part of Dupage County on St. Joseph Creek, a branch of Dupage River.

Waterworks were installed in 1894. The original supply was obtained from 2 wells, but it became inadequate about 1908 when a third deeper well was sunk and one of the old wells was abandoned. The original well still in use is 240 feet deep, 10 inches in diameter, is cased to bedrock, probably terminates in limestone, and yields approximately 150 gallons a minute. The well is pumped by a 200,000-gallon motor-driven double-acting pump with the cylinder placed at 160 feet. The newer well is 2,250 feet deep, 10 inches in diameter at the top and 6 inches at the bottom, yields approximately 175 gallons a minute, and its static level is within 90 feet of the surface. This well is pumped by a 263,000-gallon motor-driven double-acting pump with the cylinder placed at 210 feet. Both deep-well pumps discharge into a concrete collecting reservoir 26 feet in diameter and 20 feet deep with a capacity of 80,000 gallons. The reservoir is beneath the concrete floor of the pumping station. Water is pumped from the reservoir into the distribution system by 2 electrically driven 2-stage centrifugal pumps. The distribution system comprises 8.7 miles of 4-inch to 12-inch cast-iron pipe with 740 service connections, all of which are metered. A 120,000-gallon steel standpipe 90 feet high is connected to the distribution system. The average daily consumption is 200,000 gallons.

The water is, of good sanitary quality. It contains 558 parts per million of mineral matter and 0.1 part per million of iron and it has a total hardness of 487 parts per million.

DOWNEES GBOVE. Sewerage and sewage disposal.—A system of sanitary sewers and a sewage-treatment plant were installed in 1904 at a cost of $54,835. The sewer system comprises 8.5 miles of 8-inch to 18-inch pipe. The treatment plant, comprising a septic tank, a dosing chamber, and 6 sand filters, is one-fourth mile west of the village in a thickly wooded valley adjoining St. Joseph Creek. The available fall westward and the presence of gravel deposits led to the selection of this site. The concrete septic tank is 60 feet by 18 feet in plan and 7 feet and 9 feet deep, respectively, at inlet and outlet. Its capacity is 65,000 gallons. A by-pass around the rest of the plant is provided for the effluent from the tank. The filters have a total area of one-fourth acre. The filter material originally was sand and gravel, but this was removed and replaced with crushed rock about 1910 because the beds had become badly clogged through lack of attendance. The same trouble will probably occur again soon as the beds are already partly clogged and matted. The sewage is distributed unevenly over the filters by wooden troughs in poor repair. Black deposits have formed where the heaviest dosing takes place, foul odors were noticeable around the sewage-treatment works, and the effluent was of unsatisfactory quality at the time of visit. St. Joseph Creek above the sewer outlet has a drainage area of only 7 square miles and goes entirely dry except for the sewage entering it. Much better results could be obtained if more attention were given to the operation of the treatment plant.

DUQUOIN (5,454). Water supply.—(Bull. **9**, 19; **11**, 58.) Visited July 8.

A larger and more substantial pump pit had been built since previous visits at the abandoned-mine pumping station. The solid concrete floor of the new pit is 28 feet below the surface and the walls are of natural rock which according to the plans will ultimately be covered with concrete. A 430,000-gallon centrifugal pump was removed from the old to the new pit and an 865,000-gallon 2-stage centrifugal pump also has been installed. Both pumps are direct-connected to electric motors on concrete foundations raised slightly above the floor. During 1914 a second reservoir adjoining the old reservoir was constructed. It is 200 feet long, 100 feet wide, and 7 feet deep, thus having a capacity of about 1,000,000 gallons, equal to that of the old reservoir. The walls are concrete one foot thick and the bottom is the natural clay soil exposed in excavation.

The water is still subject to pollution because of the method of operation at the mine pumping station and because of mixture with water from a badly constructed dug well at the main pumping station. Analyses of samples collected gave very unfavorable results.

DUQUOIN. Sewage disposal.—(Bull. **12**, 56.) Duquoin was visited July 8 at the request of the city officials to examine the septic tank about which there had been many complaints by local persons.

The sewage of Duquoin, having been passed through a septic tank, is discharged into a small watercourse. There has always been more or less complaint regarding the pollution of the watercourse and the odors emanating from the tank. In 1914 on the advice of the Survey the tank, which was installed in 1907, was cleaned for the first time. Complaints ceased following the cleaning but new complaints have lately been made to the city. Cleaning the tank was again recommended, but it was also pointed out that this would be of only temporary benefit and that the city prepare to install a sewage-treatment plant which would obviate the present nuisances both at the tank and in the watercourse.

DWIGHT. Water supply.—(Bull. **12**, 57.)
Sewerage and sewage treatment.—(Bull. **12**, 57.)

EARLVILLE. Water supply.—(Bull. **9**, 20.)

EAST DUBUQUE. Water supply.—(Bull. **11**, 60.)

EAST DUNDEE. Water supply.—(Bull. **9**, 20.)

EAST PEORIA. Proposed water supply.—(Bull. **11**, 61; **12**, 58.)

EAST ST. LOUIS (58,547). Water supply.—(Bull. **11**, 61.) East St. Louis was visited April 3 and 5 to inspect the operation of the purification plant and to collect. samples of water. The construction of six 500,000-gallon filter units, another clear-water basin, and additional settling basins, has been temporarily abandoned for financial reasons. The control of the alum feed has been changed from the constant-head orifice box to an orifice discharging horizontally from the end of a pipe connecting directly with a large solution tank. The rate of feed is determined by observing on a permanent scale the horizontal distance that the stream is carried out from the orifice. Observations are made hourly. As only a very alight change occurs in that time due to the drop of head in the large tank it is easy to keep the discharge at the rate desired by manipulation of a hand valve. A satisfactory water is being produced although the color is not always so completely removed as might be desired. This color could be partly corrected by more liberal use of alum. The average dose of alum during 1914 was slightly less than one grain per gallon and the average color removal was from 40 to 20. The waterworks company obtained a renewal of its franchise during the past year by paying $75,000 to the city.

EAST ST. LOUIS. Pollution of Cahokia Creek.—Visited June 7, July 29-30, and October 13 at the request of city officials and the Rivers and Lakes Commission to study the pollution of Cahokia Creek.

Cahokia Creek rises 40 miles northeast of East St. Louis and has a total drainage area of 335 square miles. It passes through East St. Louis from north to south, gradually converging with many sinuosities toward Mississippi River, and discharges into that river near the southern limits of the city. The course of the stream is through railroad yards and numerous railroad bridges over it supported on pile bents obstruct the flow of the stream, which is very sluggish at times and in its polluted condition creates a decided public nuisance. The foul condition of the stream will be prolonged throughout most of the year by diversion of the greater part of the discharge of Cahokia Creek to Mississippi River north of East St. Louis and below Edwardsville. The entire district in and around East St. Louis is low and flat and its natural drainage is poor. It was formerly subject to overflow by the river at high stage, but extensive levees and operation of pumps have reclaimed the major portion of the land. The East Side Levee and Sanitary District was formed a few years ago to take charge of and organize this work.

The sewage of Edwardsville and Collinsville enters upstream but is insufficient to produce nuisance so far downstream as East St. Louis. The sewage of East St. Louis is conveyed to one outlet into Mississippi River south of the city below Cahokia Creek. Pumps have been installed there for lifting the sewage when the river rises to a stage at which gravity flow is impossible. Three connections, which were formerly outlets, still exist between the system and Cahokia Creek; these are, however, equipped with valves that are kept closed except when it is desired to flush the sewers with creek water during high stages. The flow of the creek is influenced by gates at the lower end which are closed to prevent back flow during high water in Mississippi River. It was originally planned to install pumps at the mouth of the creek but this has not yet been done. Meantime, the water flowing in Cahokia Creek simply ponds at the lower end when the gates are closed. Shortly before the last inspection some of the gates were destroyed by a flood.

The only serious pollution now entering Cahokia Creek is from the National Stock Yards at National City just north of East St. Louis. National City covers about 0.7 square mile on both sides of Cahokia Creek; the greater part of it is owned by the National Stock Yards Co., and lots have been sold to packing companies and commission firms. Tie part of the village on the west side of the creek is open and unoccupied, but that on the east side is thickly congested with stock pens, railroad tracks, 3 packing houses, and numerous other large buildings. Most of the sewage and other liquid wastes including storm water is collected by a sewer system installed by the National Stock Yards Co. several years ago. A small part of the wastes are discharged into[1] the sewers of East St. Louis. The outlet of the stock-yards sewer is a brick conduit 2 feet by 3 feet 1½ miles long extending to Mississippi River just below the intake of the waterworks of East St. Louis. It is stated that there are also 8 pipe outlets along the east bank of Cahokia Creek near the packing plant. Four of these are said to have been abandoned, the fifth to discharge only condenser water, and regarding the other 3 no explanation could be obtained. All these outlets were covered by high water at the time of inspections and could not be seen. Waste liquors from the packing plants consist chiefly of floor washings, scalding water, and condenser water, the latter being large in volume but clean. These wastes, before flowing into the stock-yards sewer, pass through baffled settling tanks to remove fats and grease. The operators of the packing houses claim that none of their wastes enter Cahokia Creek directly, but it was evident from inspection that certain pollution enters the creek. Mississippi River was high at the time of the first) inspection, and the stock-yards sewer then flooded some of the streets at several places near the packing plants. This flood water was greenish in color, very turbid, and plainly resembled packing-house waste. Cahokia Creek below the packing plant showed evidences of pollution by stock-yards sewage. Rapidly rising bubbles showed septic action in deposits of sludge. Similar pollution in the creek was noticeable at the time of the last inspection. The East Side Levee and Sanitary District, the city of East St. Louis, and other interested organizations are studying conditions with a view of improving Cahokia Creek in respect to pollution and control of floods. Several ways of accomplishing this are under consideration.

EAST WENONA (367). Water supply.—Visited March 4. Mains for fire protection and domestic service were laid in East Wenona during 1914. The supply is obtained from Wenona. (See p. 139.)

EDWARDSVILLE. Water supply.—(Bull. **12**, 58.)
Sewage disposal.—(Bull. **12**, 59.)

EFFINGHAM (3,898). Water supply.—(Bull. **10**, 108; **11**, 63.). Visited April 1. Eflingham is in the catchment area of Little Wabash River in the central part of Effingham County, of which it is the county seat.

Waterworks were installed in 1895 when a 20-year franchise was granted to two citizens, who later sold it. About 1908 the owners failed to meet bonded obligations, and the waterworks were taken over by the bondholders who now constitute the Effingham Water Co. The supply is obtained from Little Wabash River 3 miles southwest of the city, where a dam of limestone 80 feet long and 12 feet high with a spillway its entire length has been constructed. The capacity of the reservoir thus formed by the dam is not definitely known. The water backs up 1½ miles, along which distance the average width is 75 feet. The land west of the river rises abruptly to a height of 50 feet but a wide flat area on the east side at an elevation of 6 feet above the dam is subject to overflow at high water. The river varies in stage as much as 25 feet. Its drainage area above the dam is about 300 square miles, on which are located only 3 incorporated communities; the largest of these is Neoga with a population of 1,100, and, none of them yet has sewerage. The supply has never been exhausted but in 1913 the water became so low that it was necessary to dig ditches between the small ponds in the bottom of the river to bring sufficient water to the intakes. The water is drawn from the reservoir by 2 intakes 12 inches in diameter at different levels, which discharge into a brick intake well 15 feet in diameter and 20 feet deep about 40 feet from the river. One intake very near the bed of the river is used only during low water. The water is pumped from the intake. well through a 12-inch force main into the distribution system. The pumping station is on the bank of the river 125 feet below the dam, where the ground is subject to an overflow of as much as 6 feet. There are 5 pumping units having a combined capacity of 4,450,000 gallons a day, 2 of which are 1,000,000-gallon tandem-compound duplex steam pumps located at the ground level and 3 electrically driven triplex pumps with daily capacities of 1,250,000, 600,000, and 600,000 gallons, respectively, and located in a room above flood water. The steam pumps are seldom used, but they are maintained in good condition and can be put in service on short notice. The total mains installed, including the force main, comprise 13.7 miles of 4-inch to 12-inch cast-iron pipe. There are about 370 service connections, slightly more than one-third of which are metered. A 180,000-gallon steel standpipe 120 feet high is connected to the distribution system. The pumpage is read daily from an 8-inch meter on the discharge line from the pumping station. The maximum, minimum, and average daily pumpages during 1914 were, respectively, 900,000, 480,000, and 675,000 gallons. As 2 railroads and 2 industrial plants use daily about 575,000 gallons, the average daily domestic consumption is about 100,000 gallons.

The water is of unsatisfactory sanitary and physical quality. Plans for purification works prepared by a consulting engineer in 1911 were approved by the Survey, but the installation has been delayed pending a decision by the State Public Utilities Commission of Illinois on the question of water rates.

EFFINGHAM. Disposal of wastes from catsup factory.—(Bull. **9**, 20; **10**, 108.)

ELDOEADO. Proposed water supply and sewerage.—(Bull. **9**, 20.)

ELGIN. Water supply.—(Bull. **9**, 20.)

Proposed sewage treatment.—(Bull. **9**, 147; **12**, 60.)

ELGIN. State Hospital. Water supply and typhoid fever.—(Bull. **10**, 109.)

ELMHURST. Proposed improved water supply.—(Bull. **11**, 64; **12**, 61.)

Sewerage.—(Bull. **11**, 64.)

Sewage pollution of Salt Creek.—(Bull. **12**, 61.)

ELMWOOD. Water supply.—(Bull. **12**, 62.)

EL PASO. Water supply.—(Bull. **10**, 109.)

EL PASO (1,470). Disposal of corn-canning wastes.—(Bull. **10**, 110.) El Paso was visited on October 5 after correspondence had been conducted with the superintendent of the Prairie State Canning Co. regarding disposal of liquid wastes from a corn-canning factory.

El Paso is in the southeastern part of Woodford County about 2 miles south of Panther Creek, a small tributary of Mackinaw River. This creek has a catchment area of only 15 square miles above the city and has no flow during dry weather. The city has no regular sewer system, but several tile drains intended for removing ground and storm water discharge into a small watercourse leading to Panther Creek just beyond the north edge of the city. Household drains and a drain from the canning factory have been connected with these tile drains. The resulting objectionable conditions at the outlets have been the cause of much complaint. The tendency is to attribute the trouble entirely to the wastes from the canning factory, but it is highly probable that the domestic sewage by itself creates a decided nuisance; moreover, this sewage is discharged continually whereas wastes are discharged from the canning factory only during the short corn-canning season. Farmers in the vicinity of the outlet have suggested that the tile drain be extended northward to Panther Creek. The canning company, however, does not favor this project not only because it would be expensive but also because it would only transfer the nuisance farther downstream where the resulting conditions would still be objectionable.

The corn-canning factory is similar to that at Washington at which experiments on disposal of canning wastes have been carried out under the direction of the Survey (See Bull. 11, pages 339-73). The wastes at El Paso now pass through screens and a settling tank which remove all settleable and floating solids such as silks and grains. A test hole bored on the company's land to ascertain the character of the soil showed 2 feet of loose porous top soil above clayey soil; consequently if the wastes are to be treated by disposal on land it will be necessary to install open-joint underdrains in trenches filled with sand in order to effect adequate absorption. It was suggested that such underdrains be installed and that treating the wastes on the natural soil be tried on a plot of 1½ acres divided into 4 units.

EUREKA. Water supply.—(Bull. **12**, 62.)
Disposal of cannery waste.—(Bull. **12**, 235.)

EUREKA (1,525). Proposed sewerage.—Eureka, in the southeast part of Woodford County, was visited September 16 at the request of the Rivers and Lakes Commission in reference to proposed installation of a sewer system having an outlet into Walnut Creek, which is a tributary of Mackinaw River flowing along the north and west edges of the city. Discharge from private sewers already installed has caused nuisances, and it has been necessary to extend the sewers farther downstream. The city now proposes to install 4,600 feet of 8-inch to 18-inch drains to carry storm water and sanitary sewage with an outlet into Walnut Creek southwest of the city. As the creek has a catchment area above the city of only 35 square miles the dry-weather flow is insufficient properly to dilute the sewage from Eureka, and treatment of the sewage will, therefore, be necessary. Consequently it would be advisable to install separate sewers one system to carry only sanitary sewage to a point where a suitable treatment plant can be built. This would be more economical as storm-water drains can be built from time to time and the water discharged into watercourses at the nearest points without creating nuisance.

EVANSTON (24,978). Water supply.—(Bull. **9**, 21; **10**, 110.) Visited April 28 and May 6. The filtration plant is producing satisfactory water, but some difficulty has been experienced by short filter runs. Occasionally filters can be operated 24 hours before being washed, but the length of most runs does not exceed 4 hours. It was thought at first that these short runs might be caused by the presence of microorganisms, but the counts showed only 600 to 1,000 per cubic centimeter, and the number present does not perceptibly differ before periods of long and short runs. It was suggested that possibly the difficulty might be caused by oxygen released in the sand and in the underdrains as a result of the reduced pressure caused by the down-draft. The evolution of large volumes of gas through the filter at the beginning of each wash indicates that such is the case. In order to get additional data on this point it was suggested that determinations of dissolved oxygen be made and that the results be studied in connection with the length of filter runs. If the trouble is caused by decreased solubility of oxygen under reduced pressure some improvement might be obtained by diminishing the negative head.

FAIRBURY. Water supply.—(Bull. **9**, 22; **12**, 63.)

FAIRFIELD. Water supply.—(Bull. **9**, 22; **10**, 110; **12**, 64.)
Proposed sewerage and sewage treatment.—(Bull. **12**, 65.)

FARMER CITY. Water supply.—(Bull. **10**, 111.)
Sewerage.—(Bull. **10**, 111.)

FARMINGTON (2,421). Water supply.—(Bull. **12**, 65.) Visited August 30. The supply of water has been materially reduced because of accidents to the single well that is the source. This well, 1,461 feet deep, terminates in St. Peter sandstone. A deep-well pump used until 1912 was then replaced by an air lift. When the air lift was installed the cylinder of the deep-well pump could not be removed, and it still remains at a depth of 260 feet. This reduces the cross section and consequently the discharge. A 5-inch eduction pipe was extended through the 6-inch cylinder. Pumping with air then was found to be more expensive than use of the deep-well pump, and the deep-well pump was reinstalled at the end of 1914. While this change was being made about 400 feet of the 5-inch eduction pipe was accidentally dropped into the well, and has probably become jammed in the bottom where the bore is only 6 inches. Now only 30 gallons a minute can be obtained, whereas the former yield was 135 gallons a minute, and a shortage of water is threatened. Another well should be drilled as the present well could not be taken out of service to be repaired without shutting off the water from the city for a considerable period. Moreover, the city should have 2 wells in order to provide against future breakdowns. At the time of inspection no definite steps had been taken for drilling another well. The fact that the collecting reservoir built in 1912 has developed large cracks and is leaking increases the prospect of a shortage of the water supply.

FARMINGTON. Sewerage and sewage disposal.—(Bull. 12, 66.) Visited August 30. The installation of the sewer system and sewage-treatment plant proposed in 1914, for which plans were then reviewed and reported, has been indefinitely postponed. It is unfortunate that the sewerage project has been abandoned as a system of sewers is badly needed. Farmington is one of the few cities of its size in the State that has not yet undertaken construction of sewerage.

FLORA. Water supply.—(Bull. **9**, 22; **12**, 67.)
Sewerage.—(Bull. **12**, 68.)

FOREST PARK. Water supply.—(Bull. **10**, 112.)

FORRESTON. Water supply.—(Bull. **11**, 65.)

FORT SHERIDAN. Water supply.—(Bull. **9**, 23; **10**, 112.) Visited April 26. Fort Sheridan is a Federal army post on the shore of Lake Michigan in the southeast part of Lake County. Its variable population ranges from 1,200 to 1,600.

The results obtained at this water-purification plant are not entirely satisfactory. The operator stated that recent inspection of the filters had shown that much sludge had accumulated in the filtering material and that only small areas of the bed of sand were efficiently working. The authorities at Washington had requested that the quantity of wash water used in operating the filters be reduced. The wash water now is about 5 per cent of the water filtered. One-half grain per gallon of alum and 0.05 grain per gallon of hypochlorite are being used.

FOX RIVER WATERSHED.—(Bull. **9**, 147; **11**, 66.)

FREEBURG. Water supply.—(Bull. **11**, 66.)

FREEPORT (17,567). Water supply.—(Bull. **10**, 113.) Visited February 9-10. Freeport is on Pecatonica River in the south-central part of Stephenson County, of which it is the county seat. Many manufacturing plants in the city have favored its substantial growth. The northeast corner of the corporation, cut off by Pecatonica River, is known as East Freeport. An extensive sewer system built on the separate plan has several outlets into the river.

Waterworks were installed in 1882 when a 30-year franchise was granted to the Freeport Water Co. When the franchise expired in 1912 a new one was granted for a further term of 30 years with some important alterations in terms. The supply first developed from a spring in a bluff near the river, soon became inadequate to meet increasing demands and it was supplemented for 3 or 4 years by water from Pecatonica River. A drift well of small diameter was then bored. As the water flowed at the surface several more wells were sunk. The static head soon receded, however, and it became necessary to connect the suction of the pump to the wells. After the water from the drift wells had been satisfactory for several years trouble arose because of growths of crenothrix. To eliminate this trouble a new supply was sought in 1900 by sinking a well to St. Peter sandstone, which is said to have furnished good water until it began to deposit iron. After experimentation a treatment plant was constructed in 1903 to remove the iron from the water. An appraisal was made of the plant in 1912 by three engineers, who recommended several changes and improvements in equipment which are being made.

The supply is now derived from 25 wells in drift 2½ to 8 inches in diameter and 35 to 45 feet in depth and connected at intervals to a suction main about 300 feet long. Two drilled wells terminate in St. Peter sandstone, one 6 inches in diameter and 265 feet deep and pumped by air lift and the other 16 inches in diameter and 303 feet deep. The latter well, drilled primarily as an emergency supply, has not yet been equipped because the reduction of consumption after the installation of meters has made it unnecessary. The material penetrated by the drift wells is unusual. The borings penetrated 30 to 40 feet of heterogeneous drift and then a bed of limestone 5 to 10 feet thick. After penetrating the limestone the drills dropped about 2 feet in a cavity, below which a layer of coarse water-bearing sand and gravel was entered. The shallower wells going simply to the base of the limestone draw water from the reservoir beneath and thus require no strainers. The limestone probably formed a shelf on the edge of a preglacial valley beneath which was eroded a cave that later was filled with sand and gravel; possibly the wells penetrate an old watercourse through the rock in which sand and gravel have been deposited. The static level in the drift wells is 25 feet and in the rock wells is 15 feet below the surface. The combined yield of the drift wells alone is more than sufficient to meet present demands. Though the new franchise permits the use of water from Pecatonica River in emergencies the river intake has not been used, except to supply boiler water, since the system of wells was established in 1890, and it is unlikely that it will be used.

The treatment for removal of iron includes coagulation with hydrated lime, sedimentation, and filtration through sand. The plant was designed with a capacity of 2,000,000 gallons a day and a rate of filtration of 125,000,000 gallons per acre per day. The filter area has since been doubled, but no increase has been made in the settling capacity. The water from the 25 drift wells is pumped into 2 sedimentation tanks at about mid depth through a branched discharge pipe. The water from the rock well is discharged into one of the settling tanks. The solution of lime was originally forced into the discharge line a few inches beyond the pumps, but because of incrustations in the discharge pipe the point of application was changed to within a few inches of the settling tanks. The lime water is prepared in 2 circular wooden tanks having capacities of 9,500 gallons each. It is discharged through a float-controlled valve into a tub, from which 2 small duplex steam pumps draw it at such rate as to empty one tank in 12 hours. The tank used during the day is charged with 200 pounds and that used during the night with 160 pounds of hydrated lime. This method of chemical control is not entirely accurate, but it may be reasonably so if carefully watched by the operator. The average dose of hydrated lime is about 1.6 grains per gallon. The 2 wooden sedimentation tanks are 25. feet in diameter and 16 feet deep. In each a false wooden bottom slopes from a height of about 6 feet at the circumference to a 12-inch outlet to the sewer at the center. The capacity of each tank above the false bottom is 44,000 gallons, or a total of 88,000 gallons, affording a detention of 1.3 hours with the present average daily pumpage of 1,625,000 gallons. This detention of 1.3 hours, however, is not actually realized because of the absence of baffles and because of the manner of circulating the water in the tank. The inlets discharge horizontally along the walls of the tanks at about mid depth and the floating outlets are directly opposite the inlets. As the water entering the tank causes a whirling motion some of the water undoubtedly remains in the tank only a few minutes. The whirling motion also prevents proper sedimentation. A sketch was submitted indicating how the effectiveness of the tanks might be improved by rearranging the inlets and outlets and providing suitable baffles. The floating outlets, which permit a variation of 8 feet in the drawing level, were installed to make available the water in the upper parts of the settling tanks in emergency. This reserve is now, however, small compared with the present clear-water storage, and the gain in settling capacity would warrant substitution of a stationary outlet near the top of the tank for the floating outlet.

There are 8 filters, each with a rated capacity of 500,000 gallons a day. Four are cylindrical double-walled wooden filters installed in 1903, with inner cylinders 15 feet in diameter and 5 feet 7 inches high and outer cylinders 16 feet 2 inches in diameter and 7 feet 7 inches high, the annular space between cylinders serving as influent and wash-water channels. These filters have not been used since the installation of 4 concrete filters in 1914. The concrete filters have a sand area 14½ feet by 12 feet and the filter boxes are 7 feet 7 inches deep. A 12-inch concrete channel at the end of each filter, connected to 2 sheet-iron troughs placed longitudinally over each filter, serve as the influent and wash-water channels. The tops of the troughs are 14 inches above the surface of the sand. The filter medium, sand and gravel, is 3 feet thick. When the sand in the old filters was renewed in 1914 it was necessary to use picks to remove the old sand, and apparently the only clear openings through it were small holes that had been kept open by the rush of air and wash water. Before that time portions of the sand had been removed because of heavy incrustation and cementing of the grains. This incrustation can be prevented by adding alum just before the water goes to the filters and by modifying the settling tanks to keep much of the lime from passing to the filters. The strainer systems in all the filters are essentially similar; each filter is equipped with one manifold with laterals 6 inches apart and small disc strainers at 6-inch intervals along the laterals; each manifold is supplied from four 2-inch air pipes connected with a 4-inch header across the filter above the surface of the water. The filters are washed once every 24 hours. They are first agitated with air 3 minutes, then washed with water with a vertical rise of about 10 inches a minute for 10 to 15 minutes. The wash water is estimated at 2.8 per cent of the filtered water.

The filtered water is stored in 3 concrete reservoirs having a total capacity of 800,000 gallons. One reservoir beneath the settling tanks and the wooden filters is 39 feet by 97 feet 2 inches by 8 feet deep with a capacity of 225,000 gallons. Another beneath the concrete filters is 38 feet 4 inches by 26 feet by 8 feet deep with a capacity of 60,000 gallons. The third reservoir, with a capacity of 515,000 gallons, is a rectangular structure built almost entirely in excavation and covered with a flat concrete roof. The reservoirs are interconnected by pipes. When the river rose sufficiently to flood the pumping station in February, 1911, some flood water gained access to the reservoirs. This indicates a possibility of contamination to the public supply during unusually high stage.

Two tandem-compound duplex pumps of 2,000,000- and 3000,000-gallon capacity pump water from the wells to the treatment plant. There are 3 high-service pumps having a total daily rated capacity of 8,750,000 gallons: a 1,750,000-gallon tandem-compound duplex pump in good repair but uneconomical to run; a 3,000,000-gallon compound flywheel duplex pump; and a 4,000,000-gallon compound flywheel duplex pump. The pumpage is computed daily from the log of the pumps with an allowance for slippage of 15 per cent. The maximum, minimum, and average daily pumpages during 1914 were, respectively, 2,200,000, 1,200,000, and 1,625,000 gallons. The average daily consumption during 1914 although greater than that in 1912 was less per service connection because of extensive metering of services.

The distribution system comprises 54 miles of 4-inch to 16-inch pipe. There are 4,219 service connections, of which 3,882 are in use, and 88 per cent of the active services are metered. The industrial consumption of. city water is relatively small as many factories have their own supplies. A 45,000-gallon elevated steel tank having a total height of 120 feet is connected to the distribution system. The value of the waterworks was placed at $316,000 by the appraisal commission in 1912. Many additions have been made since that appraisal, and the present value is placed at $509,000.

The water obtained from the wells is of good sanitary quality and is not subject to contamination in the station except by flood water as already noted. The water from the drift wells is slightly more mineralized than that from the rock wells. Water from the drift wells has a mineral content of 432 parts per million, a total hardness of 365 parts per million, and contains 0.7 part per million of iron. Water from the rock well has a mineral content of 356 parts per million, a total hardness of 346 parts per million, and contains 0.3 part per million of iron. Treatment has little effect on the general mineral content, but it removes all the iron and the manganese, of which 0.28 part per million is present. The iron is reduced in the settling tanks from 0.7 to 0.5 part per million, and the effluent from the filters contains no iron. So far as known the manganese has caused no trouble, but the trouble attributed to iron before the filter plant was installed may have been caused partly by manganese.

FULTON. Water supply.—(Bull. **11**, 67).
Sewerage.—(Bull. **11**, 68.)

GALENA. Water supply—(Bull. **11**, 69; **12**, 68.)
Sewage disposal.—(Bull. **12**, 68.)

GALESBURG (22,089). Water supply.—(Bull. **9**, 23; **10**, 114; **12**, 69.) Visited September 21, and 29-31, at the request of the commissioner of health. As the results of analyses of the city water had been unfavorable and several cases of typhoid fever had occurred in the city an inspection of the water supply seemed advisable. Previous investigations by this Survey had indicated unsatisfactory conditions in quality and quantity of the supply, in view! of which the city council had voted to hold an election on October 19 on the question of a bond issue of $95,000 for an additional well, necessary pumping equipment, a reservoir, and additions to the distribution system. The grounds surrounding the wells were in insanitary condition and several sources of possible pollution were observed. These included privies in close proximity to the wells and the reservoir, poor construction of sand catchers, and insanitary living conditions of railroad employees who lived in bunk cars close to the source of supply. Cedar Creek, which is badly polluted and flows close to the wells, recently overflowed its banks and was probably responsible for the unfavorable analyses.

In view of these conditions and the prevalence of typhoid fever it was advised that a temporary plant for treatment with hypochlorite be installed for use until conditions favoring contamination could be remedied. The city officials favored this installation, and the second visit to the city was to install the temporary plant and to give instructions in its operation. As it was impracticable to put the treatment plant into immediate operation the water in the storage reservoir was immediately treated with hypochlorite. The installation comprised 2 solution tanks 3 feet in diameter and 4 feet deep. The solution was fed into the suction of the high-service pumps by a specially designed locally made pump, which was actuated by the plunger of the high-service pump and thus fed the solution of hypochlorite in direct proportion to the quantity of water pumped. The displacement of the high-service pump is 116 gallons per revolution and of the chemical-feed pump 2.64 cubic inches. In order to add hypochlorite to the water to give 0.3 part per million of available chlorine it is, therefore, necessary to dissolve 4½ pounds of hypochlorite per foot of height in the storage tank. As the high-service pump has a daily capacity of 6,000,000 gallons, which is greater than the consumption, and a portion of the pumpage is by-passed to the collecting reservoir and repumped, part of the water would be dosed more than once. It was, therefore, necessary, to determine by experiment the correct strength of hypochlorite to use. This installation can be abandoned when the sanitary conditions around the wells and the reservoir are improved.

GALESBURG. Sewage disposal.—(Bull. **9**, 23; **10**, 114; **12**, 70.)

GALESBURG. Pollution of Cedar Creek. (Bull. **9**, 23; **10**, 114; **12**, 70, 196-224.) Galesburg was visited February 10 to testify before the Rivers and Lakes Commission in reference to pollution of Cedar Creek by sewage from the city of Galesburg. The testimony consisted in reading sections of the report prepared by this Survey (See Bull. **12**, 196-224), and answering specific questions regarding the treatment of wastes. At the close of the hearing the Commission issued an order requiring the abatement of the nuisance on or before July 1, 1918.

GALVA. Water supply and sewerage.—(Bull. **10**, 115.)

GENESEO. Water supply.—(Bull. **10**, 116.)

Pollution of Geneseo Creek by city sewage.—(Bull. **10**, 117; **11**, 70; **12**, 70.)

GENEVA. Water supply.—(Bull. **9**, 23.)

Sewage treatment.—(Bull. **12**, 70.)

GENEVA. Illinois State Training School for Girls. Plans for sewage treatment.—(Bull. **12**, 71.)

GENOA. Water supply.—(Bull. **11**, 70.)

GENOA (1,257). Sewage disposal.—(Bull. **12**, 71.) Genoa was visited June 2 to inspect the sewage-treatment plant, which was installed during 1914. The plant comprises a screen chamber and a 2-story settling tank. The screen chamber and the tank adjoin each other and are covered by a roof sufficiently high to permit ready access to all parts. Several windows provide good light and ventilation. The 18-inch outfall sewer terminates in the screen chamber, which is 4 feet by 16 feet in plan. The screen consists of iron bars placed about 2 inches apart inclined about 30 degrees from horizontal. A limited quantity of storm water is allowed to enter the sewers and an overflow is provided to by-pass any excess flow. The 2-story settling tank has 2 settling compartments with one sludge chamber below. Each settling compartment is 60 square feet in cross-sectional area and 20 feet long, equivalent to capacities of 7,600 gallons. The sludge chamber has a capacity of 20 cubic yards. The total depth of water to flow line in the tank is about 15 feet. A suitable valve-controlled opening is provided at the bottom of the tank for removing the sludge, which may be discharged either on a sludge-drying bed or into the outlet to the river. The sludge bed, which has an area of 1,000 square feet, consists of 15 inches of sand and gravel underlain with 3 lines of 6-inch tile placed about 7½ feet apart.

About 130 connections had been made to the sewerage system before the day of inspection, and the small flow was being treated in one of the settling compartments. Satisfactory results were being obtained. The effluent was well clarified compared with the raw sewage and there were practically no odors even inside the building. Sludge had been removed from the tank twice; the first time it had been discharged on the sludge bed, and the second time, as there was high water, it was discharged directly into the river. The sludge, which had not then been removed from the bed, was quite inoffensive. The effluent is discharged into Kishwaukee River.

GEORGETOWN. Proposed water supply.—(Bull. 9, 24; 10, 117.)
Proposed sewerage and sewage treatment.—(Bull. 12, 72.)

GIBSON CITY. Water supply.—(Bull. 10, 118.)
Disposal of cannery waste.—(Bull. 12, 73.)

GIBSON CITY (2,086). Typhoid fever.—(Bull. 10, 118.) Visited January 25. Gibson City is in the southwest part of Ford County at the headwaters of Sangamon River. The city has had a water supply for 20 years, but no sewerage system has been installed.

There occurred in all 4 cases of typhoid fever; one started on December 26, 1914, the second on January 4, and the last two on January 14. 1915. The first two cases occurred in the same household, and the last two cases in another household, and these two families were related and visited frequently back and forth. The small number of cases showed that the public water supply had no bearing on the typhoid situation. Investigation indicated that the first case probably incurred his infection from an out-of-town case who had visited Gibson City. The other three cases were probably secondary cases as they all came in direct contact with one another. The lengths of the intervening periods between the onset of these cases emphasizes the possibility of contact infection.

GILLESPIE (2,241). Sewerage.—Gillespie was visited January 12 in reference to a sewer system then under construction. Gillespie is a coal-mining center in the southeast part of Macoupin County on Bear Creek, a small tributary of Cahokia Creek. The sewer system which will comprise about 5,440 feet of 10-inch to 18-inch pipe was under construction. It will carry both storm water and household drainage and will serve the business district and a large part of the residential district. There will be 3 outlets into Bear Creek just east of the business district. As Bear Creek at Gillespie has a catchment area of less than 3 square miles and is often dry during summer discharge of the sewage into it will undoubtedly create serious nuisance. In order to avoid such nuisance the village is contemplating the construction in the bed of the creek of a large intercepting sewer, which will discharge near the south part of town. The dry-weather flow will be diverted into a septic tank. In view of the fact that treatment of the sewage will be necessary it was advised that the city consider installation of separate sanitary sewers instead of combined sewers.

GILMAN. Water supply.—(Bull. **11**, 71.)

GIRARD. Proposed water supply.—(Bull. **11**, 71.)

GLENCOE. Water-supply and sewerage.—(Bull. **9**, 24.)

GLEN ELLYN. Water supply.—(Bull. **12**, 73.)
Sewage disposal.—(Bull. **12**, 74.)

GEAFTON. Pollution of Illinois River.—(Bull. **11**, 72.)

GRAND RIDGE (403). Water supply.—(Bull. **11**, 72.) Visited July 5. Grand Ridge is in the south-central part of La Salle County about 8 miles south of the junction of Illinois and Pox rivers. The drift in this locality is more than 250 feet thick and several private wells are 175: to 200 feet deep. There is no sanitary sewerage but a limited amount of tile laid for groundwater drainage receives overflow and seepage from cesspools.

Grand Ridge experienced a disastrous fire in 1913 when a plant owned by the Public Service Company of Northern Illinois was destroyed, the loss having been estimated at $20,000. Two grain elevators and a lumber yard near the conflagration were spared only because of favorable winds. Waterworks were agitated immediately after the fire and it was voted in December to install a system. The waterworks were completed and put into operation early in 1915. The supply is obtained from one well 10 inches in diameter and 160 feet deep, which ends in water-bearing sand and gravel 46 feet thick. The well is provided with a 10-foot Cook screen. The static level is 125 feet below the surface. When the well was completed it was pumped for 22 hours at a rate of 70 gallons a minute according to weir measurements without signs of diminished yield. Water is pumped from tho well into the distribution system by an electrically driven 5¾-inch by 18-inch deep-well pump. At 30 strokes a minute the pump has a displacement of 175,000 gallons a day. The distribution system comprises 2.4 miles of 4-ineh, 6-inch, and 8-inch cast-iron pipe. Thus far 74 connections have been made and several more are to be made in the near future. All services are metered. A 60,000-gallon steel tank 20 feet high elevated on a 100-foot tower is connected to the distribution system. The average daily consumption is yet only 11,000 gallons. The system, including mains, cost $19,187, or $47.50 per capita. The operating cost thus far has been about $30 a month.

The water is of good sanitary quality. It has a mineral content of 278 parts per million, a total hardness of 118 parts per million, a content of iron of 0.9 part per million, and a trace of manganese.

GRANITE CITY (Eat. 15,000 in 1913). Water supply.—(Bull. **11**, 72.) Visited April 6 and 7 to inspect the operation of the water-purification plant and collect samples of water for analysis. A siphon line 1,800 feet long laid in 1914 from the suction well at the plant across a sand bar to the river has made it possible to obtain water direct from Mississippi River at as low as 1.6-foot stage whereas heretofore it could not be obtained below 12-foot stage.

This is a marked improvement for at low stages the supply from the wells and Cabaret Slough, which had to be used a great deal, was very hard and difficult to purify. The daily pumpage was about 2,500,000 gallons, which was about 1,000,000 gallons below normal because industrial consumption was low. About 1½ grains per gallon of alum were being used. There is still a prospect of abandoning this source for a supply from East St. Louis, but construction at the latter plant has been delayed.

GBANITE CITY. Proposed improved sewerage.—The Survey in December, 1912, investigated proposed improvements in sewerage estimated to cost $171,000 and comprising 9,450 feet of concrete outlet sewer ranging in size from 4.5 to 9 feet. The improvement has been delayed but confirmation of the assessment roll is expected early this year. Since the former investigation the proposed improvement has been enlarged to include about 25,826 feet of trunk sewer ranging in size from 3 to 9 feet and estimated to cost $410,527. The improvement will entirely eliminate the unsightly and foul open ditch east of the levee. The sewage flows westward from the levee about 3,300 feet in an open ditch into Cabaret Slough, an arm of Mississippi River. An attempt has been made to build a dike across the lower end of this slough and allow the channel to fill up behind it. This has thus far been unsuccessful, but if it should become filled the outlet sewer of Granite City would have to be extended to the river, an additional distance of about 2,200 feet.

GBANVILLE (1,391). Water supply.—Visited September 15. Granville is in the northern part of Putnam County in the drainage basin of Illinois River. The development of the coal industry has caused rapid increase in population during the past few years. The village of Mark adjoins Granville on the west. It also is a mining settlement with a population of 1,025 and it is supplied with water from Granville. Surveys and estimates were made a few years ago for sewerage in Granville, but the cost was considered beyond the means of the village and the project was abandoned. Many private dug wells are used, but since the waterworks were installed newly built homes have been supplied with city water and few new wells have been dug.

Waterworks, installed in 1911, were improved in 1915 by an additional storage reservoir. The supply is obtained from a 1,742-foot well terminating in St. Peter sandstone. It is 8 inches in diameter at the top, is cased to 800 feet, and is 4.5 inches in diameter at the bottom. The static level is 125 feet below the surface. The water is pumped from the well into 2 collecting reservoirs by an electrically driven single-acting deep-well pump having a 6-inch by 36-inch cylinder placed at a depth of 250 feet. The pump is operated at about 25 strokes a minute, equivalent to a displacement capacity of 150,000 gallons a day. Both reservoirs are built partly in excavation and partly in embankment and have substantial roofs. The older reservoir is 30 feet in diameter and 12 feet deep, equivalent to a capacity of 64,000 gallons. The new reservoir is 12 feet deep, 30 feet wide, and 54 feet long with the ends rounded, and it has a capacity of about 100,000 gallons. Water is pumped from the reservoirs into the distribution system by a 500,000-gallon single-acting triplex pump driven by a gasoline engine. There are no records of the distribution system, but it is estimated that it comprises 3 miles of 4-inch, 6-inch, and 8-inch mains. An 8-inch main leads to Mark, which is equipped with about the same amount of distributing mains as Granville There are 165 services in Granville and 76 in Mark, practically all of which are metered. Two steel pressure tanks 10 feet in diameter and 40 feet long with a combined capacity of 47,000 gallons are connected to the distribution system. The pressure ranges between 45 and 55 pounds except in case of fire when the tanks are shut off and direct pressure is applied. The average daily consumption for both villages is estimated at about 40,000 gallons.

Mark pays a flat rate of $77.50 a month for water. This is slightly more than was paid last year and it is proposed to readjust the rate from time to time as consumption changes.

Only one analysis of the city supply has been made, in 1911; though the result of this analysis was unfavorable the method of handling the water apparently precludes all chances of contamination, and the sample may have been contaminated during collection. Effort has been made to have the city send another sample but none has yet been received. The water has a mineral content of 1,007 parts per million, of which 320 parts is chloride and 119 parts is sulfate. The hardness is 270 parts per million, and the content of iron is 3.8 parts per million. The content of mineral matter is high, the water would have a mineral taste, and it would stain clothes laundered in it.

GRAYSLAKE (603). Sewage disposal.—(Bull. **12**, 75.) Visited April 1. There is a demand for improvement in the disposal of the sewage of Grayslake. The disposal problem is complicated by wastes from a large condensed-milk factory. The factory wastes amount to 300,000 gallons a day, but the volume may be cut down to 200,000 gallons by installation of new cooling devices at the plant. The volume of domestic sewage is small as there are probable not yet more than 50 house connections on the system. A treatment plant, however, should be capable of handling sewage from a population of 1,000.

The following recommendations were made:

(1) That the condensed-milk factory treat its wastes in a tank with a detention period of about 2 hours so baffled as to operate as a grease trap.

(2) That the sanitary sewage of the city be treated in a 2-story settling tank.

(3) That the combined wastes be treated on 3 intermittent sand filters having a combined area of one-half acre and that these filters be so arranged and designed that they may be enlarged at any time.

(4) That a site of 17 acres now owned by the city be utilized for treatment works and that it be parked and planted with trees so as to render the sewage-treatment works as inoffensive esthetically as possible.

GRAYVILLE. Water supply.—(Bull. **10**, 119.)

GREAT LAKES, Naval Training Station. Water supply.—(Bull. 9, 28; **11**, 134.) Visited April 26. As recommended by the State Water Survey an appropriation of $5,000 was requested from the Federal authorities for the purpose of making certain improvements in the filter plant. This appropriation was refused. It is impracticable for the Survey to make monthly analyses of the water because the institution has no funds with which to pay express charges on the samples. A second request will doubtless be made by the officials of the institution for an appropriation for improving the plant.

GREENUP (1,224). Water supply.—(Bull. **10**, 119; **11**, 74.) Greenup was visited January 20 at the request of the city officials to collect samples of water to determine its suitability for boiler use. The waterworks have been improved since the previous visit by the addition of an electrically driven 360,000-

gallon triplex pump. Leaks in joints and valves of the boiler in a newly installed electric light plant were locally believed to have been caused by the poor quality of the water. Examination showed, however, that the trouble was probably caused by the poor joints themselves, and the leakage finally stopped after sufficient mineral matter had been deposited in the joints by the water. The water has a mineral content of 669 parts per million and a total hardness of 263 parts per million. As the supply is taken from Embarrass. River it will vary in composition.

GEEENVIEW. Water supply—(Bull. **11**, 75.)

GREENVILLE (3,178). Sewerage and sewage disposal.—(Bull. **11**, 75; **12**, 76.) Visited April 8. Contracts for construction of sewerage and a sewage-disposal plant at a cost of approximately $27,000 were awarded late in 1914. Construction was under way at the time of the visit and it was expected to have the system completed by May 1. The sewerage system is of good design and if it is properly constructed it should be adequate for the community. The design of the sewage-treatment plant is not in conformity with the views of the Survey, which have been communicated to the local authorities.

The outfall sewer, 16 inches in diameter, extends to a sewage-treatment plant at the site of an old gravel and sand pit at the west edge of town. The treatment plant comprises a settling tank, a sand filter, and a sludge bed. The settling tank is 41 feet long, 15 feet wide, and 6 feet 4 inches deep, with a capacity to the flow line of 29,000 gallons, and it is divided longitudinally through the center by a wall. In each of the compartments thus formed there are 4 transverse hanging baffles about 8 feet apart extending to 15 inches from the bottom of the tank. The detention period for a flow of 75 gallons per capita per day of sewage from a population of 1,000 with both compartments in. operation will be about 9 hours. The filter is about 0.2 acre in area and[1] the filter medium consists of coarse sand and small pebbles natural to the vicinity. The sewage is applied to the bed through a 16-inch main distributor and six 8-inch laterals placed about 15 feet apart at right angles to the main distributor. All the distributing pipes are buried beneath the surface and are laid with their joints open. At the far end of three of the laterals there are brick wells similar to ordinary cesspools about 10 feet deep and covered with a few inches of earth. There are no underdrains, the supposition being that the liquid will seep out from the joints of the distributing pipes and the brick wells and filter laterally into a near-by ravine. With a daily flow of 75,000 gallons of sewage the rate of application will be 375,000 gallons per acre per day. This rate is excessive even for well-constructed sand filters, in which means are provided for properly distributing the sewage over the entire area.

HAMILTON (1,627). Water supply.—(Bull. **10**, 120; **11**, 76.) Hamilton was visited June 24 to observe the operation of the filter plant and to collect samples of water. The filter plant has a rated daily capacity of 1,000,000 gallons, but it is being operated only a few hours each day as the consumption is only 60,000 gallons. The largest high-service pump, which has a capacity of 860,000 gallons a day, had been disconnected from its motor as a higher rate per 1,000 gallons for pumping is charged by the power company when this pump is used.

HARMON. Proposed water supply.—(Bull. **10**, 121.)

HARRISBURG (5,309). Water supply.—(Bull. **9**, 24; **10**, 121; **11**, 76; **12**, 76.) Visited May 4-6. Harrisburg, the county seat, is in the central part of

Saline County in the drainage basin of Middle Fork of Saline River. The prosperity of the community is dependent upon coal mining and agriculture. The site of the city occupies slightly rolling ground above most of the surrounding country, but the flat level land near neighboring watercourses is subject to overflow at high stages of the river.

Waterworks were installed in 1901 by the Peoples Water and Light Co. Ownership was transferred in 1912 to the Central Illinois Public Service Co. The source of supply has always been Middle Fork of Saline River. Before the water-purification plant was installed in 1914 an unsuccessful effort was made to obtain a water supply from wells. The supply is taken from Middle Pork at a point about 1¼ miles east of town where a dam about 8 feet high and 75 feet long has been constructed. The dam forms a reservoir with an estimated capacity of 40,000,000 gallons and the impounding effect extends upstream for more than a mile. The reservoir is partly filled by silt. The drainage area above the dam is about 210 square miles, in which, the clayey upper portion of the soil makes the water always turbid. The great and rapid fluctuations of the discharge have been lately increased by the construction of several drainage ditches. During prolonged dry weather the stream ceases to flow. Its waters are subject to pollution by sewage from Harrisburg and surface drainage from several small communities.

Two low-lift pumps in a station near the dam raise water from the reservoir to the filter plant and main pumping station in the northeast part of the city. The pumps are electrically driven triplex pumps having capacities, respectively, of 500 and 400 gallons a minute, or a combined daily capacity of about 1,250,000 gallons. They are belt-connected to motors in the upper part of the station, which is built about 30 feet high in order to bring it above flood water. The motors are operated from switches at the main station, which is in the northeast part of the city and is operated in connection with an ice plant and an electric light plant. The high-service equipment comprises a 750,000-gallon and a 1,000,000-gallon pump.

A filtration plant near the main station was put into operation late in 1914. It comprises chemical-preparation and feed devices for alum, soda, and calcium hypochlorite, a reaction chamber, 2 settling basins, 3 sand filters, 2 clear-water basins, and a laboratory. Chemicals are stored in the main station because of lack of room in the filter house. The concrete solution tanks are built along a balcony over the end of two of the filters. Each of the 2 tanks for solution of soda and the 2 tanks for solution of alum has a capacity of 290 gallons, and each of the 2 tanks for solution of hypochlorite has a capacity of 180 gallons. The tanks discharge into constant-head orifice boxes, of which one is provided for the soda, one for the alum, and 2 for the hypochlorite solution. The solutions of soda and alum are fed into the inlet compartment of the mixing chamber, the soda near the bottom, and the alum at about mid depth. The solution of hypochlorite is fed into the clear-water basin beneath the filters. The reaction chamber, with a capacity of 19,000 gallons, affords a detention period of about 30 minutes on the rated capacity of the plant. It is provided with a series of winged baffles to produce good mixing and to maintain proper velocity. A vertical riser pipe ends at suitable height to provide a waste overflow. The two 54,000-gallon settling basins, one rectangular and the other irregular in shape in order to conform to the space available, can be operated singly or in parallel. Both afford a detention period of 2.9 hours on the rated capacity of the plant.

Each basin is provided with a sump and suitable valve-controlled outlets for removing sludge. They are covered by a flat reinforced-concrete slab roof and several manholes provide access to them.

Bach of three filter units, 10.5 feet by 10 feet, has a capacity of 300,000 gallons per 24 hours based on a filtration rate of 125,000,000 gallons per acre per 24 hours. The filters are arranged along one side of the operating floor. The filtering material comprises 10 inches of gravel overlaid by 2.5 feet of sand. The filter equipment is the standard equipment of the New York Continental Jewell Filtration Co. The strainer comprises a grid of piping tapped with strainer heads spaced 6 inches center to center. All control valves are operated by hand from wheel stands on the operating floor. Each filter is provided with a loss-of-head gage and a filter-rate controller of the Vcnturi type. Compressed air is used in washing the filters, and the electrically driven blower is on the operating floor. Taking the wash water from the discharge main of the pumping station causes' a marked drop in pressure at the station. The washings drain to a concrete basin from which they are pumped into the city sewer.

There are 2 clear-water reservoirs, one beneath the filters, built when the filtration plant was built and the other, an old reservoir, remodeled when the improvements were made. As the capacities of the new and old reservoirs are, respectively, 20,000 and 113,000 gallons, the total clear-water storage is 3.5 hours on the rated capacity of the plant. A very Commendable feature of the filter plant is the laboratory, which is only 8 feet by 6 feet in plan and located over one of the filters but very well and very neatly equipped. Daily tests are made for turbidity, color, alkalinity, number of bacteria, and gas formers. The results are tabulated and also recorded on diagrams.

The quality of the unfiltered water varies widely. The turbidity during April and May ranged from 10 to 4,000 parts per million, and was reduced to zero in the filtered water. Middle Fork of Saline River, from which the supply is obtained, is subject to serious pollution by sewage and surface drainage, but satisfactory and safe water is furnished to the consumers by careful operation of the filter plant and sterilization of the filtered water with hypochlorite. When Harrisburg reconstructs its sewerage system to eliminate the present sewer outlet above waterworks dam it will materially reduce the burden placed on the filter plant.

The distribution system comprises about 4½ miles of 4-inch, 6-inch, and 8-inch cast-iron pipe, the largest portion being 4-inch. There are about 500 service connections. The character of tho water before the filtration plant was operated made it impracticable to meter services and less than 30 meters were used; but meters have been gradually installed since then and all services will soon be metered. A 47,000-gallon elevated steel tank is connected to the distribution system, which maintains a pressure of about 45 pounds in the business district.

The daily consumption is about 400,000 gallons except during extremely dry weather when it is about 450,000 gallons. Since the filter plant has been in operation the number of consumers has increased, but installation of meters has counteracted the increase in consumption by new consumers.

HARRISBURG. Pollution of public water supply by improper sewage disposal.—(Bull. **11**, 77.) Harrisburg was visited February 5 to testify at a preliminary hearing before the Rivers and Lakes Commission, on April 1-4 to inspect the drainage basin of Middle Fork of Saline River above the waterworks dam, and on May 6 to attend a second hearing before the Rivers and Lakes Commission.

Harrisburg is provided with a combined system of sewers installed in 1906 and 1907 at a cost of $15,300. At the time of the installation there was but one outlet located just below the waterworks dam about 1¼ miles east of the city. Because of poor design and construction the system has never operated successfully, and an additional outlet was procured about 2 years ago by extending the sewer in Main Street northward to West Harrisburg drainage ditch, which discharges into Middle Fork of Saline River above the dam. When the Central Illinois Public Sexvice Co., which owns and operates the waterworks, objected to this discharge of sewage above the dam the matter was taken up by the Rivers and Lakes Commission and a formal complaint was made against the city. At the first hearing the city contended that it was not the only offender or even the most serious offender but that all municipalities along Middle Fork of Saline River contributed to the pollution of the water supply and should be included in the investigation by the Rivers and Lakes Commission. For this reason the hearing was adjourned and a sanitary inspection of the drainage basin was undertaken.

The inspection showed that the new sewer outlet discharging above the dam served about one-fourth of the area of the city. This outlet is located 1.2 miles above the mouth of the drainage ditch and 3.5 miles above the dam. The discharge is typical fresh domestic sewage and it produces objectionable conditions in the drainage ditch. At times of very small flow the sewage does not find its way into Middle Fork of Saline River as the Big Four Railroad has constructed a small dam about 2 feet high on the drainage ditch and uses this water for its locomotives. When rains occur, however, all the sewage and the accumulated sludge in the bottom of the ditch are washed into Middle Fork of Saline River and thereby seriously contaminate the water supply. In addition to the pollution from the new sewer outlet the water supply is also polluted by sewage from Harrisburg because of inadequacy of the main outlet sewer, which causes the sewage at times of rain to overflow two manholes near Pankey Branch. These manholes are 1.0 and 1.2 miles by water above the dam.

None of the other communities which Harrisburg wished to have included in the complaint have sewer systems. The contamination from Muddy, Ledford, Dorrisville, and Gaskin City consists entirely of surface drainage and consequently they pollute the water supply only during rainy weather. All their inhabitants depend entirely for sewage disposal on privies, which are generally poorly built and have no vaults. This aids the washing of the fecal matter into the streams at times of rain. The water supply will thus be polluted by surface wash, but not so seriously or so continuously as by direct discharge of sewage. Gaskin City, an unincorporated town with a population of about 500, lies east of Harrisburg and drains into Pankey Branch. Dorrisville, a village with a population of 1,400 immediately south of Harrisburg, drains partly[1] into Pankey Branch and partly into West Harrisburg drainage ditch. The distance from Dorrisville to the waterworks dam is 2.7 miles by way of Pankey Branch and 5.4 miles by way of the drainage ditch. Ledford, a mining settlement of about 600 population located 2½ miles southwest of Harrisburg, also drains into Pankey Branch 5.2 miles above the waterworks dam. Muddy, another mining settlement with a population of about 700, is northeast of Harrisburg on Middle Fork of Saline River. In addition to contamination by sewage from Harrisburg and the surface wash from the other incorporated communities named considerable water pumped from mines is discharged into the watercourses. This water contains much iron and may be objectionable because of its mineral content, but it is of minor importance from a sanitary standpoint.

At the second hearing before the Rivers and Lakes Commission it was decided that the discharge of sewage by Harrisburg from its new outlet above the waterworks dam was objectionable and that the lesser contamination by surface drainage of other incorporated communities did not furnish excuse for Harrisburg to discharge sewage directly into the watercourses furnishing the public water supply. An order was, therefore, entered against the city of Harrisburg requiring that it cease polluting the public water supply by direct discharge of its sewage by July, 1916. To comply with this order it will probably be necessary to make a thorough engineering study of the present sewerage. The system can then be altered and portions reconstructed on the basis of this study in such a manner as to provide satisfactory sewerage for the city with only one outlet, and that below the waterworks dam. The present trouble resulted from the city's failure to have a competent consulting engineer design and supervise the present sewerage system.

HARVARD. Water supply.—(Bull. **12**, 78.)
Sewage disposal.—(Bull. **10**, 122; **12**, 79.)

HARVEY (7,227). Water supply.—Visited August 11. Harvey is a manufacturing community in Cook County near Little Calumet River and about 19 miles south of the center of Chicago. It has an extensive sewerage system with an outlet into Little Calumet River. Some residents of Harvey have complained regarding the pollution of a ditch on the east edge of Harvey by wastes from Phoenix, an adjoining village on the east, which does not have a sewerage system.

The waterworks, installed about 1890, are now the property of the Public Service Company of Northern Illinois. The supply was first obtained from a 2,100-foot drilled well, 6 inches in diameter at the top. As salt water was encountered at 2,100 feet the well was plugged at 1,600 feet and the water now comes from Potsdam sandstone. Part of the well caved in during plugging and greatly reduced the yield. The water is raised by air, the nozzle being placed 345 feet below the surface. Three additional wells deriving their supply from Potsdam sandstone have been drilled as needed. Well 2, about 1,600 feet deep and 10 inches in diameter at the top, is pumped by air lift with the nozzle at 360 feet, and it yielded 186 gallons a minute during a test in 1914. Around the top of this well is a small depression above the bottom of which the casing rises about 15 inches, or to the general level of the surface. The space between the 10-inch and the 6-inch casings of the well was open at the time of the visit thus subjecting the water to possible contamination but following the submittal of the report by this department this condition was remedied and the well made absolutely tight at the top. Well 3, 1,616 feet deep and 15½ inches in diameter at the top, was recently rebored and cleaned out for the second time and a new air-lift pipe with its nozzle at 460 feet was installed. With the present pumping equipment the well yields 325 gallons a minute. Well 4, about 1,600 feet deep and 16 inches in diameter at the top, is equipped with a centrifugal pump and yields approximately 100 gallons a minute. The aggregate yield of all the wells is approximately 1,000,000 gallons a day. It is customary to pump either with air lift alone or with the centrifugal pump in well 4 alone, and to draw on all wells only at times of heavy consumption. The static level in March, 1913, was 120 feet below the surface and in June, 1915, was 155 feet below the surface, a drop of 35 feet or 15.5 feet a year.

Water is discharged from the wells into a 225,000-gallon circular uncovered concrete collecting reservoir 40 feet in diameter and 25 feet deep near the pumping station and about 25 feet from the street. The wall extends 3 feet above the surrounding ground and is surmounted by a woven wire fence 4 feet high. The pumping station is a substantial and attractive building erected about two years ago. The high-lift pumping equipment comprises 2 electrically driven units installed by the present owners and 2 steam pumps form0-erly used, but now held in reserve in case of emergency. One electric pumping unit consists of two 2-stage centrifugal pumps direct-connected on either side of a 50-horsepower motor. Piping is so arranged that these pumps may be operated either in parallel or in series. The maximum capacity of the unit is 1,000,000 gallons a day. The other unit consists of two 2-stage centrifugal pumps similarly arranged and driven by a 100-horsepower motor. This unit has a rated capacity of 2,000,000 gallons a day against 60 pounds pressure and 1,000,000 gallons a day against 120 pounds pressure. A 6-inch meter is installed on the discharge pipe from each unit. Electricity is transmitted to the pumping station over two separate lines from the company's power plant at Blue Island 2 miles away. The steam equipment consists of a 1,000,000-gallon single-expansion duplex pump and a 1,000,000-gallon tandem-eompound pump. Two air compressors, one steam driven and the other electrically driven, furnish air to the wells. The high-service pumps draw from a pit about 5 feet in diameter beneath the floor of the station, and connected to the collecting reservoir by a 20-inch pipe. The distribution system comprises approximately 16.7 miles of 4-inch, 6-inch, 8-inch, and 12-inch cast-iron pipe, and approximately 21.4 miles of 2-inch to ¾-inch wrought-iron pipe. The smaller sizes of pipe are principally service pipes. A 125,000-gallon steel standpipe 95 feet high located about a mile from the center of the city is connected to the distribution system. It affords a pressure when full of 41 pounds at its base. In case of fire the standpipe is shut off and a high direct pressure is maintained. The average daily consumption is about 400,000 gallons. The maximum and minimum daily pumpages recorded during 1915 by meters on the discharges of the pumps were, respectively, 460,000 gallons and 323,000 gallons.

Analyses show that the water is of good sanitary quality. The water has a mineral content of 1,300 parts per million, a total hardness of 640 parts per million, and a trace of iron.

HARVEY. Investigation of nuisance.—(Bull. **10**, 123.)

HAVANA. Water supply.—(Bull. **12**, 79.)
Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **11**, 77.)

HENNEPIN. Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **9**, 24.)

HENRY. Water supply.—(Bull. **12**, 80.)
Pollution of Illinois River.—(Bull. **11**, 77.)

HERRIN (6,861). Water supply.—(Bull. **10**, 125.) Preliminary plans and specifications for a water-purification plant at Herrin were received and reviewed February 18, and a conference was held February 24 with a representative of the filter company that had been retained by the city. Revised plans were received and reported March 4, and Herrin was visited October 8, on which date the purification works were under construction. The city was again visited December 16-17 to render assistance in equipping a laboratory.

The water supply of Herrin is obtained from an impounding reservoir with a storage capacity of somewhat more than 48,000,000 gallons and a catchment area of 4.7 square miles. The tributary basin is devoted entirely to farming and the likelihood of contamination is not great. Nevertheless as the possibility of contamination exists and the water is at times highly turbid it was advisable to install a purification plant. The filter plant has a rated daily capacity of 1,000,000 gallons. It comprises a reaction chamber, a sedimentation basin, 2 filter units, a filtered-water basin, and necessary appurtenances including a laboratory. The reaction chamber has a capacity of 24,900 gallons, affording a detention period of 3 6 minutes on the rated capacity of the plant. The coagulation and sedimentation, basin has a capacity of 105,000 gallons, affording a detention period of 2½ hours. Both the reaction chamber and the settling basin are provided with suitably controlled valves for removing deposits of sludge. Each of the filter units has a sand area 11 feet by 16½ feet, giving a total filter surface of 363 square feet. The filtered-water basin beneath the filters has a capacity of 40,000 gallons. The chemical solutions are prepared in 4 rectangular concrete tanks, each having a capacity of 480 gallons. A well-lighted room in the superstructure housing the filters and operating floor serves as a laboratory. At the time of the last visit to Herrin suggestions were made regarding the necessary laboratory equipment. When this is procured a test will be run during which a member of the Survey staff will be present.

HEREIN. Proposed sewerage.—(Bull. **10**, 125.)

HIGH LAKE. Proposed water supply.—(Bull. **9**, 24.)

HIGHLAND (2,675). Proposed water supply.—(Bull. **10**, 126.) Visited January 15 and June 7. An inspection was made of one of the reservoirs and the catchment area that furnishes water to a local brewery and a condensed-milk factory. This reservoir has been suggested as a source of public water supply. Inspection revealed considerable objectionable drainage, principally from pig pens. Preliminary plans for a filter plant were reviewed and various suggestions were made at a meeting of the city council. It was recommended that engineering studies of all possible reservoir sites be made before development of the supply.

HIGHLAND. Proposed sewerage.—Visited June 7. There is no sanitary sewerage though tiles for ground-water drainage have been installed. There is a decided need for adequate sewers as the large quantities of sink drainage now reaching the gutters of the streets produce odoriferous and otherwise objectionable conditions. If the proposed water supply is installed the need for a system will be much greater. As it will be necessary to treat the sewage of Highland in order to prevent nuisances a separate system would be preferable to a combined system of sewerage.

HIGHLAND PARK. Water supply and sewerage.—(Bull. **9**, 24; **10**, 126.)

HIGHLAND PAEK (4,209). Sewage treatment.—(Bull. **9**, 24.) Visited February 10 to note tha operation of the sewage-treatment plant. There were no odors at the plant and a few residences had recently been built on the bluff overlooking the plant and only 300 feet to 500 feet distant. The effluent from the settling tank was well clarified as compared with the raw sewage. Only 2 of the 6 basins for dosing the filters were properly operating. The uniformity of distribution could not be observed as the distributors are buried in the filter.

The top of the filter was entirely dry and no outward signs of clogging were evident. The effluent was cloudy and not greatly different in appearance from the settling-tank effluent.

HILLSBORO (3,424). Water supply.—(Bull. **10**, 127; **12**, 81.) Hillsboro was visited March 26 at the request of the city's consulting engineer to review a report on preliminary plans and to examine the proposed location of 'reservoirs for an improved water supply. Middle Fork of Shoal Creek, recommended by this Survey about 1912, was selected as the future source of supply. The consulting engineer had proposed two methods for developing this supply; (1) by a series of 4 small dams impounding about 65,000,000 gallons and capable of delivering continuously to the city during a dry year about 1,500,000 gallons a day; (2) by construction of one large reservoir with a capacity of 375,000,000 gallons capable of yielding more than 20,000,000 gallons a day. The large reservoir does not represent the desirable size, but it is not practicable to develop a reservoir site of any smaller capacity except in the bed of the stream.

The project involving 4 small dams and reservoirs was favored because it was the cheaper and furnished adequate quantity of water for the city for a number of years. The principal objection was the possibility that the channel of the stream might change and thus render the reservoirs useless. The large dam and reservoir would settle the water-supply problem for Hillsboro once for all, but the cost of the project is beyond the financial ability of the city.

A communication was received December 29 from the city's consulting engineer and a written report was submitted on plans which he had presented to the Survey for review. These plans call for the construction of only 2 small dams and reservoirs at present. The danger that new channels might form around the dams during periods of floods was again pointed out. The flat bottom of the valley favors the formation of side channels, and many were noticed during inspection of the basin. The possibility of raising the ground-water level in the bottom lands to such height as to interfere with cultivation of the land adjoining the reservoirs was mentioned. Although construction of one large reservoir was favored by the Survey the development of smaller reservoirs was approved; but the city was informed that it should recognize that such developments should be considered only temporary arrangements pending the time that the growth of the city and its financial resources warrant the larger project.

Plans for a water-purification plant have not yet been prepared, but it is taken for granted that the project for water supply includes water-purification works and that final detail plans will be submitted to the Survey before contracts are awarded.

HILLSBOEO. Sewage pollution of Middle Fork of Shoal Creek.—(Bull. **12**, 83.)

HINCKLEY. Water supply.—(Bull. **11**, 78.)

HINSDALE (2,451). Water supply.—(Bull. **11**, 78.) Visited June 8 and 30, September 22, and October 7. Hinsdale is a suburb of Chicago on the eastern boundary of Dupage County in the catchment area of Des Plaines River.

Waterworks were installed about 1890, the supply having been obtained from a well 800 feet deep. This well has not been used since the second well was drilled about 1900. This second well, the present source of supply, is 200 feet deep and 12 inches in diameter, and is cased for 100 feet to rock, below which the water is derived from limestone. The low-service pumps in a pit 17½ feet deep at the top of the well draw directly from the well against a suction lift of 16 to 20 feet. The pit is dirty and water stands on the floor of it. The yield has not been determined. The well is pumped normally at a rate of 600 gallons a minute, though it has been pumped at a rate as high as 940 gallons a minute during short periods.

As the water is hard and contains iron an iron-removing and softening plant was put into operation this year. The softening plant has a rated daily capacity of 1,000,000 gallons and its operation comprises treatment with lime and soda ash, sedimentation, and filtration. The steel mixing tank for chemicals has a capacity of 2,700 gallons. Six hundred pounds of soda ash is dissolved with the aid of live steam, and 1,800 pounds of lime is added just before the solution is drawn off into the feeding tank. One charge contains sufficient chemical to treat 450,000 gallons of water and the rate of 4 pounds of lime and 1 1-3 pounds of soda ash per 1,000 gallons is used. The steel softening tank in 33 feet in diameter and 39 feet high, equivalent to a capacity of 250,000 gallons. A circular steel baffle built inside the tank as the frustrum of a cone 4 feet in diameter at the top and 16½ feet at the bottom extends from a few inches above water to within about 4 feet of the bottom. The water and the solution of chemicals enter the top of this frustrum, pass downward and around the bottom of it, upward on the outside to the top of the tank, and through an overflow into the settling tank, which is similar to the softening tank in size and appearance. Both tanks are provided with suitable valves and outlets for drawing off sludge. The 3 filter units have a total area of 270 square feet. At the nominal daily capacity of 1,000,000 gallons these filters will operate at the rate of 160,000,000 gallons per acre per day. The filtering medium comprises 18 inches of graded gravel overlain by 18 inches of crushed quartz. The filters are washed by reversing the flow of water and agitating with air. The filtered water is stored in a reservoir located beneath the filters having a capacity of 16,000 gallons.

One low-lift pump is a 1,500,000-gallon duplex steam pump, and the other is an electrically driven 1,000,000-gallon single-stage centrifugal pump. Both normally discharge into the softening tank but the steam pump can discharge directly into the distribution system. The high-pressure service is supplied by a 2,000,000-gallon tandem-compound duplex pump. The distribution system comprises 25 to 30 miles of 8-inch and smaller mains and covers the built-up portion of the village. The service connections number about 750, all of which are metered. A steel tank 66 feet high on a brick tower 50 feet high is connected to the distribution system. Headings of a Venturi meter show a daily pumpage of 300,000 to 500,000 gallons; for short periods the rate has been as high as 1,000,000 gallons.

The water is of good sanitary quality and the softening plant has proven satisfactory in reducing the mineral content and hardness. The efficiency of the softening plant is shown by the following analyses of the raw, settled, and filtered water.

ANALYSES OF WATER AT HINSDALE

[Parts per million.]

	Raw water	Settled water	Filtered water
DETERMINED QUANTITIES			
Total residue	644	417	370
Sulfate	176	178	174
Sodium carbonate as $CaCO_3$	0	56	52
Non-carbonate hardness as $CaCO_3$	100	0	0
Carbonate hardness as $CaCO_3$	362	42	40
Magnesium salts as $CaCO_3$	124	20	16
Calcium salts as $CaCO_3$	338	22	24
Iron (Fe)	1.3	0	0
HYPOTHETICAL COMBINATIONS			
Sodium nitrate ($NaNO_3$)	1	1.6	0
Sodium chloride (NaCl)	2	2	2
Sodium sulfate (Na_2SO_4)	118	263	257
Sodium carbonate (Na_2CO_3)	...	59	55
Magnesium sulfate ($MgSO_4$)	120	...	...
Magnesium hydroxide ($Mg(OH)_2$)	...	12	9
Magnesium carbonate ($MgCO_3$)	20	...	...
Calcium carbonate ($CaCO_3$)	338	22	24
Iron carbonate ($FeCO_3$)	3	...	...
Undetermined	42	57	23

HOLLYWOOD (50). Water supply.—Hollywood is supplied with water by Lagrange.

HOMER (1,086). Pollution of private wells.—(Bull. **12**, 84.) Homer was visited August 27 because many wells there had been filled with surface water by heavy rainfall in the early part of August. This village is in the southeast part of Champaign County in the basin of Salt Fork of Vermilion River. There is a system of tile drains with numerous catch basins, but it is inadequate during periods of heavy rainfall and flooded cellars and wells result. The wells are nearly all of the open dug type. It was recommended that a public water supply be installed, but local authorities feel that such an improvement can not be made at least for two years or until the present indebtedness caused by paving streets is reduced.

HOMEWOOD. Water supply.—(Bull. **12**, 84.)

HOOPESTON. Water supply.—(Bull. **10**, 128.)
Sewerage system.—(Bull. **11**, 78.)

IPAVA. Water supply.—(Bull. **12**, 85.)

JACKSONVILLE. Water supply.—(Bull. **10**, 129; **12**, 85.)
Sanitary inspection of Chautauqua ground.—(Bull. **12**, 87.)

JACKSONVILLE, Illinois school for the deaf. Water supply.—The Illinois school for the deaf at Jacksonville was visited May 7 at the request of the State Board of Administration to study possible sources of water supply for the institution. This school is at the west edge of Jacksonville on relatively high ground. It was established about 40 years ago and now occupies several large buildings. The total enrollment, including pupils and teachers, is approximately 450.

The school now has 2 separate systems of water supply, one for drinking and culinary use and the other for fire protection and sanitary use. The average daily consumption is about 100,000 gallons. The supply of drinking water is obtained from a dug well 45 feet deep in a rather isolated place several hundred feet northwest of the buildings. The well is walled with brick, the upper portions of which are laid in cement, and it is surmounted by a small circular house. A small motor-driven pump lifts the water from the well into a distributing system, to which is connected a 3,000-gallon circular storage tank in a tower of one of the buildings. The quality of this supply is satisfactory, but the yield of the well is limited and on certain occasions it has been necessary to haul drinking water.

The fire and sanitary supply is obtained from the city mains and from a small reservoir on a tributary of Mauvaise Terre Creek. Both supplies are subject to pollution and are often of objectionable physical character. The reservoir is about three-fourths of a mile south of the school, where a dam about 4 feet high and 12 feet long has been built. Very little storage is afforded in the channel above the dam, but storage is augmented by a near-by artificial pond, into which the water passes through a tile. This pond possibly has a capacity of 4,000,000 gallons and has not been adequate at all times to meet the needs of the school. The yield of a dug well 40 feet deep at this site is practically negligible. Water is pumped from the impounding reservoir into a collecting reservoir at the school grounds by an electrically driven 300,000-gallon triplex pump. The collecting reservoir is built partly in excavation and partly in embankment and has a capacity of about 3,000,000 gallons. It has been paved inside with brick and concrete, but this paving has cracked and there are hollow spaces under the pavement caused by settling; as a natural consequence the reservoir leaks so badly that it has not been used lately and all water for sanitary use has been purchased from the city. As the pressure in the city mains is little more than enough to carry the water to the school the water has to be repumped. For pumping water from the collecting reservoir or city mains two 50,000-gallon duplex steam pumps are operated. These pumps discharge into a distribution system separate from the drinking-water supply system. Connected to this sanitary-water system and located in the same tower as the other tank is a second equalizing tank having a capacity of 4,700 gallons. The city charges 9 cents per 1,000 gallons for water furnished, and the monthly bill for the school is about $300. The total cost is, therefore, very high and as the supply of drinking water is also inadequate improvements or changes seem highly desirable.

Purified surface water as a supply does not appear practicable as the creek south of the school flows through wide bottom lands, in which no suitable sites for reservoirs exist. Installing a filter for purifying the city water would be feasible, but the cost of the raw water is excessive. The possibilities of obtaining a ground-water supply are uncertain as no tests of the ground-water resources have been made. A well recently bored at the site of a sanatorium to be built about one-fourth mile southwest of the school and on the ridge at about the same elevation as the State institution struck water-bearing sand and gravel 26 feet thick at 90 feet. It is stated that water was drawn from this well with a sand bucket at the rate of 1,000 gallons an hour without lowering the water level. It was suggested that the State institution arrange with the owners of this well for a thorough pumping test. The valley of the creek near the present reservoir pumping station may be a favorable site for wells. The 40-foot dug well now there yields little water, but deeper boring might reveal a water-bearing bed heretofore undiscovered. It was suggested that several test wells be put down in the bottom lands if a test of the new well at the sanatorium shows it to be inadequate.

JERSEYVILLE. Water supply.—(Bull. **12**, 88.)

JOHNSTON CITY. Water supply.—(Bull. **11**, 79.)

JOLIET. Water supply.—(Bull. **11**, 79.)

Illinois State Penitentiary, Water supply.—(Bull. **11**, 81.)

KANKAKEE (13,986). Water supply.—(Bull. **11**, 83.) Kankakee was visited May 5 to observe the operation of the filter plant and to collect samples of water.

KANSAS (945). Proposed water supply.—Visited January 21. Kansas is in the southwest corner of Edgar County in the drainage basin of Embarrass River. The village has no sewerage but several overflows from cesspools have been connected to the tiles for ground water that have been installed through the main part of town. Bonds were voted for waterworks late in 1914. A well has been sunk near the south end of the village and contracts have been awarded for a distribution system and an elevated tank. The well is 10 inches in diameter and 73 feet deep, penetrating a 10-foot stratum of sand and gravel at the bottom. The average rate of pumping during a 48-hour test was 55 gallons a minute. It was possible to obtain 75 gallons a minute but the water then carried large quantities of sand. No samples of the water were sent to the laboratory of the Survey for analysis. The distribution system comprises 14,200 feet of 4-inch, 6-inch, and 8-inch pipe. The elevated tank, 35 feet high, will have a capacity of 50,000 gallons and will be supported on a 90-foot steel tower. The estimated cost of the waterworks is $16,000.

KEITHSBURG. Water supply.—(Bull. **12**, 89.)

KENILWOETH (881). Water supply.—(Bull. 9, 24.) Kenilworth was visited February 12 and April 27 and a conference was held April 2 with an official of the waterworks at the office of the Engineer. As a result of previous investigations made by the Survey and a threatened outbreak of typhoid fever a crude hypochlorite-treatment plant was installed during 1914. This plant, however, was neglected and was operated only a short time as the use of hypochlorite was deemed unnecessary by the local health officer. The sand that was removed from one of the filters during 1914 had become badly soiled and incapable of being properly cleaned by ordinary washing. All the strainer heads in that filter were removed and cleaned at the same time and about 12 of them were replaced by new ones. At the time of the last visit the raw water was of unquestionably good character and did not place a severe burden on the filter plant.

KEWANEE. Water supply.—(Bull. **10**, 130.)

KIRKWOOD. Water supply.—(Bull. **10**, 131.)

KNOXVILLE (1,818). Water supply.—(Bull. **9**, 25; **10**, 131; **12**, 90.) Visited October 27. A new 570,000-gallon electrically driven pump has been installed.

. KNOXVILLE. Sewage disposal.—(Bull. **12**, 90.)

LACON. Water supply.—(Bull. **12**, 91.)

LADD (1,910). Water supply.—(Bull. **11**, 84; **12**, 91.) Visited July 5. The water is drawn from a well 187 feet deep and is discharged into a collecting reservoir built in excavation and lined with planks. Previous analyses by the Survey indicated that the water was of good sanitary quality as drawn from the well but became contaminated in the reservoir. After that report the village improved the collecting reservoir by placing a concrete curb around the top and putting on a new cover. The analyses still show that the water undergoes a marked change during storage in the reservoir. This is undoubtedly caused by the shallow ground water which enters through the leaky walls of the reservoir. The village officials have now decided to replace the air-lift equipment in the well by a deep-well pump discharging directly into the distribution system. This abandonment of the reservoir precludes possibility of contamination and if the reservoir and the present pumping equipment are maintained in working condition they will be available in case of fire. The cost of the proposed changes will be $2,000. An electrically driven 86,000-gallon deep-well pump is to be installed. The static level is about 40 feet below the surface and the elevated tank is 140 feet high; the pump will, therefore, operate against a head of 180 feet.

LAGRANGE (5,282). Water supply.—Visited October 12. Lagrange is in Cook County just west of Chicago of which it is a suburb.

The waterworks installed about 1890 by a private company were later taken over by the city. The city sold them to the North Shore Electric Co., by whom they were sold in 1905 to the present owner, the Public Service Company of Northern Illinois. The buildings of the waterworks have burned down twice since the installation. The supply is obtained from 3 drilled wells about 2,000 feet deep terminating in Potsdam sandstone. Two of the wells are 30 feet apart and the third is about 150 feet from the others. All are 16 inches in diameter to 150 feet, below which depth they decrease in size, the first two having been finished 4 inches in diameter and the third 6 inches in diameter. The older wells are cased only a short distance into rock, which is encountered a few feet below the surface. The third well is cased to 180 feet. The wells are drilled on the rim of an old limestone quarry which was originally 30 feet deep and there is some question whether surface water in the quarry may gain entrance to the older wells through crevices at points below the bottoms of the casings. It is difficult to say whether this actually happens though analyses do not show contamination. The old quarry has recently been about half filled. The static level of the wells is about 72 feet below the surface. A steady annual recession of about 6 feet has been observed during past years. The maximum yield of the 3 wells is unknown but probably as much as 2,500,000 or 3,000,000 gallons a day might be obtained. With the present equipment the newest well will yield about 1,500,000 gallons a day. Water is pumped from the wells by 3 electrically driven deep-well centrifugal pumps placed 90 feet below the surface, with suction pipes 30 feet long. The total daily capacity of the 3 pumps is about 3,000,000 gallons. The collecting reservoir is 47 feet by 125 feet by 14 feet deep, and it has a capacity of 450,000 gallons to the flow line. It is built of masonry and is covered with a flat concrete roof, and its walls extend 4 feet above ground. Water is pumped from the reservoir into the distribution system by 2 electrically driven pumping units. Each unit comprises two 2-stage centrifugal pumps arranged on either side of and direct-connected to a motor. The pumps of each unit may be used either in parallel or in series. One unit has a combined capacity of 2,000 gallons a minute and a capacity of 1,300 gallons a minute with only one pump operating. The other unit has a total capacity of 750 gallons a minute and a 500-gallon capacity with only one unit operating. Emergency equipment includes a dynamo and a steam engine and a 1,500,000-gallon compound duplex pump. The distribution system comprises 23 miles of 4-inch to 12-inch pipe. At the beginning of 1915 there were 1,416 services, all but 5 of which were metered. Practically the entire population uses the supply. A standpipe 15 feet in diameter and 120 feet high is connected to the distribution system. The total pumpage is measured by 2 meters, one on each discharge from the high-service pumping units. The water thus measured includes that sold to the neighboring towns of Brookfield, Hollywood, and Lagrange Park. The average daily pumpage was 370,000 gallons in 1912 and 550,000 gallons in 1914. The maximum daily pumpage during 1914 was 1,033,000 gallons.

Analyses show that the water is of good sanitary quality. It has a mineral content of 603 parts per million, a total hardness of 509 parts per million, and a content of iron of 0.2 part per million.

LAGRANGE. Sewage-treatment plant.—(Bull. **10**, 134.)

LAGEANGE PAEK (1,131). Water supply.—Lagrange Park is supplied with water from Lagrange.

LA HAEPE. Water supply.—(Bull. **12**, 92.)

LAKE BLUFF. Water supply and sewerage.—(Bull. **9**, 25; **10**, 135.)

LAKE FOEEST (3,349). Water supply.—(Bull. **9**, 25; **12**, 93.) Visited February 11 and April 27. Late in 1914 a water-purification plant with upward filtration was put into operation, and since then the old pressure filters have been used only occasionally for secondary treatment when the raw water is very turbid. The new filter consists of 18 inches of gravel and sand supported by a wooden grid. The water, having passed upward through the filter, flows into an adjoining compartment serving as a storage basin. The raw water has usually been relatively clear, and the load on the new filter has not been severe. The effluent during this time compared very favorably with that obtained from pressure filters formerly used, but the real efficiency of the new filters will not be determined until it becomes necessary to treat raw water of high turbidity and color. When the now filter was cleaned a deposit of sludge 6 to 8 inches in depth was found in the bottom of the filter, another accumulation in the gTavel, and a layer about one-fourth inch thick on the. filter sand. The top of the sand was scraped, and much of the accumulated sludge was removed by reversing the flow through the filter. In addition to filtration hypochlorite is being used.

LAKE FOREST. Sewage disposal.—(Bull. **9**, 25; **11**, 85.)

LAKE ZURICH (304). Water supply.—Visited June 3. Lake Zurich is a summer resort in the southwest corner of Lake County on the east side of the lake with the same name. A system of sanitary sewers is proposed and an engineer has been engaged to prepare plans. The discharge will probably be northward into a marsh through which the lake has an outlet to a small creek. The village has purchased 30 acres of land north of the lake as the site for the sewage-treatment plant.

Waterworks wore installed in 1912. The supply is obtained from a 218-foot well cased to the bottom with 6-inch casing. The well penetrates water-bearing sand and gravel, and it yields with present pumping equipment about 35 gallons a minute. The static level is about 100 feet below the surface. The water is pumped from the well into a collecting reservoir by an electrically driven 4¼-inch by 18-inch double-acting deep-well pump. The concrete collecting reservoir is 10 foot deep and has a capacity of 38,000 gallons. Its walls extend slightly above ground and are surmounted by a flat concrete cover with 2 manholes. Water is pumped from the reservoir into the distribution system by a 158,000-gallon triplex pump. The distribution system comprises 6,170 feet of 4-inch and 6-inch cast-iron pipe. There are 31 service connections. A 50,000-gallon elevated stool tank having a total height of 120 feet is connected to the distribution system. The daily consumption ranges from 6,000 to 10,000 gallons. The total cost of the waterworks was about $14,000.

The water is of good sanitary quality. It has a mineral content of 1,585 parts per million, a hardness of 956 parts per million, and a content of iron of 0.2 part per million.

LANARK. Water supply.—(Bull. **11**, 85.)

LA EOSE (415). Proposed water supply.—Visited March 24. La Eose in the south part of Marshall County about 11 miles east of Illinois River. There has been considerable agitation in the village for a public water supply. A well sunk in the west end of the village entered slate at 112 feet and was continued down in that formation to 150 feet without obtaining water. A second well 4 inches in diameter, which was then put down in the east end to 28 feet, enters an 8-foot vein of water-bearing gravel. It yielded 25 gallons a minute for 9 hours without apparently affecting the supply.

No plans for the pumping station and distribution system have yet been prepared. A plan was suggested to the city, which called for 4,640 feet of 4-inch and 6-inch pipe, a 50,000-gallon tank 80 feet high, and an electrically driven 70,000-gallon deep-well pump. The authorities were advised to have a competent engineer draw definite plans and superintend the installation.

Analysis showed this water to be of good sanitary quality. It has a mineral content of 485 parts per million, a total hardness of 401 parts per million, and a content of iron of 3 parts per million.

LA SALLE. Water supply.—(Bull. **11**, 86.)

Investigation of the pollution of two deep wells.—(Bull. **9**, 25.)

LAWEENCEVILLE (3,235). Water supply.—(Bull. **9**, 25; **11**, 86; **12**, 93.) Lawrenceville was visited April 15 to observe the operation of the filter plant and to collect samples of water.

LEAF RIVEE. Proposed water supply.—(Bull. **12**, 94.)

LE CLAIEE. Typhoid fever.—(Bull. **11**, 87.)

LELAND (545). Water supply.—(Bull. **12**, 95.) Visited September 23. Leland is in the north part of La Salle County. It has no sanitary sewers, but a number of tile drains installed primarily for ground-water drainage receive seepage and overflow from a few cesspools.

Waterworks were completed in the spring of 1915. The supply is obtained from a well 10 inches in diameter and 230 feet deep and cased to 100 feet, at which depth water-bearing limestone was entered. The static level is about 8 feet below the surface. The maximum yield is unknown, but pumping at 225 gallons a minute for a few hours at a time does not exhaust the supply. The water is pumped from the well into the distribution system by a 325,000-gallon electrically driven double-acting deep-well pump. The distribution system comprises about 13,000 feet of pipe 4, 6, and 8 inches in diameter. Seventy connections have been made, all of which were metered. A 40,000-gallon elevated steel tank with a total height of 120 feet is connected to the distribution system.

About half the population use the water and the daily consumption probably is 15,000 gallons. The waterworks cost about $20,000.

The water is of good sanitary quality. It has a mineral content of 328 parts per million, a total hardness of 286 parts per million, and a content of iron of 4.8 parts per million.

LENA. Water supply.—(Bull. **11**, 88.)

LE EOY. Water supply.—(Bull. **10**, 136.)

LEWISTOWN. Water supply—(Bull. **12**, 95.)

LEXINGTON. Water supply.—(Bull. **12**, 96.)

LIBERTYVILLE. Water supply and sewerage.—(Bull. **10**, 137.)

LINCOLN. Water supply.—(Bull. **10**, 138; **11**, 89.)
Sewerage.—(Bull. **12**, 96.)

LINCOLN, State school and colony. Water supply.—(Bull. 12, 97.) The State school and colony at Lincoln was visited October 5 at the request of the State Board of Administration because the water stains plumbing fixtures and a sediment that forms in the mains makes the water objectionable for drinking and for domestic and laundry use. The supply is obtained partly from the Lincoln Water and Light Co. and partly from a well on the school grounds in the bottom of the pumping pit, the walls of which are so leaky that seepage percolates through them into the well. The water of the school well is more highly mineralized than the public supply of Lincoln and responsible for most of the trouble. It has a mineral content of 442 parts per million, a total hardness of 390 parts per million, and contains 2.5 parts per million of iron. The public supply of Lincoln has a mineral content of only 284 parts per million, a total hardness of of 265 parts per million, and contains 1.4 parts per million of iron. It was advised that the difficulty could be remedied by installing a water-softening plant or by using exclusively the public supply. It was advised also that meters be installed to determine the quantity of water used from the school well, for with this measurement as a basis the cost of softening this inadequate supply can be compared with the cost of purchasing all the water from Lincoln.

LINCOLN, State school and colony. Sewage disposal.—(Bull. **12**, 97.)

LITCHFIELD (5,971). Water supply.—(Bull. **9**, 26; **10**, 141; **11**, 89.) Visited September 27. The city is interested in the possibility of developing a new water supply that will be attractive to manufacturing concerns. Recent drilling for oil showed the presence of a 50-foot stratum of water-bearing sandstone at approximately 400 feet. Another well is being sunk about 2 miles from the first drilling and if the same water-bearing sandstone is encountered and is found to yield fresh water the city may put down a well.

LITCHFIELD. Typhoid-fever conditions.—(Bull. **11**, 90.)

LITTLE YORK (358). Water supply.—Visited October 26. Little York, in the extreme northwest part of Warren County, is in the drainage basin of Middle Henderson River, a tributary of Mississippi River.

Installation of the waterworks was started in the early fall of 1915, and at the time of the visit a well had been drilled, a pump installed, and an elevated tank erected. The well is 6 inches in diameter, 400 feet deep, and is cased to the bottom. The water is derived from water-bearing sand entered at 390 feet. A test at the time of completion gave a yield of 35 gallons a minute with the pumping equipment used. The static level is 60 feet below the surface. The well is equipped with an electrically driven 100,000-gallon deep-well pump. The working barrel is placed at 160 feet. The pump will discharge directly into the distribution system and will operate against a head of 170 feet. It is proposed to lay 500 feet of 6-inch cast-iron pipe in the main street and to place a 2-inch fixe hydrant at each end of the main. The elevated tank is 20 feet in diameter, 13 feet high, and has a capacity of 30,000 gallons. It is built of steel, elevated on a steel tower, and has a total height to the top of 108 feet. No analyses of the water have yet been made. The village issued $4,500 worth of bonds for waterworks. The well cost $1,200, the tank and tower $2,200, and the pump and motor $727.

LOCKPORT (2,555). Water supply.—Visited July 2. Lockport is in the north part of Will County on the east bank of Des Plaines River. Illinois-Michigan Canal parallels the river on the Lockport side and Chicago Sanitary Canal parallels it on the opposite side.

Waterworks were installed in 1896. The supply is obtained from a well which was drilled originally to 1,922 feet but was plugged in shale at 1,650 feet to shut out salt water. The fresh water is derived from St. Peter sandstone between 630 and 860 feet and from Potsdam sandstone between 1,320 and 1,475 feet. The well is lined with. 10-inch casing to 50 feet and is 5 inches in diameter at the bottom. It is also cased from 860 to 930 feet where a caving shale was penetrated. The static level is about 6 feet below ground, and the drawdown is about 94 feet. When the well was first drilled water flowed from it at the rate of 275 gallons a minute. It became necessary in 1904 to install an air lift, and since that time the static level has receded about 6 feet, or 0.55 foot a year. The water is now raised into a collecting reservoir at the rate of 230,000 gallons a day. The air nozzle is placed at 260 feet. The reservoir is 40 feet in diameter and 18 feet deep and it has a capacity of 170,000 gallons. It is walled with stone and is surmounted by a conical wooden roof. The high-service pumping equipment comprises 2 electrically driven 245,000-gallon single-stage centrifugal pumps for normal water consumption and 2 electrically driven 500,000-gallon centrifugal pumps for fire service. The steam pumps, which were used before electric equipment was installed, are also held in reserve for emergency. These emergency pumps comprise two 1,200,000-gallon tandem-compound steam pumps. In addition to a connection with the collecting reservoir these steam pumps have a suction connection with Des Plaines River, which has not been used for 16 years. The distribution system comprises 7 miles of 4-inch, 6-inch, 8-inch, and 10-inch cast-iron pipe. There are 225 service connections, all of which are metered. A 100,000-gallon elevated steel tank having a total height of 100 feet is connected to the distribution system. The consumption ranges from 94,000 to 140,000 gallons a day. Only about 40 per cent of the population use the public supply. The total cost of the waterworks is $51,350.

The water is of satisfactory sanitary quality. It contains 1,162 parts per million of mineral matter and 0.1 part per million of iron, and its total hardness is 560 parts per million.

LOCKPORT. Inspection of a private well.—A letter was received June 1 from a resident of Lockport requesting means of determining whether two wells were connected. The wells are 125 feet apart and the surface of the ground slopes from the deeper towards the shallower well with difference in elevation of 15 feet. One well was dug 30 feet and driven with 1¼-inch pipe to 80 feet. The other well is completely cased to 88 feet with 4-inch casing. Limestone is entered in the deeper well at 3 feet and in the shallower well at 8 feet. The elevation of the bottom of the deeper well is 7 feet above the bottom of the shallower well. The static level in the 2 wells was not reported.

It was advised that eosin or fluorescein bo placed in one of the wells to determine whether they were connected; accordingly, three-fourths ounce of eosin was placed in the shallower well; eosin was noticeable in the water from the other well 15 minutes later. This proved that the wells derive their supply from the same stratum, and the rapidity of the transmission of the dye indicates that a crevice in the limestone probably connects the two wells and affords passage to the water.

LOCKPORT. Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **9**, 26.)

LONDON MILLS (555). Water supply.—Visited December 28. London Mills is at the northern border of Fulton County on the south bank of Spoon River.

The village has no water supply, but 2 fire hydrants maintained by the village have been connected to waterworks owned and operated by the Minneapolis and St. Louis Railroad. The railroad installed the waterworks about 1890. The supply is obtained from Spoon River, which has a catchment area of about 1,000 square miles above the village. As the water is not for domestic use little attention is paid to its sanitary quality. The railroad uses about 60,000 gallons of water a day. The village has had very few occasions to use the supply. The machinery consists of a 180,000-gallon steam pump. A 6-inch cast-iron main about 800 feet long extends from the pumping station at the river to a wooden elevated tank located near the tracks. Double two-way fire hydrants are connected to this main at the two most prominent corners in the village.

LOSTANT. Water supply —(Bull. **11**, 90.)

LOVINGTON. Water supply.—(Bull, **12**, 97.)

LYONS (1,483). Water supply.—Visited October 14. Lyons is on the west edge of Cook County on Des Plaines River. A sewerage system serves the built-up portions of town and has one outlet into the river.

Waterworks were commenced in 1911 but were not put into operation until 1913. The supply is obtained from a 1,600-foot well, which is 10 inches in diameter to 148 feet and terminates in a 6-inch hole in St. Peter sandstone. As the bore is clogged it has been necessary to use a 4-inch plunger on the pump. Thus the water obtained is materially less than that needed and a second well will probably be drilled in 1916. The water is pumped from the well into the distribution system by a 4-inch by 18-inch electrically driven double-acting deep-well pump. The working barrel of the pump is placed at 148 feet and the water level is drawn to that depth when the pump is operated. No information was obtained regarding the distribution system. A 100,000-gallon elevated steel tank having a height to the top of 125 feet is connected to the distribution system. No analyses of the water have been made.

McHENRY. Water supply.—(Bull. **9**, 27.)

McLEAN (707). Proposed water supply.—McLean was visited June 15 to obtain information regarding the possibilities of procuring a public water supply and again June 18 to address a public meeting on a municipal water supply. McLean is in the southwest corner of McLean County in the drainage basin of Sangamon River.

The wells now in use are dug wells about 25 feet deep or drilled wells 100 to 135 feet deep. The dug wells enter clay chiefly and have very limited yields;

the drilled wells, obtaining their supplies from sand, yield much more water. It was proposed to obtain the city supply from one or more drilled wells entering the stratum of sand encountered between 100 and 150 feet. The water from this sand has a mineral content of 478 parts per million, of which 3 parts is iron.

There was considerable opposition to the proposed installation especially among those who had installed private pressure systems of their own. Since the visits were made a bond issue of $6,000 for waterworks has been defeated by vote.

McLEANSBORO (1,796). Water supply.—(Bull. **10**, 147; **12**, 98.) McLeansboro was visited April 14 to collect samples of water. The superintendent stated that the filter was in such bad condition that it was impossible to obtain any improvement in the water forced through it.

MACKINAW. Water supply.—(Bull. **12**, 98.)

MACOMB. Water supply.—(Bull. **9**, 26; **12**, 99.)

MACON, County Almshouse. Sewage disposal.—(Bull. **11**, 90.)

MANSFIELD. Proposed water supply.—(Bull. **12**, 100.)

MANTENO. Water supply.—(Bull. **12**, 100.)

MAPLE PARK (389). Water supply.—Visited July 31. Maple Park is in the west part of Kane County near the south branch of Kishwaukee River. There is no public sewerage but a limited amount of tile which has been laid for ground-water drainage receives the overflow from several cesspools.

Waterworks, installed in 1894, comprised a well, a pump operated by a windmill, an elevated tank, and about one-third of a mile of mains. The windmill was wrecked by a severe storm soon after its installation and a gasoline engine was substituted. A new elevated tank was also erected on the old tower. The supply is obtained from a well 6 inches in diameter and 250 feet deep entering sand and gravel. The well is cased and has a strainer at the bottom. The water is pumped from the well into the distribution system by a 58,000-gallon deep-well pump. The distribution system comprises 1½ miles of 4-inch cast-iron pipe. There are 90 service connections, all of which are metered. The average daily pumpage is about 12,000 gallons. The initial cost of the waterworks was about $4,500 and subsequent changes and additions have probably increased the total to nearly $9,000.

The water is of satisfactory sanitary quality. It has a total mineral content of 324 parts per million, a total hardness of 241 parts per million, and a content of iron of 0.1 part per million. A pit around the top of the well retains several inches of dirty oil-covered water. Though the casing of the well may be absolutely tight this unnecessary pit and its undesirable contents should be eliminated.

MARENGO. Water supply.—(Bull. **11**, 91.)

MARION (7,093). Water supply.—(Bull. **10**, 142; **12**, 101.) Visited October 7. A representative of the State Food Commission visited Marion and condemned the water supply and the operating company desired that a representative of the Survey inspect the situation. The supply is obtained from 4 wells near an old pumping station and 3 wells near the new collecting reservoir and ice plant. Samples were collected from these wells and at different points on the distribution system. Analysis of the samples from the wells and reservoir near the ice plant showed the water to be of satisfactory sanitary quality. The analyses of samples from the wells near the old station were not quite so satisfactory, but even in these samples the bacterial count was low and tests for gas formers were positive in only 2 of the 10-cubic centimeter samples. All but one of the samples collected from the distribution system were satisfactory. This single exception showed a high bacterial count but tests for gas were negative in the 1.0-cubic centimeter and 0.1-cubic centimeter samples.

MARION. Sewage disposal.—(Bull. **12**, 101.) A conference was held February 8 with the consulting engineer of Marion in Chicago, and Marion was visited June 14 to examine sites for sewage-treatment works and to address the city council. The past investigations made by the Survey in reference to sewerage and sewage disposal at Marion were outlined, methods of sewage treatment were described, plans submitted by the consulting engineers were discussed with approval, and the opinion was advanced that nothing short of treatment works that would produce a non-putrescible effluent would relieve the local situation and that tank treatment alone would be merely a temporary expedient.

MARISSA. Proposed water supply.—(Bull. **12**, 102.)

MARE (1,025). Water supply.—Visited September 15. Mark is in the north part of Putnam County in the drainage basin of Illinois River. The development of coal mines in its vicinity has caused rapid increase in population. An attempt was made about 4 years ago to obtain a water supply from wells in drift, but this was unsuccessful. The water supply is now obtained from Granville.

MAROA. Water supply.—(Bull. **10**, 143.)

MARSEILLES (3,291). Water supply.—(Bull. **9**, 26.) Visited July 3. Marseilles is in the east-central part of La Salle County on north bank of Illinois River.

The waterworks installed in 1902 are owned and operated by the Consumers Water & Light Co., whose franchise stipulates that the source of supply shall be obtained from tubular artesian wells, not less than 600 feet deep. The station is near the river.

Water is obtained from 2 wells, one 600 and the other 800 feet deep, terminating in the Lower Magnesian formation, which is composed of alternate layers of limestone and sandstone. The St. Peter sandstone furnishes a small quantity of sulfurous water which has been cased off in the city wells. The wells are cased respectively to 125 and 150 feet. Both are 8 inches in diameter at the top and 6 inches in diameter at the bottom, and they are 1,000 feet apart. The shallower well is equipped with air lift and will yield continually 67 gallons a minute; the deeper well flows 45 gallons a minute; the combined daily yield is thus 161,000 gallons. The water from. the wells is discharged into a 78,000-gallon reinforced-concrete rectangular collecting reservoir beneath the pumping station. A tailrace from the company's hydroelectric plant carrying water from Illinois River adjoins the reservoir on one side, the two structures being separated by a 24-inch concrete wall. The gates controlling the entrance of the river water to the tailrace are adjusted so that the water in the race can rise only within 2 feet of the overflow from the reservoir. The pumping equipment comprises 3 electrically driven triplex pumps, 2 of which have daily capacities of 460,000 gallons each and the other a daily capacity of 375,000 gallons. The distribution system comprises 7.65 miles of 4-inch, 6-inch, 8-inch, and 10-inch cast-iron pipe. There are 360 service connections all of which are metered. A 100,000-gallon steel standpipe 65 feet high is connected to the distribution system. It is on the bluffs north of the station, where the land is about 180 feet higher than that at the station. The average daily consumption is estimated at 100,000 gallons. Approximately 40 per cent of the population use the public supply.

The water is of good sanitary quality. It contains 555 parts per million of mineral matter, and 0.1 part per million of iron and its total hardness is 372 parts per million.

MARSEILLES. Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **9**, 26.)

MARSHALL. Water supply—(Bull. **12**, 102.)
Typhoid fever.—(Bull. **12**, 103.)

MASCOUTAH. Water supply.—(Bull. **12**, 103.)

MASON CITY. Water supply.—(Bull. **12**, 104.)

MATTESON. Proposed water supply.—(Bull. **12**, 105.)
Proposed sewerage.—(Bull. **12**, 105.)

MATTOON. Pollution of public water supply by "improper disposal of city wastes.—(Bull. **10**, 144; **12**, 105.)
Proposed sewerage.—(Bull. **11**, 92.)

MAYWOOD. Water supply.—(Bull. **10**, 146.)

MELROSE PARK. Water supply.—(Bull. **10**, 148.)

MELVIN (509). Water supply.—Visited June 2. Melvin is in the central part of Ford County in) the catchment area of West Branch of Middle Fork of Vermilion River.

After two unsuccessful attempts in 1890 and 1902 to drill deep wells a satisfactory well was drilled in 1908. A deep-well pump and a gasoline engine were installed, and 5 cisterns in different parts of town were supplied. Another well was drilled and the present waterworks were installed in 1913. The old well and waterworks are now reserved for emergency. The new well is 231 feet deep and 8 inches in diameter and derives its supply from sand. It is cased to the bottom and a smaller inner pipe is provided with a screen 10 feet long. The water level is normally 70 feet below the surface and recedes 10 to 15 feet during pumping. Water is pumped from the well directly into the distribution system by a 170,000-gallon deep-well pump, operated by a 20-horsepower kerosene engine. The old well is equipped with a 70,000-gallon deep-well pump connected by a walking beam to a gasoline engine. The distribution system comprises 2.6 miles of 4-inch, 6-inch, and 8-inch cast-iron pipe. There are 60 service connections, all of which are metered. A 50,000-gallon elevated steel tank whose total height is 114 feet is connected to the distribution system. The average daily consumption is about 21,000 gallons. Slightly more than half of the population use the public supply. The new waterworks installed in 1913 cost $20,000.

The water is of good sanitary quality. It has a mineral content of 416 parts per million, a total hardness of 335 parts per million, and it contains 2.4 parts per million of iron.

MENARD, Southern Illinois Penitentiary. Water supply.—(Bull. **11**, 92.)

MENDOTA. Water supply.—(Bull. **11**, 93.)
Sewerage.—(Bull. **11**, 94.)

MENDOTA (3,806). Treatment of gas-house wastes.—(Bull. **12**, 106.) Mendota was visited September 14 to observe the operation of a plant installed at the advice of this Survey to treat wastes from the local gas works. Certain features of the plant were not built as had been intended by this department, but reasonably satisfactory results were being obtained.

The treatment plant includes facilities for applying lime and sulfate of iron, a settling tank constructed in excavation with wooden walls, and 2 coke filters, each 10 feet by 6 feet by 3 feet deep, in a wooden box. The settled wastes flow laterally through the coke, which ranges in size from 4 inches down to very fine material. At the time of inspection considerable quantites of tar were being carried over with the overflow into the new treatment devices from an old tar-settling basin 12 feet deep and 4 feet in diameter. This places an unnecessary burden on the treatment plant, which can be obviated by placing a hanging baffle in front of the outlet of the tar-settling basin. The lime and iron sulfate were being mixed in the same tank and fed together; this arrangement is objectionable as the chemicals react and form a precipitate before reaching the settling tank and thus become practically valueless. Films of oil on the surface of the settling tank were passing to the coke filters; this can be prevented by placing a hanging baffle in front of the outlet pipe. Inspection of coke that had recently been removed from the filters showed that it had absorbed much tar and oil and had become much darker than it was when it was first placed in the filters. Placing baffles in the tar-settling basin and the settling tank and changing the method of applying the chemicals will reduce the burden placed on the filters and materially improve operative efficiency.

MEREDOSIA. Pollution of Illinois River.—(Bull. **11**, 94.)

METAMOEA (694). Water supply.—Visited September 15. Metamora is in the west part of Woodford County on the divide between the drainage basins of Partridge Creek, a tributary of Illinois River, and Walnut Creek, a tributary of Mackinaw River, which in turn is tributary to the Illinois.

Waterworks, installed about 1889, comprised a pumping station, a dug well, a duplex pump operated by steam from a blacksmith shop, an elevated tank, and a system of mains. About 1895 the steam pump was replaced by a pump driven by a gasoline engine and in 1911 the gasoline engine was discarded for an electric motor. The old pumping station was destroyed by fire in 1905 and the present pumping station was built. In 1900 because of several controversies and disagreements between the city officials and the consumers the water was shut off at the corporation cocks and has not since been used for domestic purposes. The supply is obtained from a dug well 85 feet deep and 8 feet in diameter in the center of the village. The well has a 9-inch wall of brick laid in cement surmounted by a 3-inch plank cover. This cover is about 4 inches higher than the floor of the pump room, which is 7 feet below the surface and is flooded during heavy rains though it is said that flood waters have never overtopped the well. The static level is about 15 feet below the surface; the well, therefore, affords a storage capacity of 24,000 gallons. While this well is being pumped the static level in another well 20 feet away is materially affected. Water is pumped from the well into the distribution system by an electrically driven 28,600-gallon single-acting pump. The distribution system comprises 5,550 feet of 4-inch and 6-inch cast-iron pipe. A 54,000-gallon wooden tank 24 feet in diameter and 16 feet high elevated on a 65-foot brick tower in the central part of the village is connected to the system. The consumption is limited to supply for a public watering trough, leakage from mains, and water used for fires. The waterworks cost about $16,000.

Analysis of water from a point on the distribution system showed evidences of slight contamination that may be due to entrance of water into the well from the floor of the pump room,.

METROPOLIS (4,655). Water supply.—(Bull. **9**, 27; **11**, 94.) Visited July 13. Metropolis is a shipping point and manufacturing center on Ohio River at the southern edge of Massac County, of which it is the county seat.

The city granted a franchise in 1892 to a private individual to erect and maintain a water and light plant, but less than two months later, under one of the terms of the franchise and before the plant was started, the city took over the installation and issued bonds to the value of $41,0.00. The waterworks were, therefore, installed and have since been owned and operated by the municipality. A municipal electric plant also is operated at the pumping station.

Water was obtained from Ohio River until 1906, when a drilled well was installed and the supply from the river was permanently abandoned. The well is 125 feet deep and 8 inches in diameter. It ends in white sand but is not cased. The water level is about 13 feet below the surface when the well is not under draft but it is lowered to 20 feet when the well is pumped at 625 gallons a minute. The well would probably yield about 900 gallons a minute with improved equipment.

Water isi pumped from the well by air lift or by direct suction by a high-service pump. When it is pumped by air lift the water is discharged into a small open concrete receiving basin at the top of the well, from which it flows by gravity into the collecting reservoir. The collecting reservoir in the pumping station was the pump pit when Ohio River was used as a source of supply, and the pumps then had to be set low in order to draw water at low stages. The reservoir is 20 feet square and 35 feet deep, thus having a capacity of about 100,000 gallons. Its sheet-steel sides rest against brick and concrete walls from about 5 feet above to 3½ feet below the ground level and for the rest of the depth against earth. The bottom is of concrete.

In the spring of 1913, when Ohio River reached the highest stage.vever recorded, the station, which is about 400 feet from the low-water line, was surrounded by flood waters to a depth of several feet. The water in the reservoir reached so low level that the pressure of the flood water, which was within 9 inches of the top, caused one of the steel sides to bulge inward. In order to prevent collapse the polluted flood waters were admitted into the small receiving basin through a breach in the side wall and thence into the reservoir. This badly contaminated the water in the reservoir, and as this breach has never been repaired high water will again subject the city supply to contamination.

Two compressors, each furnishing 250 cubic feet per minute of free air, supply air for raising the water from the well. The high-service pumping equipment consists of a simple duplex pump and a 1,000,000-gallon tandem-compound duplex pump. When the first pump, which has been sold, has been removed two 1.000,000-gallon steam-turbine centrifugal pumps will be installed. The first pump takes suction only from the collecting reservoir but the second pump takes auction either from the; reservoir or directly from the well. A pressure of 50 pounds is normally maintained at the station but the pressure along many of the smaller mains is often as low as 20 pounds. There is no plat of the system and no record of the mains. It is now planned to obtain records of service connections and a plat of the system will probably be made. Only 2 meters have been installed. An elevated tank erected in 1892 was discarded in 1906 because of poor foundation and rusted condition of the upper part. The daily consumption, according to the log of the pumps, is about 400,000 gallons or 80 gallons per capita. This low consumption in an unmetered community is caused by the limited number of connections. The maximum consumption, which covered a 3-hour period, was about 925 gallons a, minute. This exceeds the capacity of the wells with the present pumping equipment, but the collecting reservoir has thus far been capable of meeting this excessive consumption.

The water is of good sanitary quality. The mineral content is 233 parts, the total hardness 2 03 parts, and the content of iron 0.4 part per million.

MILFORD. Water supply—(Bull. **11**, 95.)
Sewerage.—(Bull. **11**, 95.)
Alleged nuisance caused by wastes from corn-canning factory.—(Bull. **1**2, 106.)

MINONK. Water supply.—(Bull. **12**, 107.)

MINONK (2,070). Disposal of sewage.—(Bull. **12**, 107.) Visited September 17. A farmer living northwest of Minonk complained of the pollution of the creek flowing through his farm by the sewage of Minonk. The Rivers and Lakes Commission investigated this complaint and dismissed it April 13. The city is divided into two drainage districts with separate outlets. The outlet from the western district is the cause of the complaint. The farmer contended that foul conditions in the creek were injurious to his stock and that people living in the city refused to buy his dairy products. Examination showed that the creek was not so objectionablely polluted as was contended. It was denied by merchants, city authorities, and residents of Minonk that they had refused to buy dairy products from this farm because the creek received city sewage.

MINOOKA. Water supply.—(Bull. **11**, 95.)
Sewerage.—(Bull. **11**, 96.)

MOKENA (359). Water supply.—Visited July 1. Mokena is in the north-central part of Will County in the catchment area of Hickory Creek, a tributary of Des Plaines River.

Waterworks, installed in 1899, comprised a well pump operated by a windmill, a few hundred feet of 3-inch pressed-steel mains, and the present elevated steel tank. Six-inch cast-iron pipe was installed in 1900 in place of the 3-inch steel pipe as the small pipe proved inadequate for fire protection and did not stand the pressure that the elevated tank provided. The windmill was replaced by a gasoline engine in 1904. The old pump was replaced by the present deep-well pump and the gasoline engine by an electric motor in 1913. The supply is obtained from the original well, which was drilled in 1891 and acquired by the village when the waterworks were installed. It is 139 feet deep and has a 4-inch casing and a 10-foot screen. It derives its supply from sand and gravel and the static level is 61 feet below the surface. The water is pumped from the well into the distribution system by an electrically driven 88,000-gallon double-acting deep-well pump, whose working barrel is placed at 129 feet. The electric motor is automatically controlled by a float in the elevated tank. The distribution system comprises 3,600 feet of 6-inch cast-iron pipe. There are only 17 service connections, all of which are metered. A 60,000-gallon elevated steel tank 105 feet high is connected to the distribution system. The water consumption cannot be estimated. The waterworks cost $7,000.

The water is of good sanitary quality. It has a mineral content of 620 parts per million and a total hardness of 547 parts per million, and it contains 0.6 part per million of iron.

MOLINE (24,199). Water supply.—Visited April 22 and May 19-20. Moline is at the west edge of Rock Island County between Mississippi and Bock rivers, which flow westerly at this point and are about 3½ miles apart. About 86 per cent of the 8.65 square miles within the city limits drains directly into Mississippi River on the north and about 14 per cent into Rock River on the south. The divide between these two rivers rises to a height of about 140 feet above the banks. The city is primarily a manufacturing center and has had a uniformly substantial growth during the past 50 years.

Waterworks installed in 1883 were financed by private capital, but in 1886 the system was purchased by the city. The supply has always been obtained from Mississippi River, and the plant has always occupied the site on the bank of the river near the middle of the water front approximately opposite the upstream end of the island named Eock Island, but locally known as Arsenal Island. The supply is drawn from the river through 2 intake pipes; one 18 inches in diameter was laid in 1883 and extends slightly upstream from the bank one-half mile into the main river channel beyond the end of Arsenal Island; the other 20 inches in diameter was laid about 1891 and extends only 400 feet from the bank and draws from the Pool, a narrow strip of water between the main land and a wing dam built upstream from Arsenal Island several thousand feet. The water level in the Pool is nearly always above that in the channel; consequently when at extreme low water the intake in the channel is submerged only about one foot the intake in the Pool is submerged about 5 feet. The difference in water level is caused by a power dam in the Pool between Arsenal Island and the mainland. Engineers have estimated that the intake in the channel will deliver daily 3,000,000 to 6,000,000 gallons and the intake in the Pool 5,000,000 to 10,000,000 gallons depending on the stage. Both intake pipes terminate on shore in a semicircular well, beneath the floor of the pump room, from which low-lift pumps take their suction. This well is 28 feet in diameter and 20 feet deep, and the bottom is 6 feet below extreme low water in the channel. The maximum variation of stage is 14 feet, which brings high water in the well nearly to the floor of the station. Under ordinary conditions water flows through both intakes into the well. At low stages the flow in the longer intake is small; consequently provision has been made whereby one of the low-lift pumps may take suction directly from this intake. Anchor ice has caused much trouble at the intakes. Formerly water was drawn during cold weather only through the short intake until it became clogged with ice, when that intake would be closed and the low-lift pump drawing from the long intake would discharge into the well until it was filled; the short intake would then be opened and the ice would be forced out by the head of 15 feet in the filled well. This was a slow process attended by the danger that both intakes might become clogged with ice. This trouble is now overcome by forcing air into the short intake from a blower used for washing the filters.

Mississippi River above Moline is subject to pollution by sewage from St. Paul, Minneapolis, La Crosse, Dubuque, Clinton, and numerous smaller communities. There are numerous sewer outlets into the river at Campbells Island about 6 miles above Moline and it was once proposed to extend an intake above Campbells Island at considerable expense. Investigations by this Survey showed that the water above the island was similar in quality to that obtained through the existing intakes; the large expense of the proposed intake was, therefore, deemed unwarranted. A new source of pollution is sewage from the east part of Moline, for which a sewer is now under construction. The sewage from that district, however, will be treated in 2-story settling tanks and sterilized with liquid chlorine. The sewage plant will be built to serve 5,000 people at first and additions will be made as the district becomes more thickly settled. The ultimate population of this district is estimated at 25,000.

The city installed a mechanical filtration plant in 1902. Three filters were equipped at that time, and 2 more were equipped in 1911. The purification plant has a rated daily capacity of 1,000,000 gallons per filter, or a total of 5,000,000 gallons. The purification plant adjoins the pumping station, and the purified water is stored in a reservoir situated just outside it. Treatment includes coagulation with alum, sedimentation, filtration, and sterilization with calcium hypochlorite. Lime and eulfate of iron were used as coagulants before 1911, but they were replaced by alum chiefly because of incrustation of pipes and filter sand by lime. Hypochlorite has been used only since 1911, and replacing it with liquid chlorine is now being considered. Chemical-feed appliances, filter washing machinery, and a laboratory are at the end of the building. The sedimentation basins are in the middle, and the filters and the pipe gallery are at the opposite end. Tour circular concrete tanks 10 feet deep are provided for the chemical solutions. Each of the two used for alum is 12 feet in diameter and has a capacity of 8,000 gallons. Each of the two used for hypochlorite is 11 feet in diameter and holds 6,000 gallons. All are equipped with cleaning drains. Formerly chemicals were fed by pumping the solutions with small centrifugal pumps into elevated tanks from which they flowed under constant head maintained with overflows leading excess pumpage back to the solution tanks. This apparatus was replaced with float-controlled orifice boxes into which the solution tanks discharge. The consumption of alum varies with the character of the raw water, but averages about 2.5 grains a gallon. It is the practice to use 10.5 pounds of hypochlorite per million gallons. The 2 concrete settling basins have a combined capacity of 450,000 gallons. The floor of each slopes toward one corner at the inlet end where a valve-controlled outlet is provided for cleaning. In each basin there are three equidistant transverse baffles. Those nearest the inlet are solid except for 8-inch by 24-inch openings in the ends. The other baffles have ½-inch horizontal slots every 8 vertical inches. The water enters each basin through four 20-inch openings controlled by float-controlled butterfly valves and leaves the basin over skimming weirs. Alum solution is applied as the water enters the basin and hypochlorite as it leaves. The basins are cleaned at intervals of 4 to 8 weeks.

Each filter has an area of 352 square feet and a rated daily capacity of 1,000,000 gallons. The filter medium consists of 30 inches of sand overlying 14 inches of graded gravel. Four filters contain Eod Wing sand with an effective size of 0.67 millimeter and a uniformity coefficient of 1.42. Local river sand used in the other filter has an effective size of 0.51 millimeter and a uniformity coefficient of 1.34. The Red Wing sand cost $6.73 a cubic yard in place and the local river sand only $1.47 a cubic yard in place. The underdrainage consists of a central cast-iron manifold with laterals 6 inches apart equipped with perforated brass strainers placed 6 inches center to center. Washing is preceded by preliminary agitation with air supplied from a main along the center line of each filter above the water level from which eight 2-inch drop pipes lead down to the manifold of the strainer system. Air at about 4 pounds' pressure is applied for 2 or 3 minutes; the air is then shut off, and water is used at the rate of 9 inches vertical rise a minute for 6 minutes. The wash water is removed by means of gutters along each side of each filter, and it is 2¼ to 3½ per cent of the daily pumpage. Each filter is equipped with an open float rate controller. All the valves are operated by hand from the operating platform.

Filtered water is stored in a 760,000-gallon reservoir 90 feet in diameter, 15 feet 8 inches deep to the overflow. The reservoir is divided equally by a 7-foot wall that permits cleaning without taking the entire reservoir out of service. The reservoir is covered by a conical metal roof. The walls are of concrete and the floor of brick laid in cement.

A 5,000,000-gallon centrifugal pump driven either by steam or water power and a 6,000,000-gallon 2-stage centrifugal pump direct-connected to a steam turbine raise the raw water to the purification plant. The water power for the smaller pump is furnished by 2 motors operated by water from the high-service mains. With 95 pounds' pressure one gallon is sufficient to pump about 3 gallons of raw water. All water used in the motor is returned to the clear well. The high-service pumping equipment comprises a 5,000,000-gallon tandem-compound duplex pump installed in 1891, a 6,000,000-gallon cross-compound crank-and-fly-wheel duplex pump installed in 1903 and a 10,000,000-gallon cross-compound fly-wheel duplex pump installed in 1915. The pumpage is measured by a Venturi meter installed in 1914, in which year the average daily pumpage was 3,820,000 gallons. The installation of meters was begun last year; though only 20 per cent of the services have so far been metered the effect on the pumpage is noticeable. The distribution system comprises 67.1 miles of pipe of which 1,494 feet is 3-inch wrought-iron pipe and the remainder 4-inch to 20-inch cast-iron pipe. There were 4,682 services at the end of 1914. A 500,000-gallon elevated steel tank with a total height of 104 feet is connected to the distribution system.

The water furnished by the purification works is of satisfactory sanitary quality. The value of the purification plant is shown by the reduction in typhoid-fever death rate. Between 1899 and 1902 the typhoid death rate was 117 per 100,000 whereas during the 10 years following the installation of the purification plant it dropped to 31.6. A menace to the public water supply exists due to two connections between the distribution system and the fire underwriters' system in the factory district. The latter system, provided for fire protection, is supplied with raw water from Mississippi River, and it is at times under a greater pressure than the domestic pressure in the city mains. The only safeguard to prevent the raw river water from passing into the city mains is one swing check-valve on each of the two connections. These valves open toward the factory system but they can not be safely depended on to close and remain tight.

MOLINE. Additional sewerage.—(Bull. **11**, 96.)
Sanitary survey of Mississippi River.—(Bull. **9**, 27.)

MOMENCE. Water supply.—(Bull. **11**, 97.)
Sewerage.—(Bull. **11**, 97.)

MONEE (411). Water supply.—Visited June 29. Monee is in the eastern part of Will County in the catchment area of Kankakee River.

Waterworks were installed in 1897. The supply is now obtained from 2 wells, one a part of the original installation and the other put down in 1913 about 20 feet from the first well. The wells are, respectively, 166 feet deep and 6 inches in diameter and 169 feet deep and 10 inches in diameter. Both terminate in limestone, from which the supply is derived, and the water rises within 75 feet of the surface. A test at the rate of 60 gallons a minute was made on well 1 when it was drilled; without indication of diminished yield. Well

2, though larger and deeper, has less yield. Water is pumped from the wells into the distribution system. Well 1 is equipped with a 50,000-gallon deep-well single-acting pump with the working barrel placed at 85 feet. Well 2 is equipped with a 240,000-gallon double-acting deep-well pump with the working barrel placed at 95 feet. Both wells are belt-connected to a 20-horsepower gasoline engine. The pump in well 2 draws air after running about 90 minutes. The distribution system comprises 7,200 feet of 4-inch and 6-ineh cast-iron pipe. There are 37 service connections, all but 2 of which are metered. Two pressure tanks, each, 8 feet in diameter and 36 feet long with a capacity of 2,000 gallons at pressure of 45 to 60 pounds, are connected to the distribution system. The average daily consumption is 9,000 gallons. The waterworks cost about $15,000.

The water from both wells is of good sanitary quality. Though the wells are near together and are nearly the same depth the mineral contents of their waters are different. Water from well 1 has a mineral content of 903 parts per million and a total hardness of 713 parts per million, and contains 8 parts per million of iron. Water from well 2 has a mineral content of 742 parts per million and a total hardness of 602 parts per million, and contains only 1.2 parts per million of iron. The difference in mineral content indicates that the wells draw from different crevices in the limestone.

MONEY CREEK TOWNSHIP, Typhoid fever.—At the request of the State Board of Health an investigation was made June 24-26 of the prevalence of typhoid fever on farms north of Towanda in Money Creek Township, McLean County. The investigation included visiting all farms in that vicinity at which cases of the disease had occurred during the past two years.

Farmhouses are scattered over Money Creek Township, with here and there an occasional group of several houses. Natural conditions are favorable to health, and the presence of any contagious or infectious disease may be looked upon as caused by neglect of sanitary principles. Each farm has one or more wells generally dug 4 or 5 feet in diameter to 30 feet and bored at small diameter 5 to 10 feet deeper to a water-bearing bed of sand. The water is under sufficient pressure to rise several feet into the dug part of the well, and the yield generally is adequate. The dug parts of the Wells are not water-tight, and few wells are tightly covered. Consequently, though the water from the bored part of the well would be of good sanitary quality, it may become contaminated in the poorly constructed dug portion of the well. Privies in this locality are of the type too often found in rural communities. None suitably or decently constructed were seen, and the filthy privy is the outstanding objectionable condition.

Occasional cases of typhoid fever have occurred in Money Creek Township, but an unprecedented number developed during the past few years. Records were obtained of one case late in 1912, 3 cases in 1913, 8 cases in 1914, and 4 cases up to the time of the investigation in 1915, a total of 16 cases. Because of the time that had elapsed and the consequent difficulty in obtaining reliable and complete data the exact source of infection of the 5 cases before August, 1914, was not definitely ascertained except one, which was undoubtedly a secondary case infected by a previous case in the same household. The remaining 11 cases occurred between September 8, 1914, and June 1, 1915, mostly scattered, though 2 groups of 3 cases each occurred almost simultaneously. Eight of these 11 cases were in one family and 3 in another. The 8 eases in one family occurred first and this family, between the development of the seventh and eighth cases, moved near the second family. The members of the two families associated freely with one another, especially when the eighth case in the first family was ill in the hospital. While the mother was visiting the hospital her children would stay with the family in which the 3 cases later occurred; moreover, this family procured water from their neighbor's well and bought milk from them. The dates of incidence of the 11 cases, their close relationship with one another, and the prevailing insanitary conditions and lack of personal cleanliness showed that the disease was spread through contact of one person with another or with some article handled or used by an earlier case. The cause of the first case of the 11 was not definitely ascertained. The patient at the time of his infection was working around the country on a baling machine. . He had worked and eaten dinner at the farm where one of the 5 cases previously mentioned was ill in bed, but as the exact date of this possible contact in relation to his illness could not be ascertained it is impossible to draw definite conclusions.

The prevalence of typhoid fever was concluded to be caused by direct contact with those ill or recently recovered from the illness, aggravated by personal uncleanliness and general insanitary conditions. Infected discharges from the patients were carelesly disposed of without any or with entirely inadequate disinfection. The privies are poorly built and filthy. Most of the wells are improperly constructed and subject to more or less contamination.

These causes combined produce one of the most effective means of spreading typhoid fever. They do not appeal to the popular imagination so strongly as an infected water or milk supply but are far more important in rural communities. Not until the individual realizes the danger of insanitary privies and exercises more care in regard to personal cleanliness will typhoid fever cease to exist in rural communities. The following recommendations were made covering measures necessary to prevent the continued prevalence of typhoid fever:

(1). Obtain an early and accurate diagnosis of cases.

(2). Fight the spread of the disease at the bedside of the patient.

(3). Adopt the same rigid sanitary precautions with suspected cases as with established cases.

(4). Practice personal cleanliness.

(5). Substitute sanitary privies for poorly built dilapidated privies.

(G). Sink new wells or remodel existing wells to prevent their contamination from filth that can seep into the ground and into the wells or can enter directly through the top.

(7). Avoid contact as much as possible with persons who have just recovered from typhoid, especially if they are uncleanly. Avoid eating in places where there is typhoid, and avoid the use of any food or water from a house where typhoid exists.

MONMOUTH. Water supply.—(Bull. **10**, 149.)

MONTGOMERY. Sewage disposal.—(Bull. **12**, 108.)

MONTICELLO. Water supply—(Bull. **10**, 150; **12**, 109.)

MORRIS. Water supply.—(Bull. **12**, 109.)

Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **9**, 27.)

MORRISON. Water supply.—(Bull. **12**, 110.)

MORRISONVILLE. Water supply—(Bull. **11**, 98.)

MORTON (1,004). Water supply.—Visited September 14. Morton is in the north-central part of Tazewell County in the catchment area of Mackinaw River.

Waterworks were installed about 1895, when the village erected a wooden tank on a brick tower and laid about 6 blocks of cast-iron mains. The water was furnished by a local light company. The Illinois Traction System purchased the local company's properties and discontinued its operation in 1913. The village then developed the present water supply, which is obtained from 2 wells, each 230 feet deep and 8 inches in diameter, cased to 214 feet and provided with Cook screens 16 feet long. A thin bed of water-bearing sand and gravel was entered at 120 feet and a 10-foot stratum, from which the supply is obtained, was entered at 220 feet. The water stands about 190 feet below the surface. No tests have been made to detemine the yield, but when the wells have been pumped continuously for 16 hours they have given a combined yield of 200 gallons a minute. Water is pumped from the wells into the distribution system by 2 electrically driven deep-well pumps. One pump has a daily displacement of 300,000 gallons and its working barrel is placed at 214 feet; the other has a daily displacement of 250,000 gallons and its working barrel is also placed at 214 feet. The pumps operate against heads of slightly more than 300 feet, 190 feet of which is in the well and the remainder in the height of the elevated tank. The distribution system comprises 3 miles of 8-inch, 6-inch, and 4-inch cast-iron pipe. There are 150 service connections, about 90 per cent of which are metered. A 75,000-gallon elevated steel tank with an elliptical bottom is connected to the distribution system. The height to the top of the tank is 116 feet. The average daily consumption is about 25,000 gallons. The original waterworks cost about $8,000 and the recent installation cost $24,000.

The water is of good sanitary quality. The water from one well has a mineral content of 554 parts per million and a total hardness of 403 parts per million and contains 1.0 part per million of iron. Water from the other well has a mineral content of 447 parts per million and a total hardness of 332 parts per million and contains 1.0 part per million of iron.

MOUND CITY (2,837). Water supply.—Visited July 9. Mound City is on Ohio River at the south end of Pulaski County. A levee 3½ miles long surrounding the city constitutes the corporation limits. The city is 10 feet to 14 feet below the top of the levee, the elevation of which is about 59 feet above Cairo datum. The land surrounding the city is flat and becomes flooded during high water. The highest water ever recorded occurred April 6, 1913, when the river reached a stage of 56.4 feet above Cairo datum.

Waterworks were installed in 1900 by a local citizen who had been operating a light plant since 1894. During 1910 the water and light plant was purchased by the present owners, the Mound City Light and Water Co. The source of supply is a drilled well 630 feet deep; the last 275 feet of it is in siliceous rock, locally called "Elco Rock", from which the water is obtained. The well is cased to 450 feet with 8-inch pipe. The water is under sufficient pressure to flow at the surface. The natural flow when the well was drilled was 85,000 gallons a day. Pumping tests, that have been made several times, indicate that the maximum yield is 700,000 gallons a day.

Steam pumps were formerly used but when the property was acquired by the present company the steam pumps were dismantled and 3 motor-driven 500,000-gallon double-acting triplex pumps were installed. Current is normally obtained from a generating station at Cairo but an engine and a generator are maintained at the plant for use in emergency. The pumps can take their suction either directly from the wells or from a storage reservoir. The concrete storage reservoir has a capacity of 150,000 gallons and is maintained full for fire use. The reservoir has a substantial conical wooden roof. About 7 miles of 4-inch to 10-inch mains have been laid. There are about 350 service connections, only 6 of which are metered. A 75,000-gallon elevated steel tank was erected in 1913. Its total height is 136.5 feet and it thus affords a pressure of about 60 pounds.

The water from the well is of good sanitary quality and the method of operating precludes contamination. The water has ay mineral content of 266 parts per million, a total hardness of 164 parts per million, and a content of iron of 0.3 part per million.

MOUND CITY. Proposed sewerage.—Visited July 9. A limited system of storm drains has been installed in Mound City, but a few house connections to it have been made. These drains are built of vitrified tile laid with uncemented joints. The 3 outlets, 2 directly into Ohio River and one through the back levee to a borrow pit around the levee, are provided with automatic check valves to exclude the river water at high stages when it becomes necessary to pump the drainage. The need of more and improved sewerage was forcibly brought to the attention of the city during the spring of 1913 when the river reached the highest stage ever recorded. A consulting engineer who was engaged submitted a report and plans early in 1915, but the city has not yet undertaken the new construction.

The plans call for one system for storm water and one system for sanitary sewage. The systems are to have 2 combined outlets at the present outlets into the river and the pumping stations will be equipped with compressed-air ejectors to handle the normal flow and centrifugal pumps to handle the storm-water flow.

Both sanitary and storm-water systems are well designed and they should be satisfactory if they are properly constructed. The sanitary drains will range from 8 to 15 inches in diameter and the storm-water drains will range from 12 inches in diameter to a rectangular conduit 3 feet by 6 feet in cross-section. The sanitary system is designed to cover the entire settled portion of the city, but estimates were submitted for all and parts of the system. The estimated costs of the storm-water and sanitary systems are, respectively, $51,000 and $25,000 and of the 2 pumping stations and equipment, $16,000. The estimated cost of the portion of the system needed immediately is $60,000.

MOUNDS. Water supply.—(Bull. **9**, 27; **11,** 98.)

MOUNDS (1,686). Sewerage and sewage-treatment plant.—Visited July 10. Mounds, in the southern part of Pulaski County about 3 miles from Ohio River, is the site of repair shops of the Illinois Central Eailroad.

A system of sanitary sewers and a sewage-treatment plant were constructed in the fall of 1914. The plans had been reviewed by the Engineer of the Survey and comments thereon had been made by letter to the city's consulting engineer. The design of the sewerage was approved on condition that the construction be carried out in substantial manner. The design of the sewage-treatment plant was disapproved and on recommendation of the Survey the Rivers and Lakes Commission notified the city September 16, 1914, that the plans for the sewage-treatment plant were not approved. The city and its engineers, unwilling to accept the advice of the Survey, let the contract before receiving notification of the action of the Rivers and Lakes Commission. Thus the construction was carried out according to original design.

The sewerage system consists of 13,700 feet of 8-inch, 1,120 feet of 10-inch, and 3,700 feet of 15-inch pipe. Very flat grades were followed as the corporation site is nearly level and little fall is available to the outlet. There are only 27 manholes on the entire system, and distances of 900 feet between manholes prevail in sections of the 8-inch laterals. To date the system has apparently worked satisfactorily. Few connections, however, have yet been made, and most of the flow is ground-water leakage.

The sewage-treatment plant is about 1,000 feet south of the corporation line on the bank of Trinity Slough. It consists of a concrete septic tank and a bed of crushed rock and cinders designed to act as a filter. The tank is 70 feet long, 20 feet wide, and 10 feet deep to the flow line, thus having a capacity of about 100,000 gallons. The detention period at present is probably at least 24 hours. A wall divides the tank longitudinally into two compartments connected at one end near the flow line by a 12-inch pipe; thus the sewage traverses the length of the tank twice. The original design provided 7 hanging baffles; it could not be ascertained whether the design in this particular had been modified on the advice of the Survey. The flat reinforced-concrete top of the tank is about 2 feet above the ground. The only means of access to the tank is through 2 manholes and no way of removing sludge is provided.

The filter which receives the discharge from the tank is hexagonal in plan, 83 feet long, and 53 feet wide. The filtering material according to the design was to consist of a 5-inch layer of broken stone overlain by an 8-inch layer of cinders. As a matter of fact either the cinders were never all placed or have been washed away by high water while the filter and surrounding country have been flooded. The cinders now in place range in size from dust to pieces 6 inches long. The surface of the bed is uneven and broken stone is visible in places. A pool of stagnant water was in one corner and luxuriant growths of weeds prevailed in other portions. Sewage is applied to the filters at one end by a main distributor and laterals and is supposed to filter horizontally to a collecting system near the other end of the filter bed. Inspection shows that most of the flow is passing directly from the end of the main distributor to the main collector and that it has scoured a channel in the central part of the bed. The filter is of absolutely no benefit in its present condition and even if repaired to conform with the original design it would be practically valueless. At the time of the visit to the plant there were no disagreeable odors because only a few connections had been made to the system and most of the flow was ground-water leakage. The effluent from the filter spreads out over the swampy area, known as Trinity Slough, which extends eastward to Ohio River. At times of high water in Ohio River the surrounding country is flooded to a depth of several feet; the sewage-treatment plant is submerged at such times and a film of mud from submergence had been left on the surface of the filter.

MOUNT CARMEL (6,934). Water supply.—(Bull. **9**, 27; **12**, 111.) Mount Carmel was visited April 13 to collect samples of water and to observe the operation of the filter plant. A change in the method of applying the solutions of alum and hypochlorite has been made since previous visits. An automatic arrangement formerly provided a flow of chemicals proportional to the amount of water discharged by the low-service pumps, but the orifices occasionally became clogged because of imperfect preparation of the solution of, hypochlorite.

Alum is now dissolved in one compartment of a large shallow wooden box in a stream of water that flows into contact with it and discharges into the raw water. Hypochlorite is similarly applied except that it is added to the tank at 2-hour intervals. Eeeent analyses of the water indicated reduced efficiency probably due to the new method of application, and it was suggested that standard orifice boxes be installed.

MOUNT CARROLL. Water supply.—(Bull. **11**, 100.)

MOUNT MORRIS. Water supply.—(Bull. **11**, 100.)

MOUNT OLIVE. Water supply.—(Bull. **10**, 151.)

MOUNT PULASKI. Proposed additional water supply.—(Bull. **11**, 101; **12**, 113.)

Sewerage.—(Bull. **12**, 113.)

MOUNT STERLING. Water supply.—(Bull. **11**, 102.)

Proposed sewerage.—(Bull. **11**, 101.)

MOUNT VERNON (8,007). Water supply.—(Bull. **10**, 152; **11**, 102; **12**, 113.) Mount Vernon was visited April 14 to collect samples and to observe the operation of the filter plant.

MOWEAQUA. Water supply.—(Bull. **11**, 99.)

MURPHYSBORO (7,485). Water supply.—(Bull. **10**, 155; **11**, 103; **12**, 114.) Visited January 5 and a consultation was held February 27 in the office of the Engineer of the Survey with representatives of the water company of Murphysboro. The city was visited to confer with the mayor and commissioners in reference to proposed terms of the new contract between the local company and the city; It was recommended that a clause be inserted covering the quality of the water, stating in substance that the water should be free from visible turbidity and color, objectionable taste and odor, and any matters that might cause disease; that the city require the submittal on the part of the water company of completed plans and specifications for purification works intended to effect such purification; and that they be embodied in the contract on approval by the State Water Survey. The question of rates was discussed only briefly as the city contemplated referring that to the State Public Utilities Commission.

NAPERVILLE (3,449). Water supply.—Visited June 4. Naperville is in the south-central part of Dupage County on the west branch of Dupage River.

Waterworks were installed in 1904. The supply is obtained from one well sunk in 1904 and one well sunk in 1913. The wells are 60 feet apart. The older well was originally 1,425 feet deep, but it has become clogged at 700 feet. It is 12 inches in diameter at the top and 6¾ inches at the bottom, and it is cased to 115 feet to shut out flow from crevices in limestone. The water comes from St. Peter sandstone, and the static level is 85 feet below the surface. The newer well is 1,375 feet deep, 12 inches in diameter at the top, and 8 inches in diameter at the bottom. The casing extends only to bedrock and, therefore, in addition to flow from the sandstone it receives water from limestone. It is understood that there is a considerable flow from limestone at 45 feet. The static level is 14 feet below the surface, and the water level is lowered to 80 feet when the well is pumped. The limestone may admit water from the near-by river, but analyses thus far made do not indicate that this happens. Water is raised from the older well by air lift and from the newer well by an electrically driven 500,000-gallon double-acting deep-well pump. The water from both wells is received in a 100,000-gallon concrete reservoir 33 feet in diameter and 15.5 feet deep. The water is pumped from the reservoir by an 845,000-gallon compound duplex double-acting pump into the distribution system, which comprises about 12 miles of pipe ranging from 6 to 12 inches in diameter. A 100,000-

gallon elevated steel tank having a total height of 120 feet is connected to the system. There are about 695 services, all of which are metered. The daily consumption is estimated at 400,000 gallons.

Analyses indicate that the water is of good sanitary quality. The water from the newer well has a mineral content of 496 parts per million, a total hardness of 392 parts per million, and a content of iron of 0.1 part per million.

NAUVOO. Water supply.—(Bull. **10**, 157.)

NEOGA (1,074). Proposed water supply.—Visited January 19. Neoga is in the northwest part of Cumberland County about 2 miles east of Little Wabash River.

A well 16 feet deep and 15 feet in diameter has been dug in an alley near the east end of the village. The wall of this well is 8 inches thick near the bottom and 4 inches thick at the top. A water-bearing gravel was entered at 11.5 feet. At completion of the well it was pumped at a rate of 100 gallons a minute for 12 hours. Other wells in the vicinity became dry during the test. As this well was considered adequate to meet the needs of the city, contracts have been awarded for a pumping station, a motor-driven 200,000-gallon triplex pump, purchase and laying of 12,000 feet of 4-inch and 1,400 feet of 6-inch cast-iron mains, and erection of a 50,000-gallon steel tank 37 feet high on a 90-foot steel tower at a total cost of $9,600.

The water is of satisfactory sanitary quality. The wall of the well should be carried above ground, and a covering which will exclude accidental or malicious contamination should be built over it. The water has a mineral content of 226 parts per million and a total' hardness of 52 parts per million, and contains a trace of iron.

NEOGA. Proposed sewerage.—Neoga was visited April 17 to attend a public hearing called to consider a special assessment to defray the cost of installing sewerage; Neoga was visited again July 6 at the request of the State Board of Health to confer with local authorities regarding the desirability of sewerage. There was very little objection to the installation of sewerage at the public hearing. A city election was to be held in a few days, and as it was not known what the attitude of the new officials might be it was decided to approve and ratify the plans and assessment roll before the election. The estimated cost of the proposed sewerage is $7,170. It will serve the entire settled area, and the pipes will be 6 to 10 inches in diameter. The sewage will flow into a 10,000-gallon settling tank on a drainage ditch tributary to Little Wabash River. The outlet pipe of the tank will be carried for the present only a few feet to the ditch but it may be found desirable in the future to extend the outlet downstream.

The matter was in abeyance at the time of the second visit, and a brief statement was made of reasons why sewerage should be installed at an early date.

(1) A sanitary sewerage system is needed for full utilization of the newly installed waterworks. Indoor plumbing is impracticable without sewerage except for those who are wealthy enough to build expensive private drains. The absence of indoor plumbing in turn promotes the continued use of private wells, many of which are" known to be dangerously polluted.

(2) The present conditions with lack of proper sewage disposal and use of private wells constitute a grave sanitary menace which can be eliminated by installation of sanitary sewerage.

(3) The cost of sanitary sewers to property owners is eventually less than

construction and maintenance of a privy or cesspool that may be regarded as complying with reasonable sanitary requirements; moreover, sewers are far more effective and far less offensive than such contrivances.

(4) Failure to install sanitary sewers at an early date will result in installation of private drains in more or less haphazard imperfect way, and it may reasonably be expected, as has occurred in many other small communities, that those whose dwellings are connected to private drains will constitute a strong opposition to any later proposal to install public sanitary sewers.

(5) Sanitary sewerage is the only economical system for disposing of sewage without nuisance. Furthermore it is to be anticipated that the State, which possesses rights in connection with all the natural watercourses within its boundaries will sooner or later demand such collection and disposal of sewage ais is necessary to prevent undue contamination of public watercourses. It is, therefore, to the financial interest of the village to install sewerage that may be developed along lines that will make purification in the future possible at minimum expense and avoid losses that would otherwise result from condemnation of numerous poorly designed and poorly laid drains that will surely be installed unless the municipality takes the initiative in constructing sewers in accordance with a comprehensive plan.

NEW ATHENS. Proposed water supply.—(Bull. **10**, 158.)

NEW WINDSOR. Typhoid fever.—(Bull. **11**, 103.)
Proposed water supply.—(Bull. **11**, 104.)

NEWTON (2,108). Water supply.—(Bull. **10**, 159.) Visited May 24 and August 13.

Newton has had a water supply since 1895. The water, obtained from Embarrass River below a sewer outlet, is dangerously polluted and suitable only for flushing and sprinkling. Moreover, the suspended material in the water causes excessive wear and tear of the pumps and prevents the use of meters which consequently results in the waste of water by consumers. The local commercial club has started an agitation for a better water supply and is cooperating toward this end with the city officials. There are two possibilities for an improved supply, filtration of the river water or development of a supply from wells. An intake could be constructed above all points of local pollution by sewage and the water could be rendered safe and satisfactory for domestic use by a filter plant properly designed, constructed, and operated. A supply from wells, however, would be preferable if water of suitable quality could be obtained in sufficient quantity.

The covering of drift at Newton is only about 20 feet thick and many private wells derive their supply from thin sand layers at its base. A few wells have entered rock, but little additional water is encountered below the drift in the upper strata, and salt water is encountered at greater depths. A wide strip of bottom land on the opposite side of the river from the city was chosen as favorable for development of ground water. An effort to procure a supply from wells in this vicinity several years ago was abandoned because of lack of adequate drilling equipment. An 8-inch test well was recently sunk 24 feet to bedrock. A 12-foot bed of sand and gravel was found to overlie the rock strata, and a strainer 6 feet long with 1/16-inch slots was installed in the bottom of the well. The maximum continuous yield was 11 gallons a minute. As this water contained 18 parts per million of iron and 1.6 parts of manganese it would be very unsatisfactory as a domestic supply though the content of these undesirable constituents might possibly decrease after long-continued pumping. In order to determine further the quantity and quality of water that might be obtained from wells it was advised that further test wella be sunk at other locations in the bottom lands. If development of a well supply in this locality is impracticable or inadvisable development of a filtered river-water supply can be undertaken.

NOKOMIS. Water supply.—(Bull. **11**, 105.)

Proposed sewerage and sewage treatment.—(Bull. **12**, 114.)

NORMAL. Water supply.—(Bull. **10**, 159.)

NORTH CHICAGO (3,306). Water supply.—(Bull. 9, 28; **12**, 115.) North Chicago was visited August 12 to examine the water supply and on September 13 to confer with the city council regarding installation of a purification plant. Typhoid fever, which has been prevalent in North Chicago, may be partly due to numerous poorly constructed private dug wells, but the city water probably is also an important factor in the spread of the disease. The water, drawn from Lake Michigan only 400 feet from shore, is often very turbid and objectionable in appearance, and for this reason many shallow wells are used. If the city would provide a satisfactory public supply the shallow wells undoubtedly would be abandoned and the typhoid-fever rate would decrease. The subject of water purification was outlined at the council meeting, and various phases of water purification were described. The consumption is very high, but when the purification plant is installed metering service connections can materially reduce consumption, reduce the present expense of pumping, and effect a saving in the operation of a purification plant. The maximum daily pumpage during the summer of 1914 reached about 1,000,000 gallons. As it requires several months to prepare plans and construct a purification plant it was recommended that the city immediately install apparatus to disinfect the present supply with hypochlorite or liquid chlorine.

NORTH CHICAGO. Sewerage.—(Bull. **9**, 28; **11**, 105.)

NORTH CRYSTAL LAKE. Water supply.—(Bull. 12, 116.)

OAK PARK (Est. 25,000 in 1915). Typhoid fever.—Oak Park was visited June 5-8 at the request of the. State Board of Health to investigate the prevalence of typhoid fever.

Eight scattered cases of typhoid fever occurred between November 21, 1914, and June 8, 1915. All except one of those ill were pupils at the high school. The data obtained indicated that the infection had taken place at the high school but the exact source of infection could not be ascertained. The one case who had not been at the high school but had roomed at the Y. M. C. A. probably was infected by contact with a high-school case, who also roomed at the Y. M. C. A.

After the investigation was completed it was learned that a banquet was held after the high school had closed for the year and that several more cases of typhoid fever then developed among the guests. Investigation by local and State health authorities showed that one of the persons employed in preparing the food for the banquet was a typhoid carrier. This person had been an employee of the cafeteria of the high school, and, therefore, the cases of typhoid fever that occurred earlier during the school year were probably caused by infection of the food supply by this individual.

OAKLAND. Water supply.—(Bull. **12**, 116,)

OBLONG (1,482). Proposed water supply.—Visited March 19-20 and June 11. Oblong is in the eastern part of Crawford County in the catchment area of North Fork, a tributary of Embarrass River. The village has grown. rapidly in the last decade because of development of oil wells.

Development of a surface supply does not seem feasible as the water of North Pork has a high content of chloride because of the entrance of salt water from the oil wells. Several deep wells have been drilled in the vicinity for oil, but little attention, naturally enough, has been paid to water-bearing formations near the surface. By recommendation of the Survey a pumping test was made on a prospecting well one-half mile south of the village, which was drilled several years ago to 1,000 feet but was later plugged at 100 feet. The presence of oil in the water during the test indicated that the plug in the well is not tight or that the ground in that locality is saturated with oil. A short test indicated a yield of 50 gallons a minute, but a longer test made later indicated that the well could yield continuously only about 15 gallons a minute. A test well put down north of the village yielded less than the well south of the village. A communication received July 28 stated that a well was to be drilled south of town to supply the high school and that a pumping test on it was planned.

ODELL (1,035). Water supply.—(Bull. **12**, 116.) Odell was visited August 16 at the request of the village officials to examine the water supply for hydrogen sulfide. An aerating device, a sketch for which was submitted to the village in 1914, had not been installed. The supply is obtained from 2 wells, respectively, 1,298 feet and 1,360 feet deep, cased to 1,000 feet and tapping the St. Peter sandstone. Comparative analyses of the two waters showed that water from the deeper well has a mineral content of 2,300, a content of chloride of 725, and a content of hydrogen sulflde of 6.4 parts per million, and that corresponding figures for water from the old well are, respectively, 1,150, 272, and 3.7 parts per million.

After the wells have remained idle for some time the first water drawn contains a black sediment of iron sulfide produced by action of hydrogen sulfide on the casings. The water delivered to the consumers has a hydrogen-sulfide content of about 0.8 part per million. The reduction in content of hydrogen sulfide is due to aeration received in the collecting reservoir. It was advised that the hydrogen-sulfide content be further reduced by installing at the collecting reservoir the simple aerator previously recommended by this Survey.

OLNEY. Water supply.—(Bull. **11**, 106.)
Sewerage and sewage disposal.—(Bull. **12**, 117.)

ONARGA. Water supply.—(Bull. **11**, 107.)
Proposed sewerage.—(Bull. **12**, 118.)

OREGON. Water supply.—(Bull. **11**, 107.)

OREGON (2,180). Pollution of creek by wastes from a silica sand-washing plant.—Oregon, in the north-central part of Ogle County, was visited June 18 at the request of a complainant to investigate the character of waste from a silica sand-washing plant and its effect on the stream into which the waste is discharged. The sand-washing plant is 2½ miles west of the city, where the company owns and operates a quarry for sand suitable for the manufacture of glass and pottery. The plant has a rated daily capacity of 400 tons. The raw material is a comparatively clean silica sand. The preparation of the sand involves 3 separate washings, the soiled water from which is discharged into a basin 8 feet square and 10 feet deep. Some sand settles and is recovered in this basin. The overflow passes through a ditch a few hundred feet long and discharges into a small pond 2 or 3 feet deep. As the pond had been partly drained just before the inspection it could not be observed under normal working conditions. The overflow from the pond discharges into a 1,200-foot tile into a small creek. The creek traverses 2 miles of farm land and discharges into Bock River just below Oregon. It has a catchment area of 10 square miles. Conditions at the time of inspection did not permit satisfactory examination of the conditions produced by the waste. Heavy rains had abnormally increased the flow of the stream and had also greatly increased the suspended matter in the water of the creek. The sand plant had not been operated for the preceding 10 days and was started only during the afternoon of the visit.

After the plant had been operated an hour a sample of the water used for washing the sand, a sample of the waste water, and a sample of the creek water above the waste-pipe outlet were collected. The suspended matter in the waste water was 10,000 parts per million. If the discharge of waste is 300 gallons a minute for a 10-hour day and the determined amount of suspended matter is representative a day's waste would be 7.5 tons. As the settling pond was not in operation the amount of suspended matter that was removed by it could not be ascertained. The pond is, however, small and very shallow; though some sand settles in it a large part passes into the creek and gives it a milky turbid appearance at low stages. This water carrying fine sand would not have a toxic effect on stock, but the result of mechanical action might cause physiological disturbances.

It was advised that the trouble could be readily and inexpensively overcome by installing a suitable settling basin or tank. The detention period and rate of flow of the waste through such a basin could best be determined by experimenting with small volumes of the waste water. The sand recovered by such a settling basin would be valuable and the clarified water might be used again.

OTTAWA. Water supply.—(Bull. **9,** 28.)

PALATINE. Water supply.—(Bull. **12**, 119.)

Sewage treatment.—(Bull. **10**, 161; 12, 119.)

PANA (6,055). Water supply.—(Bull. **9**, 29; **10**, 161.) A set of plans and specifications for improvements in the water-purification plant at Pana were received April 5. As a supply from wells had proved to be inadequate a new supply was developed in 1912 by constructing an impounding reservoir on Beck Creek east of the city and a water-purification plant also was built near the center of the city. This plant consisted of two 500,000-gallon filter units, two solution tanks, and a 55,000-gallon clear-water reservoir. Satisfactory results have not been obtained because of the absence of reaction and sedimentation basins, proper chemical-preparation and feed devices, and unsatisfactory location of the rate controllers, which are inaccessible for inspection and repair. The proposed improvements remedied the above defects and were designed to conform to the existing installation. The mixing chamber will have a capacity of 15,000 gallons, providing a detention period of 20 minutes based on the nominal capacity of the filters, and it will be baffled to produce a velocity of one-half foot per second. The settling basin, with a capacity of 155,000 gallons, will afford a detention period of 3.7 hours and will be baffled to produce an approximate velocity of 0.8 foot per minute. The mixing and sedimentation basins are so arranged that they may be used together or independently or either may be taken out of service for cleaning or repairs. Accumulations of sludge will be removed through 6-inch openings provided with mud valves. Tor economy the sedimentation basin will be uncovered. The new solution tanks and feed devices to replace the old inadequate and poorly constructed tanks comprise two rectangular 800-gallon reinforced-concrete tanks for alum, which will discharge into constant-head orifice-feed tanks through lead pipes. The piping will be so arranged that either or both of the solution tanks may be used with either or both of the orifice tanks, No provision is made for treatment of water with hypochlorite, but the authorities are considering the use of liquid chlorine and in the meantime the old solution tanks may be utilized as hypochlorite tanks. No provision is made in the proposed plans for increasing the size of the clear-water basin, which is entirely too small, nor for modification of the pipe gallery to make the filter-rate controllers more easily accessible for adjustment and repair. It was learned during a visit to Pana July 6 that the proposed improvements in the water supply would be postponed until 1916 at least because of the necessity of building a sewage-treatment plant in 1915.

PANA. Pollution of a tributary of Beck Creek.—Pana was visited July 6 at the request of attorneys for the Hayward estate to investigate the alleged pollution of a small tributary of Beck Creek by sewage. This tributary has its headwaters on the Hayward estate in the northeast part of the city and then flows eastward through flat swampy land to Beck Creek. The headwaters consist of 2 small ditches, which may be designated as the east and west Hayward ditches. The dwelling on the Hayward estate is located 300 feet and 500 feet, respectively, from these ditches. Three city drains discharge into west Hayward ditch and a gas plant and an ice plant discharge their wastes into east Hayward ditch. One of the city drains carries the waste from several business buildings and a few houses; another receives the waste from, a grammar school; the third drain carries only ground and surface water. School was not in session July 6 and there was no discharge from the schoolhouse drain. The discharge from the first drain, carrying sewage, was about 30 gallons a minute. Fecal matter was present, a disagreeable odor was noticeable at the outlet, and a thin deposit of sludge had formed along the bed of the ditch. Cattle pastured along this ditch select for drinking the discharge from the third drain, which contains no sewage. The drain from the gas plant discharges into the gutter along Washington Street almost opposite the dwelling on the Hayward estate. This unsightly and malodorous gas-house waste then flows about 300 feet along the gutter into east Hayward ditch. The discharge from the ice plant is unobjectionable, or rather, it is beneficial as it dilutes the gas-house waste and flushes the small ditch. Below the junction of east and west Hayward ditches a mining company has built a small pool and uses in boilers the ditch water collected therein. The mine officials of the company state that the water never becomes seriously objectionable for their use though the presence of the sewage and gas-house wastes are very noticeable during dry weather. A copy of the report on the investigation was forwarded to the attorneys for the complainant with the suggestion that the complaint be referred to the Rivers and Lakes Commission if further action were desired and that the report prepared by the Survey could be used for evidence before the commission.

PANA. Sewage disposal.—(Bull. **12**, 120.) On February 9 a conference was held in Chicago with the consulting engineers for Pana regarding plans for proposed sewage-treatment works. Preliminary plans were reviewed and discussed especially with reference to the size of the plant needed. A brief visit was made July 6 to the sewage-treatment plant, which was then under construction. The plant is to comprise grit chambers, primary settling tanks, trickling filters, secondary settling tanks, and a sludge bed. The engineers' estimate of the cost was $29,000 and the successful contractor's bid was $26,692.15.

PANA. Typhoid-fever epidemic—(Bull. **12**, 120.)

PARIS. Water supply.—(Bull. **10**, 164.)

PARK RIDGE. Typhoid fever.—Park Ridge was visited February 25 to March 5 at the instance of the State Board of Health to investigate an epidemic of typhoid fever involving 28 cases. The epidemic is described in detail on pages 287-94.

PAXTON. Water supply.—(Bull. **10**, 165.)

PEARL. Water supply.—(Bull. **12**, 120.)
Pollution of Illinois River.—(Bull. **11**, 108.)

PECATONICA (1,022). Water supply.—(Bull. **11**, 108.) Visited June 1. A previous inspection of the waterworks indicated that there was a possibility, remote perhaps, that pollution might gain access to the 20-foot dug well from which the public supply is obtained. For this reason it was deemed advisable to make another visit and to collect samples from time to time for analysis. There is a marked difference between the condition of the sample collected at the time of the former visit and during this second visit. The chloride had increased from 4 to 9 parts per million, nitrate nitrogen from 0.12 to 11.20 parts per million, and total residue from 336 to 436 parts per million. This indicates possibly a recent inflow of some contaminating matter into the source of supply. Whether the contamination is of objectionable character can not be ascertained from the analysis. The well is dug mainly in limestone and when the water level is lowered a stream flows in through fissures in the rock. If leachings from privies and cesspools enter fissures in the limestone they might gain access to the well. The best way to ascertain the true condition is to test by introduction of powerful dyes the underground connection between the wells, and near-by privies, cesspools, and sink-holes.

PEKIN. Water supply.—(Bull. **10**, 166.)
Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **11**, 108.)

PEORIA. Water supply.—(Bull. **9**, 29; **11**, 109.)

PEORIA, State hospital. Water supply.—(Bull. **10**, 166.)

PEORIA HEIGHTS. Water supply.—(Bull. **9**, 29; **11**, 109.)

PEOTONE. Water supply.—(Bull. **11**, 109.)

PERU (7,984). Water supply—(Bull. **11**, 109.) Visited July 6. Information obtained during a previous visit to Peru indicated that the water in a brick collecting reservoir became contaminated and that Illinois River, on the bank of which the pumping station is located, rose near the overflow from a suction pit during high stages. Further investigation showed that the overflow of the suction pit was 4 feet above the highest water that had ever occurred in the river and that there was no danger from contamination of the public supply in this respect. A brick reservoir which receives the discharge from one of the 4 flowing wells is located on a hillside below chicken yards and privies. Though the walls are believed to be water-tight the character of the water indicates slight contamination. The casing of the well which discharges into this reservoir must leak, allowing salt water from a bed above that yielding fresh water to enter the well. Gradual increase in the mineral content of the water from the well indicates continual deterioration of the well casing. It was recommended that water from this reservoir be used only in absolute emergency.

PETERSBURG. Water supply.—(Bull. **10**, 167.)

PINCKNEYVILLE. Water supply.—(Bull. **11**, 110.)

PIPEE CITY. Water supply.—(Bull. **11**, 111; **12**, 122.)

PITTSFIELD. Water supply.—(Bull. **11**, 111.)

PITTSFIELD (2,096). Disposal of sewage at the high school.—Pittsfield was visited May 8 at the request of the local school board to inspect the method and effect of sewage disposal from the high school, which has an enrollment of about 225 pupils. The school is fully equipped with plumbing for toilet and laboratory use and the service meter indicates an average daily consumption of 2,500 gallons 5 days a week. The liquid wastes are conducted to a tank which has been used about 5 years. The tank is built entirely underground just to the rear of the school building, and the effluent is conducted through a tile to an open ditch about 500 feet away. Immediately below the outlet there are two houses, one on each side, within 100 feet of the ditch. The owner of one of these houses has complained that disagreeable odors prevail and has threatened to sue the school district. At the time of the visit the school was not in session and objectionable conditions did not prevail. It is conceivable, however, that objectionable conditions may sometime prevail. The tank through which the sewage passes is 25 feet long, 12 feet wide, and 6 feet deep. In it are 2 parallel rows of 6 cells each, each cell being made of two 36-inch sewer pipes placed vertically one on the other. Adjoining cells are connected at about mid depth so that sewage entering the first flows forward through all the cells on one side and back through all the cells on the other side. The sewage flowing from the last cell passes through coke occupying the space between and surrounding the cells. The total settling capacity in the 12 cells is about 3,000 gallons, or slightly more than the average daily flow. As emphasized in former correspondence with the local authorities it was advised that the only adequate solution of the sewage-disposal problem would be installation of a comprehensive municipal sewer system and a properly designed and operated sewage-treatment plant. Plans for a sewerage system were prepared in 1911 but since then the matter has been allowed to rest.

PLAINFIELD. Water supply.—(Bull. **11**, 112.)
Sewage disposal.—(Bull. **12**, 122.)

PLANO. Water supply—(Bull. **9**, 29.)
Sewerage and sewage disposal.—(Bull. **12**, 122.)

PLEASANT HILL. Typhoid fever.—(Bull. **11**, 113.)

POLO. Water supply.—(Bull. **11**, 113.)

PONTIAC (6,090). Water supply.—(Bull. **9**, 30; **11**, 113.) Pontiac was visited February 1 and May 4 to inspect the operation of the water-purification plant and to collect samples for analysis. To prevent the deterioration of stored hypochlorite a double-walled compartment with tar roofing paper interlining has been built. This retards deterioration of stored hypochlorite by excluding moisture. The solution of hypochlorite is carried by an improvised ejector pump to the inlet of the sedimentation tank. During cold weather much difficulty was experienced by incrustation of the nozzle of the ejector, which had to be cleaned every few hours. This difficulty was overcome by connecting to the ejector a steam pipe and admitting a small amount of steam which keeps the apparatus at such temperature that incrustation does not form. Difficulty has been experienced in washing the filters because the overflow troughs are not large enough to carry away the wash water. Methods for modifying these troughs were discussed with the local officials. The rate controllers and loss-of-head gages have been installed and have proved to be valuable. There will be less chance of a shortage of water in the future than heretofore as the Rivers and Lakes Commission has granted the water company certain powers of regulation over a dam just below the intake. Heretofore, even during lowest stages water has been allowed to flow by the dam to operate a privately owned mill. In the future at low stages if the water company requests it the mill owner will use electric power for which the water company will pay.

PONTIAC. Sewage disposal.—(Bull. **12**, 123.)

PORTLAND (3,194). Water supply.—(Bull. **11**, 115.) Portland (Oglesby post office) was visited September 1 to ascertain progress in installation of the water supply for which plans and specifications were reviewed by the Survey during 1914. A well, 14 inches in diameter at the top and 8 inches in diameter at the bottom, had been drilled 1,645 feet deep. The well ends in St. Peter sandstone, and the static level is 105 feet below the surface. A 13-hour pumping test showed a yield of 350 gallons a minute. Permanent pumping equipment has been ordered, and a contract has been awarded for laying mains. The water-works should soon be in operation.

PRINCETON. "Water supply.—(Bull. **12**, 124.)
Sewage disposal.—(Bull. **12**, 125.)

PRINCEVILLE. Proposed water supply.—(Bull. **11**, 116; **12**, 126.)

QUINCY. "Water supply.—(Bull. **9**, 30; **11**, 116; **12**, 126.)

RANKIN (858). Proposed water supply.—Rankin was visited July 30 at the request of local officials to advise in reference to the proposed installation of a water supply.

Plans and estimates for installation of a water supply were prepared in 1912, and the city was visited at that time by a representative of the Survey. The bond issue for the installation, however, failed to carry and since then a sewerage system has been installed which has made the need of a water supply more felt than ever. The two possible sources of supply are a deep drilled well and wells in drift. A well was drilled during 1909 in the southeast edge of the village in search of oil. No oil was struck and the well was abandoned at a depth of 1,608 feet. What was locally considered a strong flow of soft water was encountered between 690 and 730 feet. More highly mineralized water was encountered above and below this stratum. It is understood that the well was successfully plugged below the 730-foot level after drilling was discontinued. The amount and condition of the casing are unknown; it would be necessary to ascertain these facts and to clean the well before a pumping test could be run.

Wells in drift seem to be the more practicable and advisable source of supply. Glacial drift at Rankin is about 350 feet thick and with the exception of the upper 80 to 100 feet consists largely of sand or gravel. Many drilled and driven wells around the village are 100 to 130-feet deep. No screens are ordinarily used in these wells, which are usually 3 to 4 inches in diameter, and they yield sufficient water to meet the limited demands on them. The city already has a 6-inch well 117 feet deep, from which water is pumped to 3 fire cisterns in the business district. This well cannot be pumped at a rate of more than 35 gallons a minute without raising sand as it has no screen. About one mile east of the village the Lake Erie & Western Railroad has 3 wells, 2 of which are 174 to 200 feet deep and one 306 feet deep. The shallow wells are pumped 22 to 24 hours a day and the deep well about 10 hours a day, the total average daily pumpage being 100,000 gallons. The third well was made deeper in order to obtain a less highly mineralized water than that from the shallow drift wells.

Water from the 306-foot railroad well has a total mineral content of 637 parts per million, a content of iron of 1.6 parts, and a total hardness of 441 parts per million. Water from a 125-foot well in the village contains 880 parts per million of mineral matter, of which 1.6 parts is iron, and its total hardness is 608 parts per million. Water from two other wells of similar depth had nearly the same composition.

It was recommended that the village engage a competent consulting engineer to direct installation of a public water supply.

RANKIN. Proposed sewerage.—(Bull. 11, 117; 12, 127.)

RANTOUL. Water supply.—(Bull. 10, 168.)

RED BUD (1,240). Water supply.—(Bull. 12, 127.) Visited July 10. Red Bud is in the northwest part of Randolph County in the drainage basin of Kaskaskia River.

Waterworks were put into operation early in 1915. The supply is obtained from a 294-foot well entering rock at 18 feet and deriving its supply from 54 feet of sandstone at the bottom. It is eased with 10-inch pipe to 20 feet 8 inches and with 8-ineh pipe to 246 feet 10 inches. Water is pumped from the well directly into the distribution system by an electrically driven 210,000-gallon double-acting deep-well pump, whose working barrel is placed 245 feet from the surface. The static level is about 60 feet below the surface, but not more than 50 gallons a minute can be pumped without drawing the level below the auction. It is proposed to lower the pump cylinder to a depth nearer the bottom of the well. The head against which the well pump works is very great and places a great strain on it.

REDDICK. Proposed water supply.—(Bull. 11, 117.)

RIVER FOREST. Water supply.—(Bull. 10, 169.)

RIVERDALE (917). Water supply.—Visited June 30. Riverdale, a suburb of Chicago, is in the southwest part of Cook County on Little Calumet River.

Waterworks were installed in 1902. A collecting reservoir and a triplex pump were added in 1911 and connection was made with the mains of Chicago through a 6-inch meter. This connection affords an emergency supply and also the regular supply during the night. A flap valve between the two systems opens when the village pressure falls to 25 pounds. The pressure from Chicago is low for adequate fire protection. The regular supply is obtained from a well 430 feet deep near the center of the village. It is 12 inches in diameter at the top and 8 inches at the bottom, and it is cased to 200 feet. Rock was encountered at 50 feet. The static level is now about 45 feet below the surface, and it has receded about 30 feet in 5 years. A 46-hour test when the well was drilled gave a yield of 120 gallons a minute. After being pumped continuously for 12 hours at 140 gallons a minute the pump now draws air. The working barrel of the pump is placed at 195 feet. Water is pumped from the well into a collecting reservoir by a 216,000-gallon single-acting deep-well pump operated by a 20-horsepower kerosene engine. The collecting reservoir is 28 feet in diameter, 6 feet deep at the wall, 7 feet deep at the center, and has a capacity of 30,000 gallons. It is built of concrete and has a conical roof surmounting the wall, which extends 6 inches above ground. The water is pumped from the reservoir into the distribution system by a 280,000-gallon triplex pump driven by the kerosene engine. The distribution system comprises 9,300 feet of 8-inch and 6-inch cast-iron pipe. A 60,000-gallon elevated steel tank having a total height of 120 feet is connected to the distribution system. The estimated average daily pumpage is 80,000 gallons and about 30,000 gallons is also obtained from Chicago, thus making the total average daily consumption about 110,000 gallons. This is high for the population, but none of the services is metered and at least 95 per cent of the population use the public supply. The waterworks cost approximately $12,000.

The well water is of good sanitary quality. It has a mineral content of 394 parts per million, and a total hardness of 87 parts per million, and contains 0.3 part of iron.

RIVEESIDE. Water suppply.—(Bull. **11**, 118.)

ROANOKE (1,311). Water supply.—(Bull. **11**, 119.) Visited September 16. Roanoke is in the central part of Woodford County in the catchment area of Mackinaw River. Many shallow dug wells are used. A few tubular wells 80 to 180 feet deep furnish water unsatisfactory because of its high content of iron and its corrosive action on the well casings.

The supply of the waterworks, completed in May, 1914, is obtained from 4 wells, each 4 inches in diameter and 30 feet deep located at the four corners of a 30-foot square. Each well contains 22 feet of 4-inch casing and an 8-foot Cook strainer. The beds of sand and gravel from which the water is derived are about 12 feet thick. The water normally stands about 4 feet below the surface and lowers 2 feet during pumping. The wells are connected underground to a single suction pipe, but each well is controlled by a valve so that any one may be cut out. The water is forced by a 250,000-gallon electrically driven triplex pump into the distribution system, which comprises 1.4 miles of 4-inch, 6-inch, and 8-inch cast-iron pipe. There are 35 service connections, all of which are metered. A 40,000-gallon steel tank elevated to a total height of 108 feet is connected to the distribution system. The average daily consumption is estimated at 10,000 gallons. The waterworks cost $13,500.

The water is of good sanitary quality. Its mineral content is 580 parts per million, its total hardness is 480 parts per million, and its content of iron 0.6 part per million.

BOBEBTS (466). Water supply.—Visited June 1. Eoberts is in the central part of Ford County in the catchment area of Spring Creek, a tributary of Iroquois River.

Waterworks installed about 1890 comprised a well 3 inches in diameter and 216 feet deep, from which water was pumped by windmill power to a cistern in the public square, from which it was drawn by a hand pump. In 1907 the well was reamed to a diameter of 4 inches, a deep-well pump operated by a gasoline engine through a walking beam was installed, a wooden tank on a steel tower was erected, and cast-iron mains were laid. The well ends in an indurated sand, is cased to 206 feet, and is provided with a 10-foot strainer. Water rises to within 95 feet of the surface and recedes but little under the prevailing draft. The working barrel of the pump is just above the strainer. The water is pumped from the well into the distribution system by a 45,000-gallon deep-well pump. The pump is driven by a 50-horsepower gasoline engine installed in 1913, when the electric light plant was installed in the station at the waterworks. The old gasoline engine is held in reserve for emergency. The distribution system comprises 1.25 miles of 4-inch cast-iron pipe. There are 90 service connections, all of which are metered. A 34,000-gallon wooden tank, 18 feet in diameter and 18 feet high elevated on a 51-foot steel tower, is connected to the distribution system. The average daily consumption is estimated at 18,000 gallons. Somewhat more than three-fourths of the population use the public supply. The waterworks cost $6,515.

The water is of good sanitary quality. It has a mineral content of 653 parts per million, a total hardness of 425 parts per million, and contains 2.4 parts per million of iron.

ROBINSON. Water supply.—(Bull. **9**, 30; **12**, 127.)

ROCHELLE. Water supply.—(Bull. **11**, 120.)
Sewerage.—(Bull. **11**, 120.)

ROCK FALLS (2,657). Water supply.—Visited June 29. The water supply is derived from Sterling.

ROCK ISLAND (24,335). Water supply.—(Bull. **9**, 30.) Visited April 21 and July 1-2. Eock Island is on the west-central edge of Eock Island County at the confluence of Rock and Mississippi rivers. It extends along Mississippi River about 5 miles on the north and west and along Eock River about 3 miles on the south. Land within the city rises 140 feet above the river. It is a large industrial center. The island of Eock Island, locally known as Arsenal Island, the site of a Federal arsenal lies north of the city in Mississippi River.

Waterworks installed before 1870 comprised a pumping station at the west end of the city drawing from Mississippi River below local sewers. In 1878 Mr. P. L. Cable donated the city funds to erect a new plant directly opposite the lower end of Arsenal Island 2 miles farther upstream. The intake was extended past the end of the island into the main channel of the river to avoid local sewage. Mr. Cable again in the nineties supplied funds for a filtration plant. The wooden filter tanks continued in use until 1899 when a new purification plant comprising sedimentation basins and 3 slow-sand filters of one-half acre each was built on the bluff at a high point in the city. Slow-sand filtration proved impracticable in purifying a water so high in turbidity and color, and the consumption had increased in a few years so that unfiltered water frequently had to be turned into the mains.

The contract for the present purification plant was awarded in 1910. The supply is now drawn from Mississippi River through a 16-inch and a 20-inch intake pipe both extending from a suction well near the river pumping station 2,100 feet to the main channel beyond the lower end of Arsenal Island. The suction well is 26 feet in diameter and a wall with a screen having a ½-inch mesh divides it to keep fish and rubbish from the suction. The river is subject to pollution by sewage from communities upstream, but no local pollution reaches the intake. The sewage of Moline, which joins Eoek Island on the upstream side, is discharged into the Pool, a narrow strip of water between Arsenal Island and the Illinois bank. The purification plant, with a rated daily capacity of 6,000,000 gallons, is on the bluffs at the site of the old slow-sand filter plant. The old coagulating basins and filtered-water reservoir have been utilized as such, and the new filters have been built in one of the old filter basins while the other two basins have been converted into clear-water reservoirs. Treatment includes coagulation, sedimentation, disinfection with hypochlorite, and filtration. Occasionally the water has been treated with copper sulfate to destroy growths in the clear-water basins. Branches of the 16-inch discharge line from the raw-water pumping station enter the corners of the 2 settling basins. A small mixing box baffled to cause the coagulant to mix with the water before entering the settling basins has been built around the end of each branch inside the basins.

Aluminium sulfate is added through a 2-inch fiber pipe at this point from the headhouse of the filter building about 350 feet away, where the solution is prepared in 2 concrete tanks having capacities of 6,000 gallons each. Feeding the solution is regulated by a constant-head orifice box controlled by an automatic float valve. The proportion of alum varies with the character of the raw water and averaged 3.44 grains per gallon during 1914. Each of the 2 old settling basins has a capacity of 2,400,000 gallons. At the rated capacity of the filters the basins afford a detention period of 19 hours, but at the present average rate the detention period is about 36 hours. Each basin is 240 feet by 120 feet in plan at the top, 177 feet by 57 feet at the bottom, and 21 feet deep and has a depth of flowage of 18½ feet. The sides and bottom are paved with brick laid in cement mortar on concrete. The 2 basins have been baffled differently in order to add elasticity to operation. One basin has 3 transverse baffles with openings at mid depth; this entire basin must, therefore, be used when it is in commission. The other basin is baffled and equipped with gates so that part or all of it may be used, thus affording 2 different settling periods. Thus use of part the basins or both makes possible 4 different settling periods. A 12-inch valve-controlled opening to the sewer facilitates cleaning the basins twice a year.

Ordinarily calcium hypochlorite is fed into the settled-water conduit leading from the basins to the filters at the end in the filter building, but a hose line leads to the end near the settling basin so that hypochlorite may be applied at the farther end if the filters are by-passed. The solution is prepared in two 6,000-gallon concrete tanks similar to the alum tanks, and the feeding is controlled by a float-valve orifice box. The average dose during 1914 was 10.2 pounds per million gallons.

The filters and the headhouse occupy a space 65 feet by 88 feet in one of the old slow-sand filters, which is 125 feet by 145 feet. Waste wash water runs into this additional space, and means are provided for pumping it back into the settling basins. This recovery, however, is seldom practiced, the wash water flowing into the sewer. In winter wash water collects in the basin to full depth in order to protect the walls of the filters and certain piping from freezing. Each of the 6 filters is 21½ feet by 17 feet with a rated capacity of 1,000,000 gallons a day. Three troughs over each filter make the maximum lateral flow of wash water 2 feet. The strainer system consists of perforated brass strainers placed at 6-inch intervals in a grid of piping. Another grid of piping supplies air for washing the filters. The filtering material comprises 24 inches of gravel graded from 2 inches in diameter at the bottom to fine gravel at the top and 26 inches of filter sand, with an effective size of 0.51 millimeter and a uniformity coefficient of 1.78, obtained from near-by fluvial deposits. The effluent pipe from each filter is provided with a closed rate controller. All main valves are hydraulic and are controlled from operating stands. It is customary to agitate the filters with air 3 minutes and then wash for 5 minutes. Wash water is supplied by a pump with a capacity of 2,900 gallons a minute, thus producing a vertical rise of 12 inches a minute. The average consumption of wash water during 1914 was 1.8 per cent of the total pumpage. There are 3 reservoirs for storing filtered water, 2 of which are old filter basins and the other of which is the clear-water reservoir of the slow-sand filter. Bach of the reservoirs converted from the old filter basins is 125 feet by 145 feet in plan and 10 feet deep. They have a common wall in which an opening controlled by a gate makes them essentially one basin having a capacity of 2,600,000 gallons. The walls

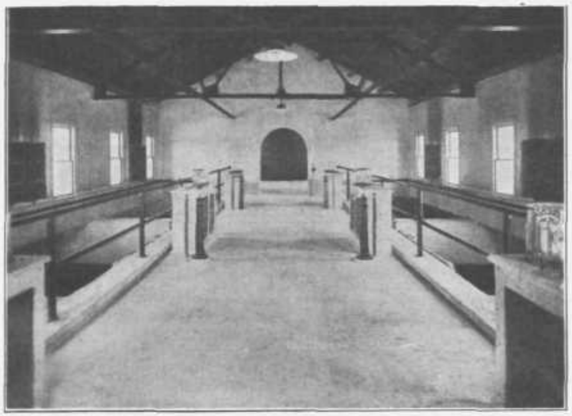


Figure 5.—Operating floor and filters, Rock Island.

Figure 6.—Filter house and elevator tank, Eock Island.

Figure 7.—Filtration plant, Rock Island.

and bottoms are of heavy limestone masonry. The filtered water first enters these 2 reservoirs, from which it is either pumped to an elevated tank supplying a high-level district or overflows into the other reservoir, which supplies a low-level district. This third reservoir is 245 feet square at the top, 175 feet square at the bottom, and 19 feet deep to the flow line, and it has a capacity of 6,000,000 gallons. Its sides and bottom are paved with brick laid in cement, and a woven-wire fence about 4 feet high surrounds the walls. The reservoirs are not covered and vegetable growths occasionally develop in them, to avoid which copper sulfate is occasionally applied by suspending a cloth sack containing the chemical in a channel leading to the reservoir.

The low-lift pumping equipment comprises an 8,000,000-gallon cross-compound fly-wheel duplex pump and two 2-stage 6,000,000-gallon centrifugal pumps operated in series and gear-connected to a steam turbine. There are 2 electrically driven centrifugal high-service pumps having capacities of 3,000,000 and 1,500,000 gallons a day, respectively, and an electrically driven 1,500,000-gallon double-acting triplex pump, which has not been used for several years, but is kept in good repair for emergencies. Accurate records of the distribution system are not available, but there are about 60 miles of 4-inch to 16-inch mains. The city is divided into high- and low-level districts served with water at different pressures. There are gate valves between the two portions of the distribution system, but which gates separate these two districts is not recorded, and the relative extents of them are not known. The low-level portion of the distribution system is supplied from one of the storage reservoirs. A 500,000-gallon elevated tank 150 feet high is connected to the high-level distribution system. There are approximately 5,800 service connections, of which 22 per cent are metered. The total pumpage is determined from revolution counter readings on the low-lift pumps. The consumption in the high-level district is determined by the time the high-service pumps are operated, and the difference is calculated as the consumption of the low-level district. The average daily consumption during 1914 was 560,000 gallons and 2,597,000 gallons, respectively, for the high-level and low-level districts, making a total average daily consumption of 3,157,000 gallons.

Water of satisfactory sanitary quality is furnished by the purification plant. The necessary bacterial and chemical tests are made in a well-equipped laboratory in the filter plant. During 1914 the raw water had an average turbidity of 108, an average color of 38, and these, respectively, were reduced in the filtered water to 0 and 1.5. Danger of contamination of the supply exists through a connection with the fire system of a factory using raw river water. This connection is controlled by a check valve and a gate valve. The check valve cannot be regarded as valuable as there is no assurance that it will seat perfectly. There is a connection between the Bock Island and Moline distribution systems. The Moline supply is of good sanitary quality, but it also is endangered by existence of fire connections controlled by check valves alone.

ROCK ISLAND, Disposal of gas wastes.—(Bull. **12**, 128, 225-8.) Eock Island was visited May 19 in reference to the waste from the gas plant, plans for treatment of which have been submitted to this Survey for review. All liquid wastes, which amount to less than 3,000 gallons during the customary 12-hour run, will be conveyed to 2 relief holders, from which they will overflow to the treatment plant. Treatment will consist of sedimentation aided by the addition of lime and filtration through coke. The sedimentation tank will be 10 feet by 15 feet and will be divided longitudinally into 2 equal compartments. The compartments will be 7 feet deep at the outside walls and 6 feet deep at the center walls. If proper allowance is made for a sludge-settling capacity in each compartment a capacity of 3,000 gallons still remains to afford a detention period of 12 hours. Sludge pipes will be placed at the low portion of the bottom of each compartment for removing the sludge, and a heating pipe will be placed along the bottom near the center wall in each compartment to assist in separation of oil and tar. The waste will enter one corner of one of the compartments, flow forward beneath 6 transverse hanging baffles, and then through a 2-inch pipe at the opposite end into the second compartment. A single baffle 2 feet from the inlet end is placed in! the second compartment. Lime will be fed into the waste at the inlet into the second compartment from a mixing barrel provided with a motor-driven agitator. It is proposed to install a suitable device to apply the solution of lime in proportion to the flow of waste. The liquid, after passing from the second compartment of the settling tank, will filter through a coke filter 10 feet by 12 feet by 3 feet deep in a box adjoining the settling tank. It is planned to keep the depth of waste over the filter approximately the same all the time. The pressure at the outlet will be controlled by drawing off the effluent at different levels. No special underdrainage system will be provided. Inasmuch as the plant does not run continuously officials of the gas plant consider that there will be ample time for cleaning the tanks and the filter when gas is not being made; therefore, duplicate tanks and filters are deemed unnecessary.

ROCK ISLAND, Arsenal. Water supply.—(Bull. 11, 120.) The Federal Arsenal at Eock Island was visited April 21 to inspect the operation of the filter plant and collect samples for analysis. The filter is giving satisfactory results. An improvement that would effect an economy in the operation of the plant would be automatic regulation of discharge from the low-lift pump. At present the level in the settling basin is kept constant by an overflow—a makeshift which wastes large quantities of chemically treated water.

ROCKDALE (1,101). Water supply.—Visited July 1. Eockdale is in the north part of Will County near Illinois-Michigan Canal which at this point is about 1,500 feet north of Des Plaines River.

The waterworks were completed early in 1915. The supply is obtained from a 660-foot well 12 inches in diameter at the top terminating in St. Peter sandstone. Eock was entered 5 feet below the surface, and the well is cased to 260 feet. The water rises to 25 feet below the surface, and the working barrel of the pump is placed at 50 feet. A 24-hour test following the drilling of the well gave a yield of 160 gallons a minute. The water is pumped from the well into the distribution system by an electrically driven 230,000-gallon deep-well pump. The distribution system comprises 1.43 miles of 6-inch and 8-inch cast-iron pipe. There are 261 service connections extending to the curb line, but only 72 have yet been carried into buildings. A 60,000-gallon steel tank elevated to a total height of 125 feet is connected to the distribution system. The average daily consumption is 57,000 gallons. The cost of the waterworks was $28,000.

The water is of good sanitary quality. It contains 525 parts per million of mineral matter and 0.6 part per million of iron, and its total hardness is 234 parts per million.

ROCKFORD. Water supply.—(Bull. 10, 170.)

ROODHOUSE. Water supply.—(Bull. **11**, 121.)

ROSEVILLE (882). Sewerage.—Visited May 21, October 29, and December 24. Eoseville is in Warren County in the drainage basin of Nigger Creek, a small tributary of Swan Creek, which is in turn tributary to Spoon River. There is no sewerage system at present though overflows from cesspools and private septic tanks have been connected to stretches of drain tile that have-been laid primarily to carry ground-water drainage. The drains discharge into an open ditch beside a street in the east part of town. The ditch runs from there northeastward through private property a distance of a few hundred feet, then runs under a railroad, and enters another tile discharging into Nigger Creek, whose drainage area covers only a few square miles. There are several houses in the vicinity of the open ditch and the residents have complained considerably regarding the foul conditions created by discharge from the drain tiles.

It was recommended that the open ditch be replaced by tile drains as a temporary measure and that installation of a permanent and complete sewerage system be undertaken. Eoseville has had a public water supply since 1895 and complete sewerage is badly needed. Some residents have already expended for private septic tanks more than their share of the cost of comprehensive sewerage and even now their problem is not satisfactorily solved. Other residents pay annually for care and cleaning of privies and cesspools almost as much as would be the annual assessments for installation of sewers. After the first visit by a representative of the Survey the city engaged the services of a consulting engineer, and plans for a comprehensive system were prepared. This system included about 4.5 miles of vitrified pipe and was to carry only sanitary sewage. The preliminary plans also provided for a sedimentation tank, the design and size of which were not stated. At the time of the last visit it was learned that the question of sewerage had been laid aside until the spring of 1916.

ROSSVILLE. Water supply.—(Bull. **10**, 172.)

RUSHVILLE. Water supply.—(Bull. **9**, 30; **12**, 128.)

ST. ANNE (1,065). Water supply.—Visited June 4. St. Anne is in the south part of Kankakee County in the catchment area of Kankakee River.

Waterworks installed about 1898 by a private company are now owned and operated by the Public Service Company of Northern Illinois. The supply is obtained from a 6-inch well 210 feet deep, which is cased to limestone at 100 feet. The supply probably comes from crevices in the limestone. The static level is 60 feet below the surface. The working barrel of the pump is placed at 65 feet and the water level recedes during pumping until at times the pump draws air. Water is pumped from the well into a collecting reservoir by a 118,000-gallon single-acting deep-well pump belt-connected to a steam engine. The brick collecting reservoir is 28 feet in diameter and 16 feet deep, and it has a capacity of 74,000 gallons. It is built partly in excavation, the walls extending about 6 feet above ground with earth mounded up around it. It is in poor condition and a flat plank roof which covers it has badly deteriorated. The water is pumped from the collecting reservoir into the distribution system by a 380,000-gallon single-acting triplex pump driven by a 100-horsepower steam engine. Electric power will probably replace the steam plant when the company's transmission line from Kankakee is completed. The distribution system comprises 2.97 miles of 4-inch, 6-inch, and 8-inch cast-iron pipe. About three-fourths of the 200 service connections are metered. A pressure tank in the pumping station is 8 feet in diameter and 38 feet long. The average daily consumption registered on the discharge from the triplex pump is 66,000 gallons. More than three-fourths of the population use the public supply.

The water is of good sanitary quality. It has a mineral content of 809 parts per million, a total hardness of 525 parts per million, and contains 2.6 parts per million of iron.

ST. ANNE. Proposed sewerage.—(Bull. **11**, 122.)

ST. CHARLES. Water supply.—(Bull. **9**, 30; **12**, 129.)

ST. ELMO. Water supply.—(Bull. **10**, 174.)

SALEM. Water supply.—(Bull. **11**, 123.)

SALEM (2,669). Proposed sewerage and sewage treatment.—(Bull. **11**, 123.) Plans and specifications for proposed installation of sewerage and sewage-treatment works at Salem were received November 1 from the consulting engineer. Plans for a sewerage system and sewage-treatment plant were reviewed and approved by the Survey in 1913, but the proposition of installing the system was defeated by popular vote. The project was again advanced in 1915 in Salem, another consulting engineer was retained, and a second set of plans and specifications were prepared. Salem is near the center of Marion County, of which it is the county seat. It is on the upper reaches of Crooked Creek, a tributary of Kaskaskia River. A public water supply was installed during 1912 and the need of a sewerage system is becoming more pressing as the number of consumers increases.

The proposed system of sewers is for sanitary sewage only, and will cover the entire built-up portion of the city. It will comprise 12.1 miles of vitrified-clay pipe ranging from 6 to 18 inches in diameter with a suitable number and arrangement of manholes and appurtenances. The outlet of the system will lead into Crooked Creek, which flows southeasterly through the city and has a catchment area of about 7 square miles above the proposed point of discharge. As the stream has no flow during dry periods it will be necessary to treat the sewage to prevent objectionable conditions at the outlet and downstream. The proposed location of the treatment plant is remote from habitations.

The sewage-treatment works designed by the consulting engineers comprise 2 uncovered Imhoff or 2-story settling tanks and a sludge-drying bed. Each of the sedimentation compartments of the settling tanks is 33.5 feet long, 8 feet wide, and 6 feet deep below the flow line and has a capacity of 12,000 gallons. With an assumed future daily sewage of 300,000 gallons the detention period with both tanks in operation will be 2 hours. Each of the sludge-digestion compartments of the tanks have a capacity of 197 cubic yards. With the assumed quantity of sewage and a deposit of sludge of 3 cubic yards per 1,000,000 gallons of sewage both compartments will afford storage for the sludge for 14 months. This is a larger capacity than is necessary. The sludge compartments have hopper bottoms and are provided with pipes controlled by suitable valves for removing the sludge. The sloping sides from the sedimentation compartment to the sludge compartment were originally designed with a slope of 4.5 degrees, but it was advised that a slope of about 60 degrees would be preferable. Tie plans provide a sludge-drying bed 92 feet long and 60 feet wide; this area of 5,520 square feet is larger than is necessary, and it was advised that a smaller area would be as satisfactory and less expensive. The bed will have underdrains of 6-inch tile placed 7 feet 8 inches center to center and the filtering material will comprise 6 inches of coarse gravel and 6 inches pf sand.

The plans provided for discharge of the effluent from the sedimentation tanks into Cahokia Creek without further treatment. During the first year or two of operation the discharge will probably be small and the effluent will probably not create serious nuisance. As the amount and strength of the sewage increases, however, foul conditions in the creek may be objectionable to riparian owners downstream. It was, therefore, recommended that the plans for the sewerage system be approved and that the plans for the sewage-treatment plant be approved after making certain minor modifications in the details of design and subject to the condition that additional treatment be provided as the volume and strength of the sewage increase.

SALEM. Disposal of sewage from high school.—A conference was held June 25 with the superintendent of the Salem high school regarding proper disposal of the sewage from the high school pending the construction of municipal sewerage. The city has been contemplating installation of sewerage for some time but the matter has been delayed, and it is, therefore, necessary to provide temporary means for disposing of the sewage from the high school. The school is near a small stream, which flows through the city. The stream is dry during summer but it usually has some discharge during the school year. It was, therefore, recommended that a simple form of covered tank be constructed as a temporary device until adequate municipal sewerage is installed. Such a device can be constructed at relatively low cost and can be abandoned when the city's system becomes available.

SAN JOSE. Water supply.—(Bull. **12**, 131.)

SANDWICH. Water supply.—(Bull. **9**, 30; **12**, 130.)

SANDWICH (2,557). Sewage treatment.—Sandwich was visited September 14 to inspect the operation of the sewage-treatment plant, which was installed in 1913. The plant comprises two 2-story settling tanks, a dosing chamber with automatic siphons, 6 intermittent sand filters with a combined area of about 0.5 acre, and a sludge bed. The plant was in excellent condition and showed that it had been receiving careful attention. The sewage as it left the settling tanks appeared to be fairly well clarified and materially better than the raw sewage. The volume of sewage is not known, but the number of discharges per day of the dosing chamber indicates that it is about 80,000 gallons. Only one compartment of the settling tank was being used at a time as this is sufficient to handle the present sewage. Sludge is removed from the settling basins about once every two months except in winter. The sludge is black and inoffensive except in appearance. It dries out in 3 or 4 days and the neighboring farmers are glad to obtain it for use as fertilizer. The siphons in the dosing chamber were operating regularly and a siphon was discharging every hour and one-half; at this rate each filter has a period of rest between doses of about 9 hours. The surfaces of the beds were level and even distribution of the sewage was being obtained. The sand had been scraped once during the season and was about ready to receive a second scraping. Examination showed that the sand below a depth of one-half inch was quite clean. The effluent from the filters was very clear and inoffensive. This effluent is probably diluted by ground water, as springs were encountered when the treatment plant was built.

The present system is designed to remove sanitary sewage only, and plans are now being prepared for a system of storm sewers, which will cost ultimately about $60,000. The outlet of this system will empty into the dredge ditch near the treatment works.

SANGAMON, County poor farm. Proposed sewage treatment.—(Bull. **11**, 123.)

SAVANNA. Water supply.—(Bull. **11**, 124.)

SEARS (236). Proposed water supply.—(Bull. **12**, 131.) Visited May 20. Since the visit July 22, 1914, Sears has become part of Rock Island, and the matter of a water supply is now in the hands of the officials of Bock Island. Before this change the village had drilled a well to a depth of 270 feet in limestone, from which it was thought an adequate supply could be obtained; no pumping test had been made. Development of a supply from this well will probably be abandoned, and the mains will probably be extended from Eock Island.

SECOE (358). Water supply.—Visited October 5. Secor is in the south-central part of Woodford County in the drainage basin of Mackinaw River.

Waterworks, installed about 1895, comprised a drilled well with pumping equipment, a pressure tank, and a few blocks of mains. The mains have since been extended until they now cover practically the entire village and a second well was drilled 10 feet from the first early in 1915, and pumping equipment was installed in it. The older well is 115 feet deep and is cased with 6-inch pipe. A brick pit about 7 feet deep has been built around the top. The static level is about 60 feet below the surface. The new well is 185 feet deep and is cased with 8-inch pipe; it is equipped with a sand screen 17.5 feet long in coarse sand and gravel. This well apparently draws its supply from a stratum different from that in the older well, as the static level in this new well is 85 feet below the surface. The yields of the wells are sufficient to meet the demands of the village. When the new well was drilled it was pumped for 32 hours at a rate of 60 gallons a minute without apparently exhausting the supply. Water is pumped from the wells directly into the distribution system. The old well is equipped with a 30,000-gallon single-acting pump driven by a gasoline engine. The working barrel of the pump is placed at about 100 feet and it has also a suction pipe 10 feet long. The new well is equipped with an 85,000-gallon single-acting deep-well pump driven by a kerosene engine. The working barrel is placed at 135 feet, and it has also a suction pipe 10 feet long. Without allowance for recession of water level during pumping the pump at times operates against a head of at least 265 feet. The distribution system comprises about 2 miles of mains practically all 4 inches in diameter. There are 32 service connections, 3 of which are metered. An air-pressure tank, 8 feet in diameter and 36 feet long, is connected to the distribution system. The average daily consumption is estimated to be 10,000 gallons. The waterworks cost about $12,000.

The water is of good sanitary quality. Water from the new well has a mineral content of 672 parts per million, a total hardness of 550 parts per million, and a content of iron of 4.0 parts per million.

SHAWNEETOWN. Flood conditions on Ohio River.—(Bull. **11**, 124.)

SHEFFIELD. Water supply.—(Bull. **1**2, 131.)

SHELBYVILLE. Water supply —(Bull. **11**, 125.)

SHELDON. Water supply.—(Bull. **11**, 125.)

SILVIS. Water supply.—(Bull. **10**, 173.)

SOMONAUK (591). Water supply.—Visited September 23. Somonauk is in the southeast corner of Dekalb County on Somonauk River, a tributary to Illinois River.

Waterworks were installed about 1880, the original installation comprising one well, 190 feet deep in gravel and 10 inches in diameter, a pump operated by a windmill, a small elevated wooden tank, and a short distribution system of small wrought-iron pipe. The windmill equipment was later replaced by a deep-well pump driven by a gasoline engine. The pump suddenly failed to deliver sufficient water about 1902 and a second well was put down as it was thought that the supply in the first well was becoming exhausted. After the second well had been put in service the old well could be examined and it was found that the trouble was caused not by decreased yield, but by leakage through a hole that had rusted through the suction pipe.

The supply is now obtained from these two wells, which are about 8 feet apart in a pit in the pumping station. The new well is 500 feet deep and 10 inches in diameter, and it terminates in St. Peter sandstone. The static level in both wells is about 16 feet below the surface. The maximum yields of the wells have never been determined, but with the present pumping equipment it is customary to pump both wells at the same time at the rate of about 340 gallons a minute. The old well is equipped with an 8-inch by 30-inch single-acting deep-well pump placed at 24 feet, and the new well is pumped with a 7-ineh by 8-inch single-acting triplex pump. The pumps have a combined daily capacity of about 500,000 gallons and are belt-connected to a gasoline engine. They are operated about 2½ hours a day and discharge directly into the distribution system. This system, covering practically the built-up area, comprises a small amount of 8-inch and 6-inch pipe; the rest is 4-inch pipe with a few short lengths of the old 2-inch pipe. An 80,000-gallon wooden tank, 24 feet in diameter and 24 feet high elevated on an 85-foot brick tower, is connected to the distribution system. The tank has been in service about 13 years and is still in excellent condition. The average daily consumption is about 50,000 gallons and the maximum is about 70,000 gallons. There are approximately 100 services, none of which is metered.

The water is of excellent sanitary quality. Its mineral content is 329 parts, the total hardness is 229 parts, and the content of iron is 1.4 parts per million.

SOMONAUK. Stream pollution.—Somonauk was visited September 23 at the request of the Eiyers and Lakes Commission to investigate a complaint of pollution by sewage of a stream south of the village. Somonauk drains into a small branch of Somonauk River flowing just beyond the southern limits of the corporation. The village has no sanitary sewerage, but drain tiles, which have been laid from time to time to remove ground water, receive seepage from numerous cesspools. The outlet to the drainage system is 18 inches in diameter. At the time of the visit only a small quantity of water was issuing from the drain, and this waste was clear and did not visibly pollute the creek. According to statements of city officials regarding the construction of cesspools and the limited amount of sewage that enters the drain it seems improbable that the contamination is sufficient to be injurious to live stock. The complainant had lost several animals during the year and laid the blame for his loss on the polluted water of the creek; yet this contention seems unwarranted. It would be advisable, however, for the village to consider installation of a system of sanitary sewers inasmuch as a water supply is available.

SOUTH BELOIT. Pollution of Turtle Creek.—Visited June 1. Late in April a resident of South Beloit complained to the State Game and Fish Conservation Commission that a large number of fish were dying in Turtle

Creek. A representative of the commission visited the stream, made a brief report which was transmitted to the Rivers and Lakes Commission, and that commission in turn requested the Survey to make a detailed investigation. It was learned that largo numbers of fish had died late in April in the lower reaches of Turtle Creek near confluence with Bock River. This condition is said to have lasted only a few hours, when all the fish in that part of the stream had perished or conditions. producing the ill effects had ceased to exist. It seems that the same condition has been observed on several occasions at intervals of 3 or 4 months. The automobile-supply factory of the "Warner Instrument Co., and the hosiery factory of the Eacine Knitting Co., are located in this neighborhood, and both discharge wastes into the creek. Solutions of sodium cyanide, hydrogen sulfide, and nickel sulfate are used by the Warner Instrument Co., and the wastes discharged from its plant contain more or less of these chemicals.

Though little of the chemicals normally reach the creek its waters may become fairly polluted with them at certain intervals when solution tanks ara cleaned or the floors are flushed. This conforms with the fact that the fish die only at certain intervals. The wastes of the Racine Knitting Co. comprise dilute dye waters, which are much weaker than the wastes from the other factory, and are, moreover, discharged continuously, a fact which indicates that they constitute pollution of only secondary importance. The Warner Instrument Co. is planning to install a cesspool or tank, which will receive the chemical wastes. This should prevent future objectionable conditions in the stream. The coarse sand and gravel in this neighborhood would probably absorb the wastes rapidly if they were discharged into a. cesspool. There are no wells in the immediate neighborhood which might be endangered by this disposal.

SPARTA. Proposed water supply.—(Bull. **12**, 132.)
Typhoid fever.—(Bull. **12**, 132.)

SPEING VALLEY. Water supply.—(Bull. **11**, 126.)
Pollution of Illinois River.—(Bull. **11**, 126.)

SPEINGFIELD. Water supply.—(Bull. **9**, 31; **11**, 126.)
Sanitary condition of State fair grounds.—(Bull. **12**, 132.)

SPEINGFIELD, Pollution of Sangamon River.—At the instance of the Game and Fish Conservation Commission and the Rivers and Lakes Commission the cause of large numbers of fish dying in the Sangamon River, below Springfield, early in January was investigated on January 20 and 21. The results of the investigation are embodied in a report which is printed in full on pages 251-5.

STANFOED (525). Water supply.—Visited September 14. Stanford is in the west-central part of McLean County in the drainage basin of Sangamon River.

Waterworks were installed in 1911. The supply is obtained from a well 131 feet deep and 6 inches in diameter, ending in water-bearing sand and gravel. The well is provided with a Cook strainer 10 feet long. The static level is 70 feet below the surface. Water is pumped from the well into the distribution system by a 78,000-gallon double-acting deep-well pump driven by a gasoline engine. A pressure tank 9 feet in diameter and 40 feet long, affording a storage between pressures of 40 and 90 pounds of 7,000 gallons, is located at the pumping station. The distribution system comprises 2.2 miles of 3-inch, 4-inch, 6-

inch, and 8-inch cast-iron pipe. Twelve of the 40 service connections are metered. The average daily consumption is about 8,000 gallons. The cost of the water-works is estimated at $14,000.

The water is of good sanitary quality. It contains 430 parts per million of mineral matter, and 1.4 parts per million of iron, and its total hardness is 356 parts per million.

STAUNTON (5,048). Water supply.—(Bull. **10**, 174.) Staunton was visited December 21, 1914, to investigate a local water famine, and January 13-15, 1915, to witness pumping tests on a well.

The present water supply is obtained from an impounding reservoir north-west of town on a branch of Cahokia Creek which has a catchment area above the dam of approximately 1,000 acres. As this part of the State had exceedingly limited rainfall during 1913 and 1914 the reservoir was lowered so far that consumers were notified to discontinue the use of city water to guard against shortage of water for the city electric light plant. The average daily pumpage is 300,000 gallons, about 80,000 gallons of which is used by a railroad and 20,000 gallons by an ice plant. After the shortage the city engaged a consulting engineer who submitted two propositions to the city, one for a supply from wells north of the city in the bottom land along Cahokia Creek, and the other for construction of a dam on Cahokia Creek. He recommended that test wells be sunk and the well supply obtained if possible. A well 6 inches in diameter and 20 feet deep put down in the bottom land penetrated 12 feet of clay and 8 feet of coarse sand and gravel. A 24-hour test was run with a centrifugal pump with the suction pipe 2 feet above the bottom of the well, and during pumping the water level in holes 100 feet and 200 feet from the test well was observed. The yield was 28 gallons a minute. No material increase in flow was obtained by slightly lengthening the suction pipe. The water level dropped 13 inches and 7 inches, respectively, in the observation holes 100 and 200 feet distant. The water obtained was of good sanitary quality. It has a mineral content of 313 parts per million, a hardness of 290 parts per million, and contains no iron. The engineer advised construction of a dug well, which could be supplemented by several scattered tubular wells if necessary. An election was held after January 15 at which the proposed improvement was "defeated.

If the supply from wells should fail recourse may be had to a surface supply. The engineer estimates that sufficient supply of water can be obtained by continuing to use the present reservoir and constructing a dam about 5 feet high on Cahokia Creek. As the banks of the stream in the vicinity of the proposed dam are fairly steep it would probably be unnecessary to acquire land for a reservoir because the channel of the creek would serve for storage. The drainage area above the proposed location of the dam is 44 square miles. The estimated cost of a supply from wells is $13,700 and that of a surface supply excluding a filter plant is $14,100.

STAUNTON. Proposed sewerage and sewage disposal.—(Bull. **12**, 134.)

SIEGER. Water supply—(Bull. **12**, 134.)

STERLING (7,46.7). Water supply.—(Bull. **11**, 127.) Visited June 29. Sterling is in the central part of Whiteside County on the north bank of Eock River directly opposite Eock Falls (2,657), which receives its water supply from Sterling. Both cities are industrially important. A dam at this point supplies power to a few factories in the lower end of town, and a government dam above it diverts water into a feeder of Illinois-Mississippi Canal. Both cities are well sewered, and the sewage is discharged into the river below the lower dam.

Waterworks were first installed in 1885 by a private company whose present franchise expires in 1935. The source of supply has always been deep wells entering Potsdam sandstone. One well was first drilled and others have been added from time to time until there are now 4, the last of which was drilled in 1910. The franchise gives the water company the right in case of fire to take additional water from galleries or conduits extending along, under, or in Eock River as may be deemed best. There is a suction line from the pumps to the river, which has been used once during the past 14 years. The wells are about 100 feet apart in a line parallel to and about 200 feet from the river. The wells range in depth from 1,334 to 1,829 feet. They are cased with 8-inch pipe to limestone, which is encountered at a depth of about 250 feet, and have been drilled below that 4 inches in diameter into Potsdam sandstone. The wells flow under natural pressure and the yield of about 1,800,000 gallons a day, is sufficient to meet ordinary needs of the city'. Air-lift equipment is provided in 3 wells for increasing the yield when necessary. The top of well 1 is surrounded by a brick basin 8 feet in diameter and 15 feet deep, in which water rises and overflows into 2 collecting reservoirs. Each reservoir is 30 feet in diameter and 12 feet deep below the overflow, thus having a capacity of 635,000 gallons. They are connected and, with the basin around well 1, form essentially one basin with a total capacity of 1,300,000 gallons. One reservoir is covered with a flat roof and the other with a conical shingle roof. Both have stone masonry walls, which rise sufficiently above the surrounding ground to exclude surface water. Well 2 discharges into one of the reservoirs, well 3 into the basin surrounding well 1, and well 4 into the other reservoir. A pond near the reservoir, formed by excavation and embankment receives the excess flow of the wells. It is about 75 feet wide and 150 feet long and holds about 1,000,000 gallons. It is always practically full. A pipe from this pond connects with pump suction, but this connection is said to be very rarely used. The water in this pond is subject to surface drainage. Wells 1, 3, and 4 are equipped with air lift, the nozzles being set at 125 feet. The high-service pumping equipment comprises a 2,000,000-gallon tandem-compound duplex pump, a 2,000,000-gallon single-expansion duplex pump, and a 3,000,000-gallon cross-compound fly-wheel pump. The first two pumps have been in use since the waterworks were installed, and the third pump was installed in 1910. The distribution system for both Sterling and Eock Falls comprises 31.5 miles of cast-iron pipe from 4 to 16 inches in diameter and 6.6 miles of 2-inch wrought-iron pipe. There are 2 river crossings from Sterling to Eock Falls, one 10 inches and the other 12 inches in diameter. On January 1, there were 2,293 service connections, of which 2,266 were used, and about one-half of these are metered. A 235,000-gallon steel standpipe 100 feet high is connected to the distribution system. It is placed on the highest point in the city, the ground there being about 50 feet above the level of the floor of the pumping station. The average daily consumption during 1914, according to the log of the pumps, was 675,000 gallons. An appraisal of the properties of the waterworks was made several years ago. If the sum of $80,000 is added to that appraisal for construction since the appraisal was made the total value of the waterworks is approximately $350,000.

The water from the wells is of good sanitary quality, but the connections to the river and to the overflow pond expose the water supply to contamination under extraordinary conditions. The waters from the different wells are similar in mineral content and in composition. The mineral content of water from the 1,829-foot well is 341 parts per million, the total hardness is 300 parts per million, and the content of iron is 0.15 part per million. Similar determinations on water from the 1,630-foot well gave, respectively, 325, 297, and 0.13 parts per million.

STOCKTON. Water supply.—(Bull. **11**, 127.)
Sewerage.—(Bull. **11**, 128.)

STONINGTON. Water supply.—(Bull. **11**, 128.)

STEAWN (277). Water supply.—(Bull. **11**, 130.) Visited June 3. Strawn is in the extreme southeastern part of Livingston County in the catchment area of Vermilion River.

Waterworks installed about 1895 comprised a dug well .40 feet deep, a triplex pump driven by a gasoline engine, an elevated wooden tank, and about 1,200 feet of 4-inch cast-iron mains. As the dug well was believed to be subject to contamination it was abandoned about 1909, and a well was drilled 45 feet deep and 6 inches in diameter, cased to 40 feet, and is equipped with a screen 5 feet long made of 6-inch pipe perforated with ¼-ineh holes spaced ½ inch center to center. The water stands about 20 feet below the surface and recedes but little under the prevailing rates of pumpage. The water is pumped from the well into the distribution system by a 250,000-gallon single-acting triplex pump driven by a gasoline engine. The distribution system comprises 3,500 feet of 4-inch cast-iron pipe. There are 34 service connections, none of which is metered. A 30,000-gallon elevated steel tank, which replaced the wooden tank in 1912, is connected to the distribution system. The height to the top is 92 feet. The average daily consumption is estimated at 9,000 gallons. The waterworks cost about $15,000.

The water is of good sanitary quality. It has a mineral content of 529 parts per million and a total hardness of 404 parts per million, and it contains 2.5 parts per million of iron.

STRAWN. Typhoid fever.—(Bull. **11**, 130.)

STREATOR (14,253). Water supply.—(Bull. **9**, 31; **11**, 128.) Streator was visited May 5 to inspect the operation of the purification plant and to collect samples. Very satisfactory results are being obtained at the purification plant. The water is at times very difficult to treat as the color is high and the alkalinity is low. At such times it has been found advisable to use lime in conjunction with alum. It was suggested that as it is necessary to use lime some saving might be effected on such occasions by using iron instead of alum. The officials are considering the installation of a liquid chlorine outfit though the present hypoehlorite plant has only recently been installed and is in good working order.

STEEATOE, Pollution of Vermilion River.—At the instance of an official of the Chicago Portland Cement Co. at Portland the cause of the foul odor of water from Vermilion River and the death of fish in that stream below Streator early in January was investigated on January 14 and 15. The results of the investigation are embodied in a report printed in full on pages 234-50.

STRONGHURST. Proposed water supply.—(Bull. **12**, 135.)

SULLIVAN (2,621). Proposed water supply.—(Bull. **11**, 130.) Visited April 8. It is proposed to develope a surface-water supply. After an inspection the opinion was expressed that the project was entirely feasible. Preference, however, was expressed for a ground-water supply if enough could be obtained of suitable quality. Present data does not give assurance that a ground-water supply is feasible, but it was recommended that tests of available wells be made.

SULLIVAN. Proposed sewerage.—Visited March 27 and April 27. During the first visit preliminary plans for a proposed sewerage system and septic tank were discussed with the consulting engineer of Sullivan. It was advised that inasmuch as sewage treatment is necessary the separate system of sewers for sanitary sewage is preferable to the combined system as planned. It was recommended to the sewerage committee and their engineer that comparative estimates of cost of a combined and a separate system be prepared. This system had been designed to receive storm water due to misconception as to the necessity of having large volumes of water flowing in the sewers. This matter was explained to the city officials and detailed plans and specifications are being prepared for a system of sanitary sewers.

SYCAMORE. Water supply.—(Bull. **11**, 131.)

TAYLOEVILLE. Water supply.—(Bull. **11**, 132.)

TINLEY PARK. Water supply.—(Bull. **12**, 136.)

TISKILWA. Water supply.—(Bull. **9**, 31; **10**, 175.)

TOLEDO (900). Proposed water supply.—Toledo was visited July 2 at the request of local officials to meet the members of the commercial club and discuss possibilities for procuring a water supply. Toledo is in the central part of Cumberland County in the catchment area of Embarrass River. The installation of a water supply was first considered in 1899, when a contract was awarded to a private company of Chicago to build waterworks and an electric light plant for about $25,000. The plans and specifications included an impounding reservoir on a small stream northeast of a pumping station, combined with an electric light plant, an 80-foot standpipe, and a distribution system to cover practically the entire town. On completion of the reservoir the contractor encountered financial difficulties and failed to complete the contract. The town paid $3,100 for the reservoir and for some reason the waterworks project was then abandoned, but the electric lighting project was completed at a cost, it is believed, of about $15,000. The only use that has been made of the impounding reservoir is to supply the electric light plant with boiler water.

The town is again actively taking up the question of a water supply. Definite information regarding the impounding reservoir and its catchment area could not be obtained, but the brief inspection made indicates that the latter is very limited and that the reservoir does not hold more than 4,000,000 gallons. This would be wholly inadequate with normal consumption during dry years in a town as large as Toledo. Moreover, it would be necessary to build purification works in order to make the water suitable for domestic use.

Wherever ground water can be obtained in suitable quality and quantity wells constitute the most desirable source of water supply for small communities, and it is, therefore, advised that the town before spending any money on construction of waterworks should carefully investigate the feasibility of procuring the supply from wells. There have been very few wells of any depth drilled in and around Toledo and it is impossible to state with any assurance that a ground-water supply may be obtained. Just west of the town a well 125 feet deep, which ends in glacial drift, yields very little water. North of the town a well 400 feet deep encountered little water in the glacial drift but yielded considerable quantities of salt water from the rock underneath. Of 4 wells in the town square 2 are dug 16 feet deep, one is bored 40 feet, and one is dug 56 feet. It is stated that when the 56-foot depth was reached in the last well water under considerable pressure entered so rapidly that further progress could not be made. The yield of this well has not been tested. As the 400-foot well north of town yields salt water there would appear to be little hope of procuring a satisfactory supply from deep-rock wells; attention should, therefore, be given to wells in the drift. The deepest well in the town square is reassuring as to the existence of water-bearing sand and gravel and its yield would warrant making a pumping test or sinking some test wells. It was advised that the first test well be put down on the property already owned by the town adjoining the electric light plant. If this or other wells prove adequate the town can then have their engineer prepare plans and specifications for waterworks. The existing impounding reservoir may be maintained as a valuable source of supply in emergencies. The sanitary dangers from such a source may be minimized by maintaining apparatus for applying chlorine as a disinfectant.

TOLONO. Water supply.—(Bull. **12**, 139.)

TOLUCA. Water supply.—(Bull. **11**, 132.)

TOULON. Water supply.—(Bull. **11**, 133.)
Sewage-treatment plant.—(Bull. **12**, 140.)

TREMONT. Water supply.—(Bull. **12**, 140.)

TRENTON. Water supply.—(Bull. **12**, 140.)

TUSCOLA (2,453). Proposed improved water supply.—(Bull. **12**, 141.) Tuscola was visited April 26 to address the community club regarding a better water supply. Tuscola has a public water supply, but it has never been adequate and it is of very inferior quality. Part of it is obtained from a polluted creek and part from a well yielding highly mineralized water. The waterworks are owned and operated by a private company. An effort has recently been made to obtain a better supply by sinking new wells near the waterworks.

The ground-water supply is preferable to a surface-water supply primarily because purification works are not necessary for a ground water of assured good quality. Though purification works can render a surface supply safe their operation requires continuous and intelligent attention that is generally difficult to obtain in small installations. Notwithstanding this disadvantage a surface supply is preferable to a ground-water supply that is not available in sufficient quantity, is highly mineralized, or contains iron and manganese. Little. success has been attained thus far in procuring water from wells in sufficient quantity for public supply in or near Tuscola though it is available almost everywhere in the vicinity in sufficient quantity for farms or residences.

It is quite practicable, however, to obtain an abundant supply of surface water 5½ miles east in the valley of Embarrass River, either from the main stream with small impounding storage or from a tributary which enters at this point with large impounding storage. The availability of such an abundant surface supply should be reassuring to the residents of Tuscola as it definitely insures the future progress of that city in so far as it may depend on a public water supply. This water could be delivered to Tuscola in a purified condition for not more than $50,000.

Though the development of a surface-water supply is entirely feasible the lower cost of a well supply would make it worth while for the city to investigate this problem more exhaustively than it has been investigated in the past. Many deep wells have been drilled in and near Tuscola, but very incomplete records of most of them havo been kept, and it is necessary to rely for information on the memory of the drillers. The principal defect in obtainable information is the lack of exact measurements of the quantity of water. A blank form was prepared for the city to be used in procuring the necessary data regarding the many wells now in and near Tuscola. It may be possible to draw from study of such records some conclusions as to the best locality in which to put down test wells. It was advised that a consulting engineer be retained to investigate in detail the possibilities of a well supply and to prepare survey's of reservoir sites and pipe lines in order that the relative costs of a surface and a ground supply may be compared. If the city wishes to place the matter of improved water supply with the private water company these investigations will be valuable to the city as a, basis of an equitable agreement between the city and the company.

TUSCOLA. Proposed sewerage.—(Bull. **12**, 142.)

UTICA. Water supply.—(Bull. **11**, 134.)

VILLA GROVE (1,828). Proposed water supply.—(Bull. **12**, 142.) Villa Grove was visited February 18 to witness a pumping test on the new village well. The well, the drilling of which was started in 1914, had reached a depth of 629 feet. It is cased with 12-inch casing to 240 feet, 10-inch casing to 256 feet, and 8-inch casing to 622 feet. The last 7 feet is 8 inches in diameter and uncased. The well terminates in sandstone. At about 450 feet a vein of salt water was encountered under sufficient pressure to rise almost to the surface. An air-lift equipment had been installed for testing the yield of the well but the boiler, a makeshift affair, was unable to furnish sufficient steam to operate satisfactorily the compressor, and it was necessary to stop pumping occasionally in order to allow the boiler to steam up. The air-discharge pipe was placed at a depth of 250 feet. The longest run lasted two hours and twenty-five minutes. The maximum discharge did not exceed 75 gallons a minute and the average was about 50 gallons a minute. The measurements were made by a weir. The water level before pumping was 85 feet below the surface and the drawdown was about 67 feet. The tests were not considered satisfactory as they extended only over a few hours, and it was recommended that a long-test run with satisfactory testing equipment be made before the permanent installation of pumping equipment. The length of test necessary will depend on the behavior of the well during pumping; if the water level tends continually to fall the test should be prolonged.

A sample of water for analysis was collected after the well had been pumped continuously for 2 hours. The water was colorless when collected, but it had a bluish milky appearance when it reached the laboratory. There was sufficient hydrogen sulfide in the water to render the odor noticeable several feet from the pump discharge. It was suggested that the advisability of raising the water by air lift and installing a collecting reservoir to remove the hydrogen sulfide from the water be considered if it is decided to use this well for the public supply.

The water has a mineral content of 505 parts per million, a total hardness of 198 parts per million, and it contains no iron.

VIRDEN. Proposed water supply.—(Bull. **11**, 135.)

WARREN. Water supply.—(Bull. **11**, 136.)

WARSAW (2,254). Water supply.—(Bull. **10**, 176; **11**, 136.) Warsaw was visited June 23 to ascertain why the filter plant was delivering an unsatisfactory effluent as indicated by analyses made in the Survey's laboratory. The filter plant, which was installed in 1913, comprises a circular wooden coagulating basin, a single wooden tub filter, and a concrete clear-water reservoir. The filter and pumping equipment are housed in a rather poorly constructed building, most of which is occupied by a button company, and an engineer looks after both properties. Water is drawn from Mississippi River directly opposite the plant. The intake consists of a piece of iron pipe extending into the river and lying on the bottom. A 20-foot length of 10-inch pipe perforated with small holes is to be added to the intake in order to prevent the entrance of small fish, which are troublesome at present. The water is pumped into the coagulation basin by an electrically driven triplex pump having a capacity of 120 gallons a minute. Alum is used for coagulation and hypochlorite for disinfection. Separate tanks were provided originally for preparation and application of the two chemicals, but the orifice box and connections for the hypochlorite solution became badly corroded; instead of making proper renewals this tank was abandoned, and the hypochlorite is now dissolved and stored in a circular wooden tank and is mixed with the alum solution and the two are applied to the water in a single solution. This is unsatisfactory as hypochlorite is stable only in alkaline solution; consequently when hypochlorite is mixed with the acid alum solution the chlorine is liberated and escapes into the air. At the time of the visit about 1.8 grains of alum were being used. The raw water was quite turbid and this amount was insufficient. The coagulating and settling basin is 22. feet in diameter and 12 feet deep and is on property adjoining the filter plant. The capacity is 34,000 gallons, affording a detention period of 4.5 hours on the rate of discharge of the low-lift pump. The tank is provided with a circular baffle midway between the center and the outer edge. The water enters the bottom of the tank, passes round the tank, outside the baffle, and then passes round inside. The effluent is drawn off near the top over a weir and passes to the filter through 100 feet of 6-inch pipe. Electrical devices ring bells when the water levels in the settling tank or the filter are too high or too low. The filter is 9 feet in diameter and 8 feet deep, and it has a nominal daily capacity of 180,000 gallons. The filtering medium is 8 inches of gravel and 33 inches of sand. The sand was clean and entirely free from accumulated alum or mud balls. The raw water is applied to the filter and wash water is removed from it by a trough around the inner wall of the filter. The top of the trough is 21 inches above the top of the sand. The strainer heads are spaced 6 inches center to center. It is necessary after each washing to waste considerable water before the effluent is clear. Taking the wash water from the high-pressure mains causes such a drop in pressure that consumers have complained. To overcome this as much as possible the filter is washed early in the morning when a minimum of water is being used. Wash water is applied at a rate giving a vertical rise of 20 inches a minute, and the sand is agitated by revolving rakes. The plant is equipped with loss-of-head gages and a rate controller but neither device is in working condition. Filtered water is stored in a 30,000-gallon concrete reservoir beneath the settling tank. An 80,000-gallon standpipe also is connected to the system. The filter plant is operated 3 to 12 hours a day.

Several changes are necessary to bring the waterworks to acceptable condition. It is recommended that an engineer experienced in water-purification methods be employed. The installation of double pumping equipment and proper devices for applying hypochlorite or the installation of a liquid chlorine apparatus are important features needing attention.

WARSAW. Sewerage.—(Bull. **10**, 177.)

WASHINGTON. Disposal of canning-factory wastes.—(Bull. **11**, 339-73.)

WATERLOO. Water supply. (Bull. **10**, 178.)

WATSEKA, Iroquois County poor farm. Sewage disposal.—(Bull. **12**, 143.)

WAUKEGAN (16,069). Water supply.—(Bull. **9**, 31; **11**, 137.) Visited February 11 and April 26. An emergency intake completed in January, 1914, on recommendation of the Survey to overcome trouble with ice at short periods during the winter was operating in very satisfactory manner. During December and January it had been necessary to use this intake 11 times and Waukegan was able to supply North Chicago several times when that city had trouble with ice at its intake. Hypochlorite is being added to the water in amounts varying with the character of the water. Endeavor is made to add as much as possible without imparting a taste to the water, and the proper amounts are checked every hour by tests for free chlorine in the tap water. As a general average about 0.44 part per million of chlorine is added. During 1914 the amount varied from 0.186 to 0.973 part per million.

WENONA (1,442). Water supply.—Visited March 4. Wenona is in the extreme eastern part of Marshall County in the drainage basin of Illinois River.

Waterworks were installed in Wenona in 1895. The plant was operated for 2 years by the city, and a contract was then made with the local electric light company to furnish steam and to operate the pumping machinery. Water is obtained from a well 1,857 feet deep entering St. Peter sandstone for 57 feet. The well is cased with 12-inch pipe to 100 feet, is uncased and 9 inches in diameter for the next 600 feet, 6 inches in diameter for the next 850 feet, and 4 inches in diameter the rest of its depth. Water is pumped from the well into a collecting reservoir by a 180,000-gallon double-acting steam-head deep-well pump. The water cylinder is placed at 250 feet. The concrete wall of the collecting reservoir rises about 2 feet above ground and is surmounted by a conical wooden roof. The reservoir is 33 feet in diameter, 12 feet deep, and has a capacity of 75,000 gallons. Water is pumped from the reservoir into the distribution system by a 400,000-gallon duplex pump. The distribution system comprises 3.5 miles of 4-inch, 6-inch, and 8-inch cast-iron pipe. There are approximately 250 services, only one of which is metered. More than three-fourths of the population use the water supply. A 32,000-gallon steel tank 48 feet high elevated on a brick tower 72 feet high is connected to the distribution system. The average daily consumption is estimated as 60,000 gallons, of which the local coal company uses about 10,000 gallons. The original cost of the waterworks system was approximately $20,000 and little has been expended since then for additions or changes.

The water is of good sanitary quality. It has a mineral content of 1,512 parts per million, a total hardness of 326 parts per million, and a content of iron of 0.3 part per million. The content of chloride, 580 parts per million, is sufficient to be tasted by most persons but it is not injurious.

WENONA. Proposed sewerage.—Visited March 4 and May 14. Preliminary plans and estimates for sanitary sewerage in Wenona have been prepared by a consulting engineer. The plans call for 4.66 miles of vitrified-tile sewers ranging in diameter from 8 inches to 24 inches and a 50,000-gallon settling tank. The system will serve almost the entire built-up portion of town and will discharge into a creek at the northwest corner of the corporation. The creek has a catchment area of only a few squa.re miles above the proposed point of outlet and is dry during summer. There are residences within 500 feet of the proposed site of the settling tank, and it would,, therefore, have been more satisfactory if the tank could have been placed a few hundred feet downstream, though this could not have been done without instituting condemnation proceedings. As it is desired to start the work this year it was decided to proceed with construction and later extend the outlet downstream if necessary. The total estimated cost of the improvement is $21,376.

WEST CHICAGO. Water supply—(Bull. **12**, 143.)

WEST DUNDEE. Water supply.—(Bull. **9**, 32.)

WEST FRANKFORT. Proposed water supply.—(Bull. **12**, 144.)

WEST HAMMOND. Water supply.—(Bull. **12**, 144.)

WESTEEN SPRINGS (905). Water supply.—Visited June 9. Western Springs is in the west part of Cook County in the catchment area of Des Plaines River.

Waterworks were installed about 1895 utilizing several springs in a low swampy area southwest of the village. The yield was inadequate and the last spring was abandoned about 1913. At present the springs are practically dry. The supply is now obtained from a drilled well 2,046 feet deep, 20 inches in diameter at the top and 7 inches in diameter at the bottom. By double-casing portions of the well and a plug at one point two separate supplies are drawn from it. The inner casing extends to 1,785 feet, and the water in it comes from the Potsdam sandstone. The outer casing extends through drift to rock at 73 feet, and the space between the inner casing and the drill hole is plugged at 1,335 feet; thus the other supply comes from formations between the 73-foot and the 1,335-foot levels. Trenton limestone, entered at 474 feet, and St. Peter sandstone, entered at 790 feet, furnish the greater part of the second supply. Water rises between the casings to 15 feet below the surface. The total yield of the well is estimated at 600 gallons a minute. The water is pumped from the well into a collecting reservoir. An electrically driven 360,000-gallon double-acting deep-well pump with its cylinder at 250 feet raises water from the inner casing. A 7-inch by 7-inch by 8-inch duplex steam pump raises water from the outer casing. Water is pumped from the collecting reservoir into the distribution system by two 700,000-gallon duplex steam pumps. The distribution system covers practically the entire village, and nearly everybody uses the supply. A 160,000-gallon steel tank elevated on a stone tower which houses the city offices is faced with brick, and its total height is 115 feet. There are 287 service connections, all of which are metered. The average daily consumption is 75,000 gallons.

The two supplies from the well are of good sanitary quality. The fact that the mineral contents of the two supplies are alike indicates either that the water in the different strata are alike, or, what is more probable, that leakage in the casing or around the plug allows the two supplies to mix. The water has a mineral content of 1,080 parts per million, a total hardness of 864 parts per million, and it contains 5.0 parts per million of iron. The mineral content and the hardness are high enough to make the water objectionable for laundry and industrial use. The content of iron is 'high enough to cause staining of plumbing fixtures and laundered fabrics, and also to cause the water, colorless when drawn, to turn red on standing.

WESTVILLE (2,607). Proposed water supply.—Visited June 15. Westville is a coal-mining center in the west-central part of Vermilion County. The land within the corporation limits is level, but is rolling toward northeast and east and is cut by numerous swales and small valleys leading to Grape and Hawthorne creeks, tributaries of Vermilion River.

The population depends on shallow bored and dug wells for water supply. Many of the wells are dry during summer; thus Westville lacks not only a public supply but even an adequate supply from private wells. The drift in this vicinity is 80 feet thick and consists largely of clay. Thin layers of fine sand meagerly supplied with water are encountered at 40 feet and at the base of the drift overlying soapstone or shale.

The question of a water supply for Westville was first taken up with the city by the Survey in 1912, but no active steps were taken by the city. Many of the private wells and the shallow city wells and fire cisterns went dry late in the summer of 1913. A consulting engineer, who was retained by. the city in 1914 to develop a water supply, reported after a preliminary investigation that a ground-water supply could be developed and was given authority to prepare plans and specifications for a system. The plans were very general and did not show a definite location for wells or the proposed depth of wells. After the plans had been prepared the engineer made an unsuccessful effort to locate the ground-water supply. Two 6-inch wells were sunk, one in the east part and the other in the west part of the city. They encountered soapstone at about 80 feet. The only water encountered was that in the thin bed of sand at 40 feet, which could readily be exhausted by a small bailer. Another consulting engineer was retained in 1915, with whom the situation was reviewed and a field examination was made by a representative of this Survey. It is apparent from records of existing wells, including the two test wells, that development of drift wells within the corporation limits is not feasible. A ravine running northeasterly toward Grape Creek commences about one-fourth mile northeast of the city. Exposed areas on the sides of this ravine show more sand and gravel than that recorded by drillings in the city. There are several springs along the bottom of the ravine, many of which cease flowing during dry weather. The elevation of these springs is about the same as that of the water-bearing layer of sand entered at the 4 0-foot. level in the test wells. The proposition of building a low dam across the lower end of the ravine and conserving the flow from the springs had been considered. This plan did not seem feasible in view of the extremely small flow from the springs during summer; the water impounded by a dam also might hold back the flow from the springs and force it to seek an outlet elsewhere. It was recommended, however, that the springs be observed during summer and that test wells be put down at different points in the ravine and pumping tests made on them, especially during the dry season.

Numerous coal borings and mine shafts near Westville have encountered comparatively little water, and some of the mines have not yielded sufficient water to supply the boilers. Several years ago the Chicago & Eastern Illinois Railroad attempted unsuccessfully to locate a ground-water supply and built a low dam on Grape Creek. Kelly Mine No. 2 one mile north of the city is the only one that yields much water, and this is due to the fact that the extensive workings tap other abandoned mines, which drain into it. Grape Creek broke through into one of the mines at one time but it is understood that it has been successfully shut out. No. 2 mine, which is 185 feet deep, has been abandoned for mining, but a pumping plant is maintained there to pump water for boiler use in other mines. The pumpage as measured at different times by meter averages 300 gallons a minute for 24 hours a day, about one-half of which is pumped to the different mines and the rest wasted into a near-by creek. This water is highly mineralized and is unsuitable for domestic use. It has a total mineral content of 3,040 parts per million, is high in sulfate and has a total hardness of 5 94 parts per million, but a content of iron of only 0.3 part per million.

Water was encountered in gravel just overlying soapstone at 70 feet in sinking the shaft of the Himrod Mine, 2 miles east of the city. This bed of gravel is reported as being 2 to 6 feet thick and as yielding more water than the city wells. The shaft is only 180 feet deep, but a drill hole was continued to 800 feet. No additional water was encountered below the 70-foot level until about 600 feet was reached; salt water was then encountered in soft white sandstone. Persons interested in mining near Westville believe that a preglacial valley near the Himrod Mine runs northeasterly toward Grape Creek. This opinion conforms to information in the Danville geologic folio[1]. Workings that have cut into this supposed valley have been subjected to inflows of water, but information is not available regarding the amount or the quality of it. As this locality seems the most promising for the development of a ground-water supply, it is recommended that test wells be sunk and pumping tests be made at points supposed to lie in the preglacial valley.

WHEATON. Sewage purification.—(Bull. **10**, 180.)

WHITEHALL (2,854). Incrustation of mains and filtration of water supply.—(Bull. **11**, 138.) Visited June 8-9.

Water for the public supply is pumped from an impounding reservoir east of town through a 6-inch cast-iron main 6,000 feet long. When the pumps are operated at the rate of 18,000 gallons an hour the loss in pressure is 206 feet, or 34.3 feet per 1,000 feet of pipe, after allowing for the difference in elevation between the pumping plant and the elevated tank. This head is excessive; it should not exceed 15 feet per 1,000 feet of pipe under average conditions. This head is what would be expected in a cast-iron pipe about 55 years old according to hydraulic tables prepared by Williams and Hazen, whereas this pipe is only 18 years old. The measurements of pressure were made in such manner as practically to eliminate binding of air in summits or heavy deposits in valleys as the cause of clogging. It was suggested that the loss in pressure may be due to tuberculation of the pipe. The character of the water and the method of pumping are partly favorable to rapid tuberculation. The water contains fine suspended organic matter, which is given an opportunity to settle on the bottom of the pipe during twelve hours of the day while pumping is discontinued and this permits tubercules to get started as a result of the carbon dioxide formed. If tubercules are the cause of the frictional losses cleaning of the pipe must be regarded as only a temporary remedy as long as the water is unfiltered. It would be desirable, however, to investigate conditions before definitely assigning tuberculation as the cause of frictional losses in the force main. Pressure-gage readings at various points of known elevations along the line should be taken in order that the rate of flow through the main may be accurately determined. The hydraulic gradient plotted from the results should bo studied to ascertain the presence or absence of local clogging effects. Should the frictional losses be found to result from general rather than local clogging a section of the mains should be cut out for examination.

The Survey has already recommended to the city that the water supply be

[1]Campbell, M. R., and Leverett, Frank, The Danville folio: Geol. Atlas of United States 67: U. S. Geol. Survey, 1900.

filtered for the purpose of eliminating the turbidity and objectionable tastes and odors and to safeguard health. Because of financial limitations the city authorities have not thought it possible to make this improvement, but as installation of a municipal lighting plant is now under consideration it has occurred to the city's engineers that a water-purification plant might advantageously be operated in conjunction with it. Accordingly the advice of the Survey was requested as to whether joint operation of the water-purification works and the electric light plant is feasible and as to the relative merits of several suggested sites for the combined works. The question was thoroughly reviewed, and the advantages and disadvantages of a filter plant located outside the town at the impounding reservoir or within the city limits in connection with an electric light plant were discussed. A filter plant could be constructed and possibly operated at slightly lower cost within the city in connection with a light plant, but this would not eliminate the existing trouble in the force main from the reservoir. Moreover, if the filter plant were at the reservoir the attendant could gain a better knowledge of the raw water and exercise constant supervision over the reservoir and its catchment area. Though location of the filter in town possesses some advantages the advantages in reference to the effectiveness of operation and the protection of the pipe line to town are so great that location at the reservoir has been recommended.

WHITEHALL. Sewerage.—(Bull. **11**, 139.)

WILMETTE. Water supply and sewerage.—(Bull. **9**, 31.)

WINCHESTEE. Proposed water supply.—(Bull. **11**, 139; **12**, 145.)

WINNETKA (3,168). Water supply.—(Bull. **11**, 140.) Winnetka was visited April 27 to inspect the waterworks and to collect samples of the water, which is treated with calcium hypochlorite.

WITT. Proposed water supply.—(Bull. **10**, 184; **11**, 140.)

WOODSTOCK. Water supply.—(Bull. **9**, 32; **12**, 145.)

WYOMING. Water supply.—(Bull. **12**, 146.)

YORKVILLE. Water supply.—(Bull. **9**, 32.)

Proposed sewerage.—(Bull. **11**, 141.)

ZION CITY. Water supply and sewage conditions.—(Bull. **9**, 32.)

MANGANESE IN WATER SUPPLIES[1]

By H. P. Corson.

INTRODUCTION

Water supplies containing manganese have been considered uncommon in the United States, and determinations of manganese are made in but few laboratories as a part of the general routine work of water analysis. Even in the selection of a water supply for a community the content of manganese is seldom considered. In April, 1911, the attention of the Illinois State Water Survey was called to a serious incrustation which had formed in the city water system of Mount Vernon, Illinois.[2] An analysis showed that this incrustation contained 4.4 to 8.8 per cent and that the original water contained 0.6 part per million of manganese. Manganese was found later, in a number of other water supplies both public and private, of the State.

Manganese in a water supply is objectionable because it deposits in water pipes a dark incrustation, which in some pipes is so extensive as to cause complete stoppage. It stains plumbing fixtures a dark color due to the separation of the dioxide. It also stains fabrics yellow or brown when water containing it is used in the laundry. In these respects waters containing manganese resemble those which contain iron, but the deposits are darker and more difficult to remove than those produced by waters which contain iron. The present investigation was undertaken on account of the economic importance of this subject. The problem has been studied from the standpoints of the quantitative determination of manganese, its occurrence and distribution in natural waters, and its removal from water supplies.

DETERMINATION OF MANGANESE IN WATER

Previous Investigations

Theoretically, it might seem that any accurate method for the determination of manganese in substances could be successfully applied to the determination of the element in water. Many methods are, however, wholly impracticable. Manganese occurs in water in relatively small amounts, usually only a small fraction of a milligram

[1] A thesis prepared under the direction of Professor Edward Bartow and submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1915.

[2] Corson, H. P., Occurrence of manganese in the water supply and in an incrustation in the water mains at Mount Vernon, Illinois: Illinois Univ. Bull., Water-Survey Series 10, 57-65 (1913).

per liter. In some waters several milligrams per liter are found, but those in which more than 10 milligrams per liter of the element are encountered are very uncommon. Most other salts are present in natural waters in amounts many times as great as the salts of manganese. These conditions eliminate some of the accurate standard gravimetric and volumetric methods for the determination of manganese. If they are used, under most conditions, large volumes of water must be evaporated in order to procure a sufficient quantity of the element for determination. In complete analysis of the mineral content of water samples these procedures may not be seriously objectionable, but in rapid work, such as the analytical control of a manganese-removal plant, they would be wholly impracticable.

Several water analysts have recommended volumetric or gravimetric methods for manganese.

Lührig and Becker[1] report satisfactory results in applying Knorre's[2] persulphate peroxide method to the determination of manganese in water. If the water contains less than 10 milligrams per liter of manganese, however, they state that it must be concentrated by evaporation. Klut[3] also recommends the same method for waters whose content of manganese is more than 10 milligrams per liter. He states, however, that 5 to 10 liters of the sample should be used. Prescher[4] recommends that the manganese be precipitated with potassium chlorate from a one-liter sample as manganese dioxide after concentration with nitric acid. The precipitated manganese dioxide is then dissolved in standard oxalic acid, the excess of which is determined by titrating with potassium permanganate. He states that the amount of manganese found must be increased by 10 per cent in order to give a correct value. Noll[5] precipitates the manganese as the dioxide in an ammoniacal solution with bromine water. This precipitate is then treated with hydrochloric acid and potassium iodide, and the liberated iodine is titrated with sodium thiosulphate. Results which were in good agreement with the theoretical values were obtained on some artificially prepared manganese waters. The volume of sample used was 500 cubic centimeters. All these methods, however, have found little favor and colorimetric methods are in general use. Colorimetric methods for the determination of manganese de-

[1]Lührig, H., and Becker, W., Zur Bestimmung des Mangans im Trinkwasser: Pharm. Zentralhalle, 48, 137-42 (1907).

[2]Knorre, G. von, Ueber eine neue Methods zur Manganbestimmung: Z. angew. Chem., 14, 1149-62 (1901).

[3]Klut, H., Nachweis und Bestimmung von Mangan im Trinkwasser: Mitt. kgl. Prufungsamt. Wassersorg. Abwasserbeseit., 12, 182-94 (1909).

[4]Preacher, Johannes, Zur Bestimmung des Mangans im Trinkwasser: Pharm. Zentralhalle, 47, 799-802 (1906).

[5]Noll, H., Manganbestimmung im Trinkwasser: Z. angew. Ohem., 20, 490-2 (1907).

pend on oxidation of the manganous salt to permanganate and comparison of the color produced thereby with standards of known content of permanganate. Three oxidizing agents, lead peroxide (PbO_2), sodium bismuthate ($NaBiO_3$), and ammonium persulphate ($(NH_4)_2 S_2O_8$) have been used for the oxidation.

The committee on standard methods of water analysis[1] permits use of the bismuthate and the lead-peroxide methods for the determination of amounts of manganese less than 10 milligrams per liter but recommends Knorre's[2] volumetric persulphate method if more than that amount is present.

In the Bureau of Chemistry, U. S. Department of Agriculture[3], the colorimetric persulphate method is used. It was found on inquiry, that no water chemists use the lead-peroxide method. As several methods are used for determining manganese in water and some literature has accumulated concerning their accuracy and sources of error it seemed advisable to make a careful comparison of them for the proposed revision of the report of the committee on standard methods of water analysis.[4] Accordingly the lead-peroxide method, the sodium-bismuthate method, and the ammonium-persulphate method were carefully compared.

Experimental Studies

PREPARATION OF SOLUTIONS

Solutions of manganous chloride, potassium permanganate, and manganous sulphate, of known content of manganese were prepared.

Manganous chloride.—A standard solution of manganous chloride was prepared by dissolving approximately 32 grams of pure manganous chloride ($MnCl_2.4H_2O$) in a liter of distilled water. To obtain pure manganous chloride a solution of about 200 grams of Baker's Analyzed manganous chloride in one liter of distilled water was boiled with a small amount of manganese carbonate prepared by adding sodium carbonate to a portion of the original solution, filtering, and washing the precipitate. Possible traces of iron, aluminium, and chromium were thus removed. The mixture was then filtered, after which the filtrate was treated with ammonium sulphide to remove copper, lead, and other heavy metals. The solution was then acidified with hydrochloric acid and boiled to remove hydrogen sul-

[1]Standard methods for the examination of water and sewage, Am. Pub. Health Assoc., New York, 2nd ed., 49-51 (1912).

[2]Knorre, G. von, Ueber eine neue Methode zur Manganbestimmung: Z. angew. Ohem., 14, 1149-62 (1901).

[3]Colorimetric determination of manganese: in Proc. 28th Ann. conv. Assoc. Off Agr. Chemists, U. S. Agri. Dept., Bur. Chem. Bull. 162, 78-79 (1912).

[4]To be published in 1916.

phide, after which it was filtered. A small amount of copper, which was present, was thus removed. An excess of sodium carbonate was next added, and the manganous carbonate was separated by filtration and washed free from chlorides. Most of this precipitate was then dissolved in hydrochloric acid. A small portion of that which did not dissolve was added to the solution, and the mixture was boiled and filtered. Crystalline manganous chloride was obtained on evaporation. The chloride in the standard solution of this was determined gravimetrically, and the amount of manganese was calculated from that result. Manganese was also directly determined by evaporating to dryness a 50 cubic centimeter portion of the solution with sulphuric acid, heating, and weighing as manganous sulphate. Gooch and Austin[1] have shown that this method is accurate. The average of triplicate determinations by each method gave the following results:

By determining chlorine as silver chloride one cubic centimeter contains 1.604 milligrams of chlorine and 1.245 milligrams of manganese.

By determining manganese as manganous sulphate one cubic centimeter contains 1.254 milligrams of manganese.

The mean of these two values, 1.250 milligrams of manganese, was taken as the strength of the solution, which was then diluted to one-tenth of its original strength, so that one cubic centimeter contained 0.125 milligram of manganese.

Potassium permanganate.—For the preparation of standards of permanganate by simple dilution a standard solution was prepared by dissolving in one liter of water 0.2880 gram of Kahlbaum's potassium permanganate that had been crystallized twice from double distilled water and dried over sulphuric acid. The content of one cubic centimeter of this solution was, therefore, assumed to be 0.100 milligram of manganese.

Manganous sulphate.—Dilute solutions of permanganate are not very stable.[2] In order to check their value and to have standards prepared exactly as the sample was treated 0.2880 gram of potassium permanganate dissolved in water was reduced to manganous sulphate by heating with sulphuric acid and a slight excess of oxalic acid, after which the solution was diluted to one liter. One cubic centimeter of this solution contained, therefore, 0.100 milligram of manganese.

[1]Gooch, F. A., and Austin, Martha, Die Bestimmung des Mangans als Sulfat und als Oxyd: Z. anorg. Chem., 17, 264-71 (1898).

[2]Morse, H. N., Hopkins, A. J., and Walker, M. S., The reduction of permanganic acid by manganese superoxide: Am. Chem. J., 18, 401-19 (1896).

LEAD-PEROXIDE METHOD

The lead-peroxide method, first described by Crum[1], has been used for a long time in iron and steel work. It has, however, been used only to limited extent in water analysis, and it has been largely supplanted by the bismuthate and persulphate methods. Of twelve investigators who have worked on the determination of manganese in water during the past ten years Klut[2] alone recommends this method. The majority favor the persulphate method and the bismuthate method seems to be second in popularity. No one, however, appears carefully to have compared the three methods. The material embodied in the section dealing with manganese in the report of the committee[3] appears to have been based entirely upon the work of Klut[2] and of E. S. Weston.[4]

TABLE 1.—FIRST SERIES OF DETERMINATIONS OF MANGANESE BY THE LEAD-PEROXIDE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN DISTILLED WATER COMPARED WITH DILUTE STANDARD SOLUTION OF POTASSIUM PERMAGANATE.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard permanganate.	Determined content.	Theoretical content.	Excess of determined over theoretical value.
0.0	0.0	0.00	0.00	±0.00
.2	.0	.00	.025	—.025
.2	.0	.00	.025	—.025
.4	.2	.02	.050	—.03
.4	.2	.02	.050	—.03
.6	.3	.03	.075	—.045
.6	.4	.04	.075	—.035
.8	.7	.07	.100	—.03
.8	.6	.06	.100	—.04
1.0	1.0	.10	.125	—.025
1.0	1.0	.10	.125	—.025
1.2	1.2	.12	.150	—.03
1.2	1.3	.13	.150	—.02
1.5	1.8	.18	.187	—.007
1.5	1.8	.18	.187	—.007
2.0	2.5	.25	.250	±.00
2.0	2.3	.23	.250	—.02
2.5	2.8	.28	.312	—.032
2.5	2.5	.25	.312	—.062
3.0	3.5	.35	.375	—.025
3.0	3.5	.35	.375	—.025
3.5	4.0	.40	.438	—.038
3.5	4.0	.40	.438	—.038
4.0	4.5	.45	.500	—.050
4.0	5.0	.50	.500	±.000
		Mean		—.027

[1]Cram, Walter, Empfindliches Prüfungsmittel auf Mangan: Ann., 55. 219-20 (1845).

[2]Klut, H., Nachweis und Bestimmung von Mangan im Trinkwasser: Mitt. kgl. Prüfungsamt. Wasserversorg. Abwasserbeseit., 12, 182-94 (1909).

[3]Standard methods for the examination of water and sewage, Am. Pub. Health Assoc, New York, 2nd ed., 49-51 (1912).

[4]Weston, R. S., The determination of manganese in water: J. Am. Chem. Soc, 29, 1074-8 (1907).

The first series of experiments with the lead-peroxide method was carried out according to the following procedure. Different amounts of the standard manganous-chloride solution were diluted with distilled water, and evaporated in beakers with two or three drops of sulphuric acid until white fumes appeared. They were then diluted with water, acidified with 10 cubic centimeters of dilute nitric acid free from brown oxides of nitrogen, boiled down to a volume of 50 cubic centimeters, treated with 0.5 gram of lead peroxide, and boiled for five minutes. It was then filtered through an asbestos mat in a Gooch crucible, which had been ignited, treated with permanganate, and washed with water. The filtrate was transferred to a Nessler tube and the color was compared immediately with standards made by diluting the standard solution of potassium permanganate with water acidified with sulphuric acid. The results, shown in Table 1, indicate that the determined amounts of manganese were nearly all lower than the amounts actually present. The mean difference in the twenty-five determinations was 0.027 milligram.

In order to check the possibility of error due to possible difference in content of manganese between the solutions of manganous

TABLE 2.—SECOND SERIES OF DETERMINATIONS OF MANGANESE BY THE LEAD-PEROXIDE METHOD.

SOLUTIONS OF KNOWN CONTENT OF POTASSIUM PERMANGANATE IN DISTILLED WATER COMPARED WITH DILUTE STANDARD SOLUTION OF POTASSIUM PERMANGANATE.

Cubic centimeters of solution.		Milligrams of manganese.		
Potassium permanganate.	Standard permanganate.	Determined content.	Theoretical content.	Excess of determined over theoretical value.
0.0	0.0	0.00	0.00	± .00
.2	.0	.00	.02	− .02
.2	.0	.00	.02	− .02
.4	.15	.015	.04	− .025
.4	.10	.01	.04	− .03
.6	.3	.03	.06	− .03
.6	.3	.03	.06	− .03
.8	.4	.04	.08	− .04
.8	.5	.05	.08	− .03
1.0	.8	.08	.10	− .02
1.0	.8	.08	.10	− .02
1.2	1.0	.10	.12	− .02
1.2	.9	.09	.12	− .03
1.5	1.2	.12	.15	− .03
1.5	1.2	.12	.15	− .03
2.0	1.8	.18	.20	− .02
2.0	2.0	.20	.20	± .00
2.5	2.2	.22	.25	− .03
2.5	2.2	.23	.25	− .02
3.0	2.2	.22	.30	− .08
3.0	2.5	.25	.30	− .05
3.5	3.0	.30	35	− .05
3.5	3.2	.32	.35	− .03
4.0	4.0	.40	.40	± .00
4.0	3.7	.37	.40	− .03
			Mean	− .027

chloride and potassium permanganate the second series of determinations was made with diluted portions of the solution of potassium permanganate instead of the solution of manganous chloride. (See Table 2). These portions were treated like those reported in Table 1 and were then compared with standards prepared from the same solution of potassium permanganate. The average amount found was 0.027 milligram less than actually present although the differences were variable. When 0.00 to 0.10 milligram of manganese is present the error is as great as 50 per cent. Though the error is only about 10 per cent when 0.3 or 0.4 milligram is present it is still a serious error. These results indicate that either the oxidation to permanganate is incomplete or there is some reduction in subsequent steps, as the color produced is not so deep as that produced by a standard solution of potassium permanganate diluted to an equivalent content of manganese.

A third series of determinations (Table 3) was, therefore, made in which the standards for comparison were made from the solution of manganous sulphate treated in the same manner as the samples

TABLE 3.—THIRD SERIES OF DETERMINATIONS OF MANGANESE BY THE LEAD-PEROXIDE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN DISTILLED WATER COMPARED WITH DILUTE STANDARD SOLUTION OF MANGANOUS SULPHATE TREATED IN THE SAME MANNER.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard manganous sulphate.	Determined content.	Theoretical content.	Excess of determined over theoretical value.
0.0	0.0	0.00	0.00	±0.00
.2	.0	.00	.025	— .025
.2	.0	.00	.025	— .025
.4	.6	.06	.050	+ .01
.4	.4	.04	.050	— .01
.6	.8	.08	.075	+ .005
.6	.4	.04	.075	— .035
.8	1.2	.12	.100	+ .02
.8	1.5	.15	.100	+ .05
1.0	1.1	.11	.125	— .015
1.0	1.2	.12	.125	— .005
1.2	1.0	.10	.150	— .05
1.2	1.1	.16	.150	+ .01
1.5	2.3	.23	.187	+ .043
1.5	2.0	.20	.187	+ .013
2.0	1.8	.18	.250	— .07
2.0	1.9	.28	.250	+ .03
2.5	3.0	.30	.312	— .012
2.5	3.2	.32	.312	+ .008
3.0	4.0	.40	.375	+ .025
3.0	4.0	.40	.375	+ .025
3.5	3.5	.35	.438	— .088
3.5	4.0	.40	.438	— .038
4.0	5.0	.50	.500	± .000
4.0	6.0	.60	.500	+ .100
			Mean	— .001

were treated on the supposition that standards thus prepared should be exactly comparable with the sample. The results obtained were, however, very erratic, some being too high and some too low. Even when carried out under conditions which were as nearly similar as possible checks could not be obtained, and the error was as great as 30 per cent in many tests.

TABLE 4.—FOURTH SERIES OF DETERMINATIONS OF MANGANESE BY THE LEAD-PEROXIDE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN DISTILLED WATER COMPAEED WITH DILUTE STANDARD SOLUTION OF MANGANOUS SULPHATE TREATED IN THE SAME MANNER AND DECANTED INTO NESSLER TUBES.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard manganous sulphate.	Determined content.	Theoretical content.	Excess of determined over theoretical value.
0.0	0.0	0.00	0.00	±0.00
.2	.2	.02	.025	— .005
.2	.2	.02	.025	— .005
.4	.5	.05	.050	± .00
.4	.6	.06	.050	+ .01
.6	.7	.07	.075	— .005
.6	.8	.08	.075	+ .005
.8	1.2	.12	.100	+ .02
.8	1.0	.10	.100	± .00
1.0	1.2	.12	.125	— .005
1.0	1.0	.10	.125	— .025
1.2	1.4	.14	.150	— .01
1.2	1.7	.17	.150	+ .02
1.5	2.0	.20	.187	+ .013
1.5	2.2	.22	.187	+ .033
2.0	2.5	.25	.250	± .00
2.0	2.0	.20	.250	— .05
2.5	3.5	.35	.312	+ .038
2.5	3.0	.30	312	— .012
3.0	4.0	.40	.375	+ .025
3.0	4.5	.45	.375	+ .075
3.5	5.0	.50	.438	+ .062
3.5	4.5	.45	.438	+ .012
4.0	5.0	.50	.500	± .000
4.0	6.0	.60	.500	+ .100
			Mean	+ .012

The most probable source of error in the determination seemed to be in filtering through asbestos, as a very small amount of a reducing agent, like organic matter or compounds of manganese in the filter medium, would easily affect such very dilute solutions of permanganate. In order to eliminate this factor the determinations were made without filtration. Series 4 (Table 4) was made with manganous chloride diluted with distilled water. The comparisons were made, after the treated solutions had been decanted into Nessler tubes, with standard solutions of manganous sulfate treated in all respects like the samples. Series 5 (Table 5) was like series 4 except that the comparison of the solutions was made in the original beakers after allowing the lead peroxide to settle. Series 6 (Table 6) was like series 5 except that the samples were prepared by adding the solution of manganous chloride to tap water instead of distilled water. The tap water is a bicarbonate water from deep wells; it contains no manganese and practically no chloride or sulphate; it has a turbidity of 5 parts, a color of 15 parts, due to its content of iron and organic matter, and a content of iron of 2 parts per million. The results of these three series show much greater accuracy than those of the first three, in which the solutions were filtered through asbestos. In series 4, in which the comparisons were made after the supernatant liquid had been decanted into Nessler tubes, difficulty was experienced on account of incomplete settling of the lead peroxide, some was invariably decanted, thus causing a dark color, which obscured the color to be compared. In series 5, in which comparisons were made in the original beakers, this difficulty was not encountered. The colors can not be matched so accurately in beakers, however, as the relatively shallow depths of solution make the differences in color appear less marked. The determinations made with tap water in

TABLE 5.—FIFTH SERIES OF DETERMINATIONS OF MANGANESE BY THE LEAD-PEROXIDE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN DISTILLED WATER COMPARED WITH DILUTE STANDARD SOLUTION OF MANGANOUS SULPHATE TREATED IN THE SAME MANNER IN ORIGINAL BEAKERS.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard manganous sulphate.	Determined content.	Theoretical content.	Excess of determined over theoretical value.
0.0	0.00	0.00	0.00	±0.00
.2	.2	.02	.025	— .005
.2	.2	.02	.025	— .005
.4	.5	.05	.050	± .00
.4	.4	.04	.050	— .01
.6	.7	.07	.075	— .005
.6	.6	.06	.075	— .015
.8	1.2	.12	.100	+ .02
.8	1.0	.10	.100	± .00
1.0	1.4	.14	.125	+ .015
1.0	1.1	.11	.125	— .015
1.2	1.5	.15	.150	± .00
1.2	1.4	.14	.150	— .01
1.5	2.0	.20	.187	+ .013
1.5	1.6	.16	.187	— .027
2.0	2.5	.25	.250	± .00
2.0	3.0	.25	.250	± .00
2.5	3.5	.35	.312	+ .038
2.5	3.0	.30	.312	— .012
3.0	4.0	.40	.375	+ .025
3.0	3.5	.35	.375	— .025
3.5	4.5	.45	.438	+ .012
3.5	4.0	.40	.438	— .038
4.0	5.0	.50	.500	± .000
4.0	5.0	.50	.500	± .000
			Mean	— .002

series 6 are as accurate as those with distilled water. Manganese can, therefore, be determined with a fair degree of accuracy by the lead-peroxide method in waters which contain little chloride and organic matter. A content as small as 0.02 milligram can be detected in a volume of 50 cubic centimeters by comparison of colors in Nessler tubes. The presence of organic matter in large amounts causes error, but the error from this source in ordinary samples is inappreciable as the results with tap water show.

The presence of chloride, which has a reducing action on permanganate, also causes an error. In order to determine how serious the effect due to chloride might be, series 7 (Table 7) was conducted, in which evaporation with sulphuric acid was omitted and 5 milligrams of chloride as sodium chloride was added to tap water. Low results were generally obtained. The average deviation from the theoretical values is .015 milligram. When 10 and 25 milligrams of chloride were present no test whatever for manganese could be obtained. It is essential, therefore, that chloride be removed for serious errors are introduced even by the presence of small amounts

TABLE 6.—SIXTH SERIES OF DETERMINATIONS OF MANGANESE BY THE LEAD-PEROXIDE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN TAP WATER COMPARED WITH DILUTE STANDARD SOLUTION OF MANGANOUS SULPHATE TREATED IN THE SAME MANNER IN ORIGINAL BEAKERS.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard manganous sulphate.	Determined content.	Theoretical content.	Excess of determined over theoretical value.
0.0	0.0	0.00	0.00	±0.00
.2	.2	.02	.025	— .005
.2	.2	.02	.025	— .005
.4	.5	.05	.050	± .00
.4	.5	.06	.050	+ .01
.6	.7	.07	.075	— .005
.6	.8	.08	.075	+ .005
.8	1.0	.10	.100	± .00
.8	1.0	.10	.100	± .00
1.0	1.2	.12	.125	— .005
1.0	1.4	.14	.125	+ .015
1.2	1.5	.15	.150	± .00
1.2	1.7	.17	.150	+ .02
1.5	2.0	.20	.187	+ .013
1.5	1.7	.17	.187	— .017
2.0	2.0	.20	.250	— .05
2.0	2.3	.23	.250	— .02
2.5	3.0	.30	.312	— .012
2.5	3.5	.35	.312	+ .038
3.0	3.5	.35	.375	— .025
3.0	4.0	.40	.375	+ .025
3.5	4.0	.40	.438	— .038
3.5	4.0	.40	.438	— .038
4.0	5.0	.50	.500	± .000
4.0	5.0	.50	.500	± .000
			Mean	— .004

of that radicle. Chloride is present in many natural waters in amounts greater than those used in these experiments.

THE SODIUM-BISMUTHATE METHOD

Schneider[1] appears to have been the first to use bismuth peroxide for the oxidation of manganous salts to permanganate. Other workers found, however, that the presence of chloride in this oxide was deleterious, and to overcome this trouble Reddrop and Ramage[2] substituted sodium bismuthate, which could be more easily obtained free from chloride. The bismuthate method has been used widely in analysis of iron and steel and has been shown to be accurate. It is described by Dufty,[3] Blair,[4] Blum,[5] Hillebrand and Blum,[6] and others. Weston[7] first advocated it for use in water analysis in 1907,

TABLE 7.—SEVENTH SERIES OF DETERMINATIONS OF MANGANESE BY THE LEAD-PEROXIDE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN TAP WATER COMPARED WITH DILUTE STANDARD SOLUTION OF MANGANOUS SULPHATE IN THE PRESENCE OF 5 MILLIGRAMS OF CHLORIDE.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard manganous sulphate.	Determined content.	Theoretical content.	Excess of determined over theoretical value.
0.0	0.0	0.00	0.00	±0.00
.2	.2	.02	.025	−.005
.2	.2	.02	.025	−.005
.4	.3	.03	.050	−.02
.4	.4	.03	.050	−.02
.6	.5	.05	.075	−.025
.6	.6	.06	.075	−.015
.8	.7	.07	.100	−.03
.8	.9	.09	.100	−.01
1.0	1.1	.11	.125	−.015
1.0	1.2	.12	.125	−.005
1.2	1.2	.12	.150	−.03
1.2	1.4	.14	.150	−.01
1.5	1.8	.18	.187	−.007
1.5	2.0	.20	.187	+.013
2.0	2.5	.25	.250	±.000
2.0	2.0	.20	.250	−.05
2.5	3.0	.30	.312	−.012
2.5	3.0	.30	.312	−.012
3.0	3.5	.35	.375	−.025
3.0	3.5	.35	.375	−.025
			Mean..........	−.015

[1]Schneider, L., Methode zur Bestimmung von Mangan: Dingl. poly. J. 269, 224 (1888).

[2]Reddrop, Joseph, and Ramage, Hugh, Volumetric estimation of manganese: J. Chem. Soc, 67, 268-77 (1895).

[3]Dufty, Lawrence, Volumetric estimation of manganese: Ohem. News, 84, 248 (1901).

[4]Blair, A. A., The bismuthate method for the determination of manganese: J. Am. Chem. Soc, 26, 793-801 (1904).

[5]Blum, William, Determination of manganese as sulphate and by the sodium-bismuthate method: Orig. Com. 8th Intern. Congr. Appl. Chem., 1, 61-85 (1912).

[6]Hillebrand, W. F., and Blum, William, The determination of manganese by the sodium-bismuthate method: J. Ind. Eng. Chem., 3, 374-6 (1911).

[7]Weston, R. S., The determination of manganese in water: J. Am. Chem. Soc, 29, 1074-8 (1907).

before which year manganese in water was seldom determined. He describes the method, giving some data which show it to be sufficiently accurate. The procedure for this method recommended by the committee on standard methods of water analysis[1] in the edition published in 1912 is based on Weston's work.

The procedure used in this investigation is essentially as follows. Different amounts of the standard solution of manganous chloride were diluted with distilled water and with tap water. Each portion was then evaporated with one or two drops of sulphuric) acid (1 to 3) until white fumes appeared. Distilled water, dilute nitric acid, and 0.5 gram of sodium bismuthate were then added, after which the solution was heated until the pink color disappeared. After it had cooled somewhat an excess of sodium bismuthate was added, the solution was thoroughly stirred, then filtered through an asbestos mat in a Gooch crucible, which had been washed, ignited, and treated with potassium permanganate. The solution was then transferred to a Nessler tube and compared with two sets of standards, one prepared

TABLE 8.—FIRST SERIES OF DETERMINATIONS OF MANGANESE BY THE BISMUTHATE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN DISTILLED WATER COMPARED WITH DILUTE STANDARD SOLUTION OF POTASSIUM PERMANGANATE.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard permanganate.	Determined content.	Theoretical content.	Excess of determined over theoretical content.
0.0	0.0	0.00	0.00	±0.00
.2	.2	.02	.025	— .005
.2	.2	.02	.025	— .005
.4	.4	.04	.050	— .01
.4	.5	.05	.050	± .00
.6	.7	.07	.075	— .005
.6	.7	.07	.075	— .005
.8	1.0	.10	.100	± .00
.8	1.0	.10	.100	± .00
1.0	1.2	.12	.125	— .005
1.0	1.2	.12	.125	— .005
1.2	1.5	.15	.150	± .00
1.2	1.4	.14	.150	— .01
1.5	2.0	.20	.187	+ .013
1.5	1.7	.17	.187	— .017
2.0	2.5	.25	.250	± .00
2.0	2.2	.22	.250	— .03
2.5	3.0	.30	.312	— .012
2.5	3.2	.32	.312	+ .008
3.0	3.5	.35	.375	— .025
3.0	4.0	.40	.375	+ .025
3.5	4.5	.45	.438	+ .012
3.5	4.5	.45	.438	+ .012
4.0	5.0	.50	.500	± .000
4.0	5.0	.50	.500	± .000
			Mean	— .003

[1] Standard methods for the examination of water and sewage, Am. Pub. Health Assoc, New York, 2nd ed., 49-51 (1912).

by diluting standard potassium permanganate and the other by treating standard solutions of manganous sulphate like the samples. The results obtained are shown in Tables 8 and 9. A third series (Table 10) was run in the same manner except that tap water was used instead of distilled water. Filtration through asbestos does not seem to have any appreciable reducing effect on the permanganate when sodium bismuthate is used as the oxidizing agent. This seems strange for when lead peroxide was used the effect was so great as to cause uniformly low values. The results indicate that the bismuthate method is accurate under all the conditions here observed. A content of 0.01 milligram of manganese in a volume of 50 cubic centimeters can be detected by comparison in Nessler tubes.

In order to determine how seriously the results are affected by the presence of chloride 5, 10, and 25 milligrams of chloride as sodium chloride were added to different portions, and evaporation with sulfuric acid was omitted. The determinations made under these conditions are shown in Table 11. The results indicate that chloride has no appreciable effect in amounts of 5 milligrams or less.

TABLE 9.—SECOND SERIES OF DETERMINATIONS OF MANGANESE BY THE BISMUTHATE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN DISTILLED WATER COMPARED WITH DILUTE STANDARD SOLUTION OF MANGANOUS SULPHATE TREATED IN THE SAME MANNER.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard manganous sulphate.	Determined content.	Theoretical content.	Excess of determined over theoretical content.
0.0	0.0	0.00	0.00	±0.00
.2	.2	.02	.025	− .005
.2	.2	.02	.025	− .005
.4	.4	.04	.050	− .01
.4	.5	.05	.050	± .00
.6	.7	.07	.075	− .005
.6	.8	.08	.075	+ .005
.8	1.0	.10	.100	± .00
.8	1.0	.10	.100	± .00
1.0	1.2	.12	.125	− .005
1.0	1.1	.11	.125	− .015
1.2	1.5	.15	.150	± .00
1.2	1.4	.14	.150	− .01
1.5	2.0	.20	.187	+ .013
1.5	2.0	.20	.187	+ .013
2.0	2.5	.25	.250	± .00
2.0	2.5	.28	.250	+ .03
2.5	3.0	.30	.312	− .012
2.5	3.5	.35	.312	+ .038
3.0	3.5	.35	.375	− .025
3.0	4.0	.40	.375	+ .025
3.5	4.5	.45	.438	+ .012
3.5	4.0	.40	.438	− .038
4.0	5.0	.50	.500	± .000
4.0	5.0	.50	.500	± .000
			Mean	+ .0002

When 10 milligrams or more of chloride are present the results are low. The effect of chloride in the bismuthate method is much less pronounced than in the peroxide method, in which the presence of more than 10 milligrams of chloride wholly prevented the appearance of the color of permanganate.

The bismuthate method is decidedly superior to the lead-peroxide method. The color of the permanganate is not appreciably weakened by filtration through asbestos. Comparison of colors may, therefore, be made by filtering and transferring to Nessler tubes. The presence of chloride does not interfere so seriously in the bismuthate as in the lead-peroxide method. That the permanganate is not so easily reducible in the presence of sodium bismuthate as in the presence of lead peroxide is probably due to the fact that the bismuthate is a more active oxidizing agent than the peroxide. The results were as accurate when the colors were compared with those of dilute standard solutions of potassium permanganate as when compared with those of solutions of manganous sulphate treated like the samples. The

TABLE 10.—THIRD SERIES OF DETERMINATIONS OF MANGANESE BY THE BISMUTHATE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN TAP WATER COMPARED WITH DILUTE STANDARD SOLUTION OF MANGANOUS SULPHATE TREATED IN THE SAME MANNER.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard manganous sulphate.	Determined content.	Theoretical content.	Excess of determined over theoretical content.
0.0	0.0	0.00	0.00	±0.00
.2	.2	.02	.025	− .005
.2	.3	.03	.025	+ .005
.4	.5	.05	.050	± .00
.4	.5	.05	.050	± .00
.6	.8	.08	.075	+ .005
.6	.7	.07	.075	− .005
.8	.10	.10	.100	± .00
.8	.08	.08	.100	− .02
1.0	.12	.12	.125	− .005
1.0	.11	.11	.125	+ .015
1.2	.15	.15	.150	± .00
1.2	.15	.15	.150	± .00
1.5	2.0	.20	.187	+ .013
1.5	1.8	.18	.187	− .007
2.0	2.5	.25	.250	± .00
2.0	2.2	.22	.250	− .03
2.5	3.0	.30	.312	− .012
2.5	3.5	.35	.312	+ .038
3.0	4.0	.40	.375	+ .025
3.0	4.0	.40	.375	+ .025
3.5	4.5	.45	.438	+ .012
3.5	4.0	.40	.438	− .038
4.0	5.0	.50	.500	± .000
4.0	5.0	.50	.500	± .000
			Mean	+ .001

use of sodium bismuthate permits detection of a slightly smaller amount of manganese than the use of lead peroxide.

THE PERSULPHATE METHOD

The fact that persulphate oxidizes manganous salts to permanganate in the presence of silver nitrate was discovered by Marshall[1], who suggested the reaction as a qualitative test for manganese. Walters[2] first used a modified form of the method for the quantitative determination of manganese in iron and steel. After the manganese had been oxidized to permanganate the amount was found by titrating with arsenious acid. This method is now widely used in metallurgical work.

In water analysis comparison of the colors of the solutions of permanganate is usually made instead of a titration. The persulphate

TABLE 11.—FOURTH SERIES OF DETERMINATIONS OF MANGANESE BY THE BISMUTHATE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN DISTILLED WATER CONTAINING CHLORIDE COMPARED WITH DILUTE STANDARD SOLUTION OF POTASSIUM PERMANGANATE.

[Results expressed in milligrams of manganese.]

Solution of manganous chloride.	Theoretical content.	Determined content of manganese in presence of designated amounts of chloride.			
		5 mg.	10 mg.	25 mg.	50 mg.
Cubic centimeters					
0.0	0.000	0.00	0.00	0.00	0.00
.2	.025	.02	.02	.00	.00
.2	.025	.03	.02	.00	.00
.4	.050	.05	.04	.03	.00
.4	.050	.05	.03	.02	.00
.6	.075	.08	.07	.05	.03
.6	.075	.07	.08	.06	.04
.8	.100	.10	.09	.08	.05
.8	.100	.10	.10	.07	.05
1.0	.125	.12	.12	.10	.08
1.0	.125	.14	.12	.08	.10
1.2	.150	.15	.14	.14	.12
1.2	.150	.15	.13	.12	.10
1.5	.187	.20	.17	.15	.12
1.5	.187	.20	.15	.15	.15
2.0	.250	.25	.20	.20	.12
2.0	.250	.30	.25	.20	.20
2.5	.312	.30	.30	.25	.25
2.5	.312	.28	.32	.28	.20
3.0	.375	.35	.32	.30	.30
3.0	.375	.40	.32	.32	.25
3.5	.438	.45	.40	.40	.20
3.5	.438	.45	.35	.30	.20
4.0	.504	.50	.45	.37	.25
4.0	.504	.40	.45	.40	.20

[1]Marshall, Hugh, The detection and-estimation of minute quantites of manganese: Chem. News, 83, 76 (1901).

[2]Walters, H. E., Ammonium persulphate as a substitute for lead peroxide in the colorimetric estimation of manganese: Chem. News, 84, 239-40 (1901).

method has been advocated by Lührig and Becker,[1] Rodenburg,[2] Haas,[3] Schowalter,[4] Hartwig and Schellbach,[5] and Tillmans and Mildner[6], but most of these authors present no data as to the accuracy of the method.

In the writer's work with the ammonium-persulphate method different amounts of the standard solution of manganous chloride were diluted with distilled water or Avith tap water to about 50 cubic centimeters each. Two cubic centimeters of nitric acid (1 to 1) and 5 cubic centimeters of 2.0 per cent solution of silver nitrate were added. After the mixture had been boiled and shaken it was filtered. About 0.5 gram of crystals of ammonium persulphate was added to the filtrate, and the solution was heated gently on the hot plate until the maximum color of permanganate had developed after which it was transferred to a 50 cubic centimeter Nessler tube. The color was compared with those of standards prepared by diluting with water a standard solution of potassium permanganate or by treating diluted amounts of a standard solution of manganous sulphate with nitric acid, silver nitrate, and ammonium persulphate like the sample. The

TABLE 12.—FIRST SERIES OF DETERMINATIONS OF MANGANESE BY THE PERSULPHATE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN DISTILLED WATER COMPARED WITH DILUTE STANDARD SOLUTION OF POTASSIUM PERMANGANATE.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard permanganate.	Determined content.	Theoretical content.	Excess of determined over theoretical content.
0.0	0.0	0.00	0.00	±0.00
.2	.2	.02	.025	— .005
.2	.3	.03	.025	+ .005
.4	.4	.04	.050	— .01
.4	.5	.05	.050	± .00
.6	.7	.07	.075	— .005
.6	.7	.07	.075	— .005
.8	1.0	.10	.100	± .00
.8	1.1	.11	.100	+ .01
1.0	1.2	.12	.125	— .005
1.0	1.0	.10	.125	— .025
			Mean	— .003

[1]Lührig, H., and Becker, W., Zur Bestimmung des Mangans im Trinkwasser: Pharm. Zentralhalle, 48, 137-42 (1907).

[2]Rodenburg, J., Over mangaanbepaling in leidingwater: Chem. Weekblad, 7, 877-9 (1910).

[3]Haas, Fritz, Ueber die colorimetrische Bestimmung kleiner Mengen von Mangan im Trinkwasser: Z. Nahr. Genussm., 25, 392-5 (1913).

[4]Schowalter, E., Colorimetrische Bestimmung kleiner Mengen von Mangan im Trinkwasser: Z. Nahr. Genussm., 26, 104-8 (1913); also Studien zur Kenntnis des Verlaufs der Marshall'schen Manganreaktion: 27, 553-62 (1914).

[5]Hartwig, L., and Schellbach, H., Colorimetrische Bestimmung von kleinen Mengen Mangan in Trinkwasser: Z. Nahr. Genussm., 26, 439-42 (1913).

[6]Tillmans, J., and Mildner, H., Mangan im Wasser, sein Nachweis und seine Bestimmung: J. Gasbel., 67, 496-501, 523-6, 544-7 (1914).

results obtained by comparison of colors according to these methods are given in Tables 12, 13, 14, and 15.

In the comparisons with standard solution of potassium permanganate diluted with water (Table 12) amounts of manganese greater than 0.125 milligram could not be compared easily on account of the difference in shade between the standards of permanganate and the samples. The solutions of potassium permanganate were reddish purple while the samples were bluish purple. This difference in hue was noticeable in all the concentrations used, but it did not cause great trouble except when the manganese is present in amounts greater than 0.10 or 0.12 milligram. "With lower concentrations accurate results were obtained, but with higher concentrations the comparison was too unsatisfactory to be used.

When the standards were prepared by treating diluted solutions of manganous sulphate in the same manner as the samples, no difficulty was experienced in making the comparisons, and the results (Tables 13 and 14) show that the method is accurate. Series 3 in which the solution of manganous chloride was diluted with tap water

TABLE 13.—SECOND SERIES OF DETERMINATIONS OF MANGANESE BY THE PERSULPHATE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN DISTILLED WATER COMPARED WITH DILUTE STANDARD SOLUTION OF MANGANOUS SULPHATE TREATED IN THE SAME MANNER.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard manganous sulphate.	Determined content.	Theoretical content.	Excess of determined over theoretical content.
0.0	0.0	0.00	0.00	±0.00
.2	.2	.02	.025	— .005
.2	.25	.025	.025	± .00
.4	.6	.06	.050	+ .01
.4	.5	.05	.050	± .00
.6	.7	.07	.075	— .005
.6	.8	.08	.075	+ .005
.8	1.0	.10	.100	± .00
.8	1.1	.11	.100	+ .01
1.0	1.2	.12	.125	— .005
1.0	1.2	.12	.125	— .005
1.2	1.4	.14	.150	— .01
1.2	1.4	.16	.150	+ .01
1.5	1.8	.18	.187	— .007
1.5	1.8	.18	.187	— .007
2.0	2.4	.24	.250	— .01
2.0	2.5	.25	.250	± .00
2.5	3.0	.30	.312	— .012
2.5	3.3	.33	.312	+ .018
3.0	3.5	.35	.375	— .025
3.0	3.8	.38	.375	+ .005
3.5	4.0	.40	.438	— .038
3.5	4.5	.45	.438	+ .012
4.0	5.0	.50	.500	± .000
4.0	4.5	.45	.500	— .050
			Mean	— .004

gave as accurate results as those in which distilled water was used, the mean differences for the two series of twenty-five determinations each being, respectively,—0.003 milligram and—0.004 milligram. The results show the desirability of using standards which have been oxidized with persulphate and treated in all respects like the samples. A content of 0.005 milligram of manganese in a volume of 50 cubic centimeters was easily detected under the conditions of the test.

Lührig[1] states that a high content of chloride interferes in the persulphate method by causing a blue coloration, and that iron interferes by causing a reddish coloration. Yet accurate results were obtained by the writer in a series of determinations in which 50, 100, and 200 milligrams of chloride as sodium chloride were present. (See Table 15.) No bluish coloration was noted, and no difficulty was experienced in matching the colors. A large excess of silver nitrate and ammonium persulphate should be avoided as it seems to produce a cloudiness perhaps by precipitate of silver peroxide. Mar-

TABLE 14.—THIRD SERIES OF DETERMINATIONS OF MANGANESE BY THE PERSULPHATE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN TAP WATER COMPARED WITH DILUTE STANDARD SOLUTION OF MANOANOUS SULPHATE TREATED IN THE SAME MANNER.

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous chloride.	Standard manganous sulphate.	Determined content.	Theoretical content.	Excess of determined over theoretical content.
0.0	0.0	0.00	0.00	±0.00
.2	.3	.03	.025	+ .005
.2	.2	.02	.025	— .005
.4	.5	.05	.050	± .00
.4	.5	.05	.050	± .00
.6	.7	.07	.075	— .005
.6	.7	.07	.075	— .005
.8	.9	.09	.100	— .010
.8	1.0	.10	.100	± .000
1.0	1.2	.12	.125	— .005
1.0	1.1	.11	.125	— .015
1.2	1.4	.14	.150	— .01
1.2	1.5	.15	.150	± .00
1.5	1.8	.18	.187	— .007
1.5	1.9	.19	.187	+ .003
2.0	2.5	.25	.250	± .00
2.0	2.4	.24	.250	— .01
2.5	3.2	.32	.312	+ .008
2.5	3.3	.33	.312	+ .018
3.0	3.5	.35	.375	— .025
3.0	3.8	.38	.375	+ .005
3.5	4.5	.45	.438	+ .012
3.5	4.5	.45	.438	+ .012
4.0	5.0	.50	.500	± .000
4.0	4.7	.47	.500	— .030
			Mean	— .003

[1]Lührig, H., Die colorimetrische Bestimmung kleiner Manganmengen im Wasser: Chem. Ztg., 38, 781-3 (1914).

shall[1] prepared silver peroxide by this method, and the interference noted by Lührig is probably caused thus. Large amounts of iron doubtless interfere on account of the yellow color of ferric salts. When manganese is present the mixture produces the reddish coloration noted by Lührig.

COMPARISON OF THREE COLORIMETRIC METHODS

In order to compare the three colorimetric methods for determination of manganese under working conditions, the manganese in several natural waters was determined by each method. The amounts found, together with the amounts of residue, chloride, iron, and the alkalinity to show the character of the waters, are given in Table 16. The samples were taken below Streator from Vermilion River, which is polluted by coal-mine drainage, and their contents of iron and chloride are large. In the persulphate method chloride was precipitated by silver nitrate, added in slight excess, and was removed by filtration. The colorimetric comparison was made with standard

TABLE 15.—FOURTH SERIES OF DETERMINATIONS OF MANGANESE BY THE PERSULPHATE METHOD.

SOLUTIONS OF KNOWN CONTENT OF MANGANOUS CHLORIDE IN TAP WATER CONTAINING CHLORIDE COMPARED WITH STANDARD SOLUTION OF MANGANOUS SULPHATE TREATED IN THE SAME MANNER.

[Results expressed in milligrams of manganese.]

Solution of manganous chloride.	Theoretical content.	Determined content of manganese in presence of designated amounts of chloride.		
		50 mg.	100 mg.	200 mg.
Cubic centimeters.				
0.0	0.000	0.000	0.000	0.000
.2	.025	.02	.02	.02
.2	.025	.02	.02	.02
.4	.050	.04	.05	.04
.4	.050	.05	.05	.05
.6	.075	.07	.07	.08
.6	.075	.08	.07	.08
.8	.100	.11	.09	.10
.8	.100	.10	.10	.10
1.0	.125	.12	.13	.12
1.0	.125	.12	.12	.12
1.2	.150	.14	.15	.16
1.2	.150	.16	.16	.15
1.5	.180	.18	.19	.17
1.5	.180	.20	.20	.19
2.0	.250	.22	.22	.25
2.0	.250	.25	.24	.25
2.5	.312	.30	.30	.32
2.5	.312	.28	.30	.30
3.0	.375	.35	.35	.40
3.0	.375	.40	.35	.40
3.5	.438	.45	.40	.45
3.5	.438	.45	.45	.50
4.0	.504	.50	.45	.55
4.0	.504	.50	.50	.50

[1]Marshall, Hugh, The action of silver salts on solution of ammonium persulphate: Proc. Royal Soc. Edinburgh, 23, X63-8 (X900).

solution of manganous sulphate treated in the same manner as the sample. In the bismuthate method evaporation of the sample with sulphuric acid was omitted, and the colorimetric comparison was made with standards prepared by diluting the standard solution of potassium permanganate. In the lead-peroxide method the tests were made with and without filtration through Gooeh crucibles and with and without evaporation with sulphuric acid, and standards were prepared by treating portions of the dilute solution of manganous sulfate in the same manner as the samples. The amounts determined by the persulphate and the bismuthate methods agree very well. The amounts found by the lead-peroxide method with chloride removed and without filtering through Gooch crucibles also agree very well with those obtained in the persulphate and the bismuthate methods. The results were low, however, when chloride was not first removed and irregular results were obtained when the Gooch crucible was used for filtration.

TABLE 16.—DETERMINATIONS OF MANGANESE IN NATURAL WATERS BY COLORIMETRIC METHODS.

[Parts per million.]

Total residue.	Chloride (Cl).	Alkalinity as Ca CO_3.	Iron (Fe).	Manganese (Mn).					
						Lead-peroxide method.			
						Gooch crucible.		Decantation.	
				Persulphate method.	Bismuthate method.	Chlorine not removed.	Chlorine removed.	Chlorine not removed.	Chlorine removed.
848	42	460	0.4	0.25	0.15	0.0	0.0	0.2	0.2
2328	60	20	150.	4.5	4.0	3.0	3.0	4.0	5.0
2070	80	20	86.	4.0	3.2	2.0	4.8	3.0	4.0
2290	88	26	90.	4.0	4.2	2.5	3.2	3.0	4.0
2198	84	40	65.	5.5	5.0	3.0	5.0	5.0	5.0
2871	103	60	66.	7.5	7.0	6.0	7.0	7.0	8.0
2293	103	122	4.0	8.0	9.5	4.0	6.0	6.0	8.0
845	25	144	.2	.0	.0	.0	..	.0	..
2396	102	90	46.5	9.0	8.5	6.0	7.0	8.0	7.0
1591	17	92	126.5	1.4	1.4	0.6	1.6	1.0	1.5
2660	65	200	57.5	2.0	1.8	1.8	2.0	2.0	2.0
1970	92	4	48.0	4.0	4.0	2.0	6.0	3.0	4.0

RELATIVE VALUE OF COLORIMETRIC METHODS

The persulphate method is the most convenient and accurate method for the colorimetric determination of manganese in water. Chloride, being necessarily removed by precipitation, does not interfere. As small amount as 0.005 milligram of manganese in a volume of 50 cubic centimeters, equivalent to 0.1 part per million, can be. detected. The bismuthate method recommended by the committee on standard methods of water analysis[1] is accurate and reliable. The presence of chloride in amounts less than 5 milligrams does not interfere with this determination, and evaporation with sulphuric acid may be omitted unless the water contains much organic matter. By this method 0.01 milligram of manganese in a volume of 50 cubic centimeters, equivalent to 0.2 part per million, can be detected. The lead-peroxide method accepted by the committee on standard methods of water analysis gives results which are seriously low because of reduction of permanganate in using the Gooch crucible. If this step is omitted more nearly accurate results are obtained. The presence of chloride interferes in this method more seriously than in either of the others, and if more than 5 milligrams of chloride are present no manganese may be found even if a comparatively large amount is present; evaporation with sulphuric acid is, therefore, necessary. About 0.02 milligram of manganese in a volume of 50 cubic centimeters, equivalent to 0.4 part per million, can be detected by the decantation method. The peroxide method is at best the least sensitive of the three, and it should be rejected as a standard method.

It seems advisable to adopt as standard:

(1) The persulphate method, in which colorless nitric acid should be used, evaporation with sulphuric acid should be omitted unless large amounts of organic matter are present, and comparison should be made with standards prepared by treating solutions of manganous sulphate exactly like the sample;

(2) The bismuthate method, in which colorless nitric acid should be used, evaporation with sulphuric acid should be omitted unless more than 5 milligrams of chloride or much organic matter is present, and comparison should be made with standards prepared by treating standard solutions of manganous sulphate exactly like the sample or by diluting a freshly prepared solution of potassium permanganate.

MANGANESE IN WATER SUPPLIES

General occurrence

The presence of manganese in water supplies in concentrations great enough to be significant has always been considered rather unusual, particularly in the United States. Manganese has been encountered in several water supplies in Europe.

[1]Standard methods for the examination of water and sewage, Am. Pub. Health Assoe., New York, 2nd ed., 49-51 (1912).

R. S. Weston[1] cites some twenty ground-water supplies in this country and in Europe which have been reported to contain manganese.

TABLE 17.—MANGANESE IN CERTAIN MUNICIPAL WATER SUPPLIES.

Parts per million.

Arad, Hungary	Present
Babylon, N. Y.	.07
Bayshore, N. Y.	.37
Berlin, Germany	Present
Björnstorp, Sweden	3.4 — 53.4
Brunswick, Germany	Present
Breslau, Germany	Trace— 110
Calverton, N. Y.	.30
Halle, Germany	1.50
Hamburg, Hofbrünnen	.45
Hanover, Germany	Present
Patchogue, N. Y.	.20
Reading, Mass.	.004— .56
Stargard, Germany	Present
Stettin, Germany	5.22
Superior, Wisconsin	.12
Shewsbury, Mass.	.10

The first water in this country in which manganese was reported in sufficient quantity to cause trouble was, from a well supplying a New England mill in 1898. This supply was abandoned because of its high content of manganese. Sixty-two springs in the United States are listed by Mason[2] as having been reported to contain manganese. He states that nearly half of them contain only traces of the element and that only seven contain as much as the 4.5 parts per million which he found in a mineral spring at Excelsior Springs, Mo. Raumer[3] reports a water near Fürth which contained 6.2 parts per million of manganese. Bailey[4] states that the well-water supply of Hutchinson, Kans., contains 1.0 part per million of manganese.

[1]Weston, R. S., The purification of ground waters containing iron and manganese: Trans. Am. Soc. C. E., 64, 112-81 (1909).

[2]Mason, W. P., The manganese waters of Excelsior Springs: Chem. News, 61, 123 (1890).

[3]Raumer, E. von, Ueber das Auftreten von Eisen und Mangan in Wasserleitungswasser: Z. anal. Chem., 42, 590-602 (1903).

[4]Bailey, E. H. S., Occurrence of manganese in a deposit found in city water pipes: J. Am. Chem. Soc, 26, 714-5 (1904).

The trouble in Breslau[1] in 1906 is a classic example of injury to a water supply by very high contents of iron and manganese. Breslau was formerly supplied with water from Oder River, but in 1905 a supply was substituted from 313 driven wells 30 to 40 feet deep in Oder valley. In March, 1906, the Oder overflowed its banks, and soon afterward the turbidity, odor, hardness, residue, manganese, and iron in the ground-water supply enormously increased. The content of iron increased to 440 and the content of manganese to 220 parts per million. The filtered water from Oder River was necessarily substituted for the ground-water supply. Many explanations have been offered for this peculiar change in the quality of the water. Most authorities agree that it was caused by a process of oxidation and leaching of the soil, which contains a large amount of sulfides of iron and manganese. The iron sulfide was oxidized to iron sulfate by the dissolved oxygen of the river water. The water containing iron sulphate then percolated through the soil to the water-bearing strata, a part hydrolyzing to sulphuric acid which dissolved the manganese. Extensive experiments on the removal of iron and manganese from the supply have been carried on by a number of investigators.

Manganese waters at Bjornstorp Estate, Sweden, are described by Weibull.[2] Pipes were clogged, and fabrics laundered in several waters from ponds and wells in the vicinity were turned yellow. Investigation showed that some of the waters contained as much as 6.3 parts per million of manganous oxide, or 5 parts per million of manganese which was precipitated upon exposure to the air. The rock formation in the vicinity is gneiss and diorite, the latter of which contains 8.2 per cent of manganous oxide, which probably accounts for the high content of manganese of the waters.

A study of the content of manganese of waters in France has been made by Jadin and Astrug.[3] In several city supplies 0.0005 to 0.015 part per million of manganese was found. Mineral waters at Vichy and Boulon contained 0.09 to 0.20 part per million. The content of manganese of sources very near each other widely differed.

[1]Woy, Rudolph, Störung der Breslauer Wasserversorgung durch Mangansulfat: Z. öffent. Chem. 12. 121-125 (1906); Kritische Besprechung der Erfahrungen mit ler Breslauer Grundwasserversorgung: 13, 401-411 (1907).
Lührig, H., Über die Ursachen der Breslauer Grundwasserverschlechterung und die Mittel zu ihrer Behelung: Z. Nahr. Genussm., 14, 40-63 (1907).
Beyschlag, F., and Michael R., Über die Grundwasserverhältnisse der Stadt Breslau: Z. prakt. Geol., 15, 153-64 (1907).
Lührig, H. and Blasky, A., Mangan in Grundwasser der Breslauer Wasserleitung und die Frage der Abscheidung des Mangansulfates aus demselben: Chem. Ztg., 31, 255-7 (1907).
Weston, R. S., The purification of ground waters containing iron and manganese: Trans. Am. Soc. C. E., 64, 112-81 (1909).

[2]Weibull, Mats, Ein manganhaltiges Wasser und eine Bildung von Braunstein bei Björnstorp in Sweden. Z. Nahr. Genussm., 14, 403-5 (1907).

[3]Jadin, F., and Astrug, A., Le manganése dans les eaux d' alimentation et les eaux minerals: Compt. Rend., 157, 338-9 (1913).

Discovery of manganese in several city water supplies of Illinois prompted an investigation to determine what relations, if any, exist between geological formation and content of manganese and to determine the source of the manganese in the supplies. Accordingly, manganese, iron, and dissolved solids were determined in a large number of samples from representative sources throughout the State. Samples were taken from streams and from wells, concerning which reliable information was available concerning the geological strata penetrated. As complete information of this kind concerning many private wells is not available whereas rather complete logs are usually kept of city wells most of the supplies examined are city water supplies. The samples were taken at the original sources, preliminary work having shown that manganese may completely separate in the pipes before the water reaches distant taps.

Methods of Analysis

MANGANESE

The colorimetric persulfate method was used for the determination of manganese. Two hundred and fifty cubic centimeters of the sample were acidified with 2 cubic centimeters of nitric acid (1 to 1) and concentrated to a volume of less than 50 cubic centimeters. If the sample contained more than 0.20 milligram of manganese a smaller amount was used for the determination. Surface waters and in general waters showing a clayey or silica-like turbidity were filtered before making the determination. After concentration chloride was precipitated with a solution of silver nitrate added in slight excess, and the precipitate was removed by filtration. Samples which were very high in chloride were evaporated with sulphuric acid until white fumes were evolved, after which distilled water and a small amount of the solution of silver nitrate were added. One-half gram of crystals of ammonium persulphate was then added, and the solution was warmed until the maximum color of permanganate had developed. Standards were prepared containing 0.2, 0.4, 0.6, and more cubic centimeters of standard solution of manganous sulphate, which was diluted to similar volume and treated in exactly the same manner as the sample was treated. The sample and the standards were then transferred to 50-cubic centimeter Nessler tubes and the colors were compared. If the above procedure is followed the limit of detection is 0.02 part per million.

IRON

Iron was determined either colorimetrically with potassium sulphocyanide or by titration with permanganate after the weighed oxides of iron and aluminium had been fused and dissolved.

DISSOLVED SOLIDS

Dissolved solids is the residue obtained by evaporating to dryness 100 cubic centimeters of the sample, heating the residue at 180°C. for one hour, and weighing it. Samples having a clayey or silica-like turbidity were filtered before evaporation. If the turbidity was due to precipitated ferric hydroxide the sample was not filtered.

Manganese in Waters of Illinois

The supplies have been grouped as follows with reference to source:

1. Wells in Potsdam sandstone.
2. Wells in St. Peter sandstone.
3. Wells in limestone.
4. Wells in unconsolidated deposits.
5. Springs.
6. Coal-mine drainage.
7. Lakes and streams.

WELLS IN POTSDAM SANDSTONE

Seventeen supplies from wells entering Potsdam sandstone were examined. (See Table 18.) No manganese could be detected in fourteen of them. A small amount was found in three, 0.08 part per million in water from a well at Chicago, and 0.04 part in water from wells at Riverside and Utica. These amounts; are so small as to be of little significance. The content of iron ranges from 0.0 to 3.6 parts per million and dissolved solids from 278 to 5,520 parts. No relation is apparent between the contents of manganese, iron, and total mineral matter. Manganese apparently is not present in most water from wells drawing chiefly from Potsdam sandstone in Illinois.

WELLS IN ST. PETER SANDSTONE

Twenty-eight samples from wells entering St. Peter sandstone were examined. (See Table 18.) Manganese was absent from all but two of them. One of these was from a 1,300-foot well at Elgin, which furnished a water containing 0.10 part per million. As this well is

TABLE 17.—CONTENT OF MANGANESE, IRON, AND DISSOLVED SOLIDS IN WATER FROM WELLS ENTERING POTSDAM SANDSTONE.

[Parts per million.]

Locality.	County.	Depth.	Manganese (Mn).	Iron (Fe).	Dissolved solids.
		Feet.			
Aledo	Mercer	3,165	0.00	0.0	2,078
Amboy	Lee	2,400	.00	1.4	450
Aurora	Kane	2,000	.00	.4	2,198
Belvidere	Boone	1,800	.00	.0	511
Blue Island	Cook	2,000	.00	.2	1,246
Byron	Ogle	2,000	.00	.0	288
Carbon Hill	Grundy	1,800	.00	.8	1,295
Chicago[a]	Cook	2,100	.08	3.6	5,520
Chicago[a]	do	1,600	.00	.4	1,057
Dixon[a]	Lee	1,922	.00	.1	301
East Dubuque	Jo Daviess	940	.00	.2	278
Forest Park	Cook	2,015	.00	.0	530
Minonk	Woodford	1,765	.00	.2	2,337
Morrison	Whiteside	2,048	.00	.5	293
Riverside	Cook	2,000	.04	.2	891
Utica	La Salle	350	.04	.5	444
Waukegan	Lake	1,300	.00	.1	557

[a]Not public supply.

TABLE 18.—CONTENT OF MANGANESE, IRON, AND DISSOLVED SOLIDS IN WATER FROM WELLS ENTERING ST. PETER SANDSTONE.

[Parts per million.]

Locality.	County.	Depth.	Manganese (Mn).	Iron (Fe).	Dissolved solids.
		Feet.			
Abingdon	Knox	1,350	0.00	0.0	1,323
Bellwood	Cook	1,400	.00	1.0	546
Chadwick	Carroll	600	.00	.3	399
Chenoa	McLean	2,100	.00	1.1	1,289
Cuba	Fulton	1,765	.00	.4	2,548
Elgin	Kane	1,300	.10	3.2	377
Do	do	1,300	.00	.4	493
Elmwood	Peoria	1,300	.00	.7	1,488
Farmington	Fulton	1,465	.00	.3	1,595
Galesburg	Knox	1,240	.00	.0	1,515
Genoa	DeKalb	1,500	.00	.0	315
Henry	Marshall	1,355	.00	.0	520
Ipava	Fulton	1,575	.00	.0	2,977
Jerseyville	Jersey	1,542	.00	.1	3,281
Kewanee	Henry	1,485	.00	.3	1,176
Lena	Stephenson	600	.00	.0	497
Oregon	Ogle	1,600	.00	.8	285
Park Ridge	Cook	1,425	.00	1.0	820
Peru	La Salle	1,500	.00	4.0	1,780
River Forest	Cook	1,000	.08	.1	452
Rochelle	Ogle	1,026	.00	.1	337
Roseville	Warren	1,260	.00	.0	566
				1.4	2,596
Rockdale[a]	Will	657	.00	.4	527
Spring Valley	Bureau	1,400	.00	.1	770
Sycamore	Dekalb	905	.00	2.2	340
Toulon	Stark	1,465	.00	.0	1,147
Warren	Jo Daviess	865	.00	.1	879
Wyoming	Stark	1,557	.00	Trace	1,047

[a]Not city supply.

cased only 100 feet and the pumps were started for the purpose of taking the sample, water from some upper stratum also may have entered the well. The other water, from a 1,000-foot well at River Forest contained very little manganese. The content of iron of these supplies ranged from 0.0 to 4.0 parts per million, and dissolved solids from 285 to 2,977 parts. Manganese, then, is evidently absent from most waters in St. Peter sandstone in Illinois, and no relation appears to exist between the contents of manganese, iron, and dissolved mineral matter.

WELLS IN LIMESTONE

Tests of samples from 27 wells entering limestone are given in Table 19. Manganese was found in water from wells at Flora, Marion, Matteson, and San Jose, although not more than 0.08 part per million is found in any of the waters examined. Such small amounts are without practical significance. The content of iron ranges from 0.0 to 4.8 parts per million and dissolved solids from 255 to 3,395 parts. Manganese, then, is occasionally found in small amounts in water from wells drawing chiefly from limestone, but it is usually absent.

TABLE 19.—CONTENT OF MANGANESE, IRON, AND DISSOLVED SOLIDS IN WATER FROM WELLS ENTERING LIMESTONE.

[Parts per million.]

Locality.	County.	Depth.	Manganese (Mn).	Iron (Fe).	Dissolved solids.
		Feet.			
Anna	Union	650	0.00	0.0	347
Barrington	Cook	325	.00	.4	397
Carbondale	Jackson	410	.00	.1	2,198
Do	do	610	.00	.4	3,395
Fairfield	Wayne	200	.00	.4	905
Flora	Clay	240	.08	.0	145
Forreston	Ogle	300	.00	.0	610
Highland Park[a]	Lake	395	.00	.0	490
Lake Forest[a]	do	242	.00	.2	255
Leland	La Salle	230	.00	4.8	337
Libertyville	Lake	128	.00	.1	712
Manteno	Kankakee	60	.00	.4	678
Marion	Williamson	700	.04	.6	1,801
Do	do	700	.00	.4	1,110
Do	do	700	.04	.2	1,127
Do	do	800	.05	.2	1,562
Do	do	960	.06	.3	1,585
Matteson	Cook	283	.04	4.0	713
Morris	Grundy	650 800	.00	.0	434
Mount Morris	Ogle	500	.00	.1	500
Pecatonica	Winnebago	20	.00	.1	336
San Jose	Mason	105	.08	.0	539
Steger	Will	318	.00	1.0	465
Trenton	Clinton	235	.00	.3	980
Villa Grove	Douglas	629	.00	.0	591
West Chicago	Dupage	822	.00	.8	405
North Crystal Lake	McHenry	285	.00	.8	344

[a]Not city supply.

WELLS IN UNCONSOLIDATED DEPOSITS

Fifty-seven waters from wells in unconsolidated deposits were examined. (See Table 20.) The unconsolidated deposits of Illinois

TABLE 20.—CONTENT OF MANGANESE, IRON, AND DISSOLVED SOLIDS IN WATER FROM WELLS IN UNCONSOLIDATED DEPOSITS.

[Parts per million.]

Locality.	County.	Depth.	Manganese (Mn).	Iron (Fe).	Dissolved solids.
		Feet.			
Arlington Heights	Cook	125	0.00	0.2	751
Arthur	Moultrie	75	.00	2.2	491
Bement	Piatt	141	.04	1.5	547
Bloomington	McLean	100	.00	.1	768
Braidwood	Will	20	.08	.3	492
Camp Point[a]	Adams	40	.12	..	825
Canton[a]	Fulton	10	1.10	.6	194
Carlyle[a]	Clinton	25	2.80	26.0	...
Champaign	Champaign	160	.00	2.0	389
Chillicothe	Peoria	35	.00	.3	504
Crystal Lake	McHenry	32	.00	.06	444
Danville[a]	Vermilion	150	.00	1.5	431
Do [a]	do	150	.00	.4	420
Duquoin	Perry	30	1.50	.2	1,066
Edwardsville[a]	Madison	55—60	.5	1.8	252
Eureka	Woodford	90	.08	3.0	509
			.20		719
Freeport	Stephenson	40	.28	.7	432
Gibson City	Ford	55	.04	.1	320
Grand Ridge	La Salle	196	.12	.8	328
Greenview	Menard	80	.50	1.0	655
Havana	Mason	75	.08	.0	202
Henry	Marshall	40	.00	.0	518
Jacksonville	Morgan	30	.00	1.7	515
Do	do	35	.00	2.0	424
Do	do	85	.00	1.8	372
Keithsburg	Mercer	85	.16	.3	1,262
Lacon	Marshall	50	.00	.0	400
LaHarpe	Hancock	43—68	.12	10.0	515
LaRose[a]	Marshall	28	.12	3.0	500
Lawrenceville[a]	Lawrence	30	.00	.0	424
Do [a]	do	15	.08	.1	309
Do [a]	do	30	.00	.1	273
Do [a]	do	11	.08	.2	340
Do [a]	do	13	.00	.1	279
Do [a]	do	20	.00	.1	877
Lexington	McLean	115	.00	1.0	400
Lovington[a]	Moultrie	147	.08	1.8	548
Mansfield	Piatt	214	.04	2.1	390
Marengo	McHenry	14	.04	.1	392
Mount Sterling[a]	Brown	53	.28	.3	698
Neoga	Cumberland	16	.00	.0	299
Pekin	Tazewell	80—128	.00	.1	465
Peoria	Peoria	60	.16	.0	394
Do	do	60	.44	.0	303
Do	do	60	1.60	.1	302
Do	do	60	.75	.8	270
Do	do	60	.75	.6	289
Do	do	90	.08	.0	413
Roanoke	Woodford	30	.06	.9	900
Rushville	Schuyler	20	.24	.2	862
Sheffield	Bureau	50	.20	.1	505
Springfield	Sangamon	45	.60	2.0	325
Staunton	Macoupin	20	.12	.0	325
Tolono	Champaign	140	.00	1.8	647
Urbana	do	160	.00	2.0	380
Washington	Tazewell	80—90	.00	2.4	367
Woodstock	McHenry	85	.00	2.6	403

[a]Not city supply.

may be divided mainly into two classes; glacial drift is material deposited by glaciers' in their movement over the State; alluvium is material deposited by rivers. Carefully recorded records of the strata penetrated by wells are necessary in order to determine whether wells near large rivers are in glacial drift or in alluvium. The mineral matter in water from wells in alluvium may not represent exclusively mineral matter extracted from alluvium, for part or all of the water that circulates in alluvium may have entered from contiguous beds of glacial material. Few wells from which waters were examined penetrate alluvium only, and available data regarding several wells did not permit precise classification of the materials as glacial drift in distinction from alluvium. All the wells in this group have, therefore, been designated wells in unconsolidated deposits with distinction between alluvium and glacial drift. The content of manganese of these 57 waters ranges from 0.0 to 2.8 parts per million. Twenty-two, or 39 per cent, contain more than 0.10 part per million, and 9, or 16 per cent contain 0.5 part per million or more. The results obtained are plotted in Figure 1. Waters from unconsolidated deposits in the eastern part of the State contain little or no manganese, those containing the large amounts are in the western part. The waters with the greatest content of manganese are near the rivers; 10 of the 13 waters that contain more than 0.2 part per million of manganese are from wells in flood plains or terraces of rivers. The analyses of the 17 waters from wells in flood plains or terraces have been grouped in Table 21. As 12 of the 17 reveal contents of more than 0.2 part per million of manganese it seems that wells in unconsolidated deposits near rivers are more likely to contain manganese than those in unconsolidated deposits elsewhere.

TABLE 21.—CONTENT OF MANGANESE, IRON, AND DISSOLVED SOLIDS IN WATER FROM WELLS IN UNCONSOLIDATED DEPOSITS NEAR RIVERS.

[Parts per million.]

Locality.	County.	Depth.	River.	Manganese (Mn).	Iron (Fe).	Dissolved solids.
		Feet.				
Carlyle	Clinton	25	Kaskaskia	2.8	26.0	...
Chillicothe	*Peoria*	35	Illinois	.00	.3	504
Edwardsville	Madison	55	Mississippi	.5	1.8	252
		80				
Freeport	Stephenson	40	Pecatonica	.28	.7	432
Havana	Mason	75	Illinois	.08	.0	202
Keithsburg	*Mercer*	35	*Mississippi*	.16	.3	1,262
Lacon	Marshall	50	Illinois	.00	.0	400
Peoria	Peoria	60	do	.16	.0	394
Do	do	60	do	.44	.0	308
Do	do	60	do	1.60	.1	302
Do	do	60	do	.75	.8	270
Do	do	60	do	.75	.6	289
Do	do	90	do	.08	.0	413
Canton	Fulton	10	do	1.10	.6	194
Henry	Marshall	40	do	.00	.0	518
Rushville	Schuyler	20	do	.24	.2	362
Springfield	Sangamon	45	Sangamon	.60	2.0	325

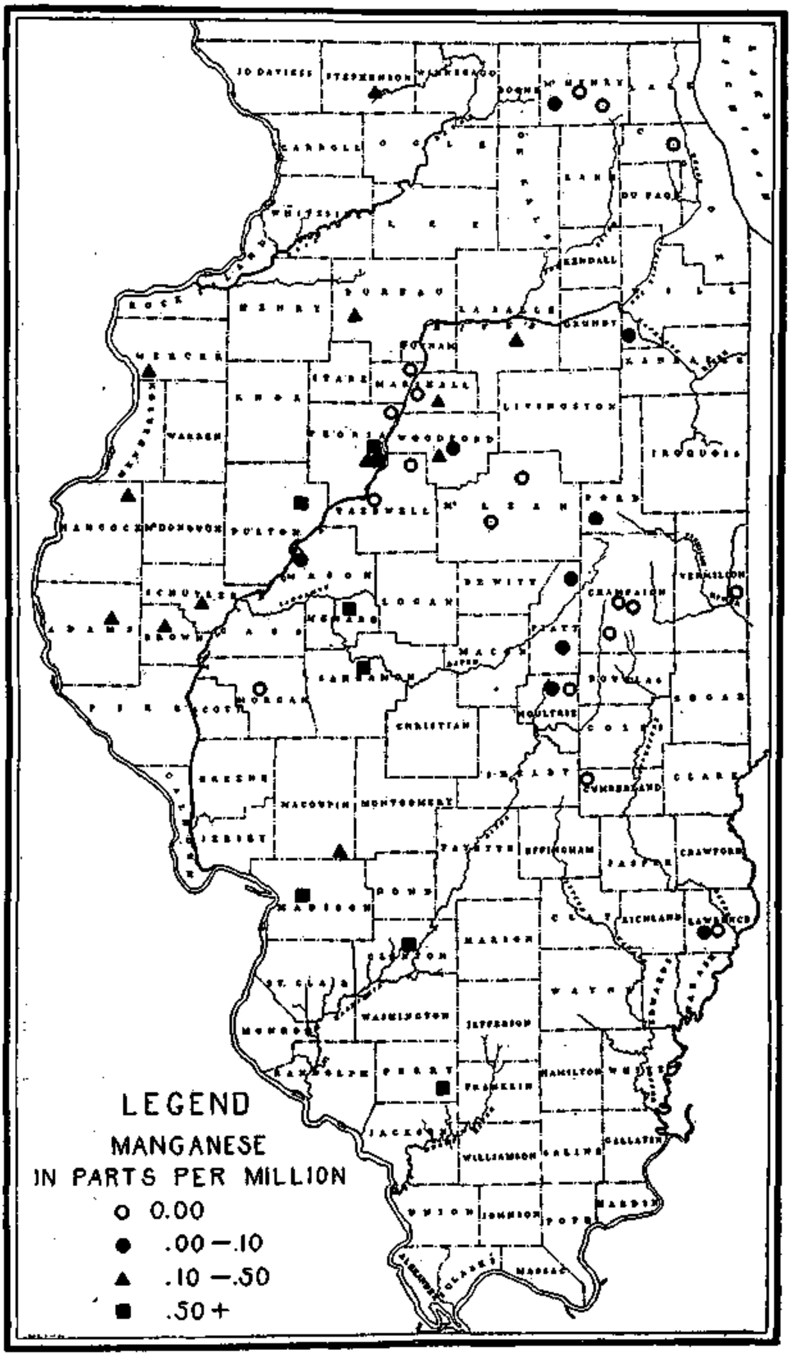


Figure 1.—Map of Illinois showing occurrence of manganese in water from wells in unconsolidated deposits,

The great difference in content of manganese of water from five 60-foot wells within a few hundred feet of one another at Peoria is rather striking. The content of manganese of water from these wells ranges from 0.16 to 1.6 parts per million, and other mineral constituents also present similar differences. The percentages of manganese are shown in Table 22. Though no data concerning the normal content of manganese of unconsolidated material are available the content of these samples does not seem unusual, but it may be sufficiently great to account for the occurrence of manganese in waters circulating in the deposits. No apparent relation exists between the contents of manganese, iron, and total mineral matter of these waters.

TABLE 22.—MANGANESE IN BORINGS FROM TEST WELLS IN UNCONSOLIDATED DEPOSITS AT PEORIA.

Number of well.	Depth of sample.	Content of manganese.
	Feet.	*Per cent.*
2	0— 8.5	0.21
7	3.5—18	.30
78	0— 5	.57
78	5— 8.5	.46
78	8.5—19.5	.56
78	19.4—24.2	.31
119	0— 5.5	.46
119	5.5— 7.5	.22
119	7.5— 9	.23
119	21.6—coal	.23

TABLE 23.—CONTENT OF MANGANESE, IRON, AND DISSOLVED SOLIDS IN WATER FROM SPRINGS.[a]

[Parts per million.]

Locality.	County.	Manganese (Mn).	Iron (Fe).	Dissolved residue.
Ashland	Cass	0.00	1.8	490
Camp Point	Adams	.40	1.2	876
Harrisburg	Saline	.12	2.3	281
Jacksonville	Morgan	.00	.0	378
Kewanee	Henry	.16	2.4	541
Oregon	Ogle	.00	.5	402
Do	do	.00	.2	449
Mount Vernon	Jefferson	7.80	51.2	1,189
Sailor Springs	Clay	.00	8.4	1,272
Taylorville	Morgan	.00	.0	368

[a]None of these springs is used as a public water supply.

SPRINGS

The 10 waters from springs that were examined show wide range in content of manganese. (See Table 23.) Six samples contained none, 3 contained 0.4 part per million or less, and one contained 7.8 parts per million. The water from Green Lawn Spring at Mount Vernon has a greater content of manganese than that from the spring at Excelsior Springs, Mo., which contains 4.5 parts per million.[1] The water contains no bicarbonates or free sulphuric acid, and the iron and manganese are reported as sulphates.

A surface water at Mount Vernon (see Table 25.) also contains 0.12 to 0.80 part per million of manganese. Water from a well at Camp Point, where the water of next greatest content of manganese is situated, contains 0.12 part per million of manganese. (See Table 20.)

TABLE 24.—CONTENT OF MANGANESE, IRON, AND DISSOLVED SOLIDS IN WATER FROM COAL MINES.

[Parts per million.]

Locality.	County.	Source.	Manganese (Mn).	Iron (Fe).	Dissolved solids.
Duquoin	Perry	Abandoned mine	0.24	0.1	1,160
Danville	Vermilion	Seepage from stripping mine	17.0	5.0	...
Harrisburg	Saline	Mine	56.0	..	7,330
Ladd	Bureau	Abandoned mine	1.3	2.8	8,144
Streator	La Salle	do	1.4	126.5	1,379
Do	do	Stobb's mine	2.0	57.5	2,245

COAL-MINE DRAINAGE

Coal-mine drainage usually contains iron and often large amounts of it, and such drainage is often acid because of hydrolysis of salts of iron and precipitation of iron hydroxide. The iron is derived from pyrite, marcasite, sulphide-bearing shales, and other compounds of sulphur, which are leached by water containing oxygen, and oxidized to ferrous sulphate, a compound soluble in water. Though manganese has not been considered a constituent of mine water examination of 6 samples (See Table 24) of coal-mine drainage shows that all contain manganese and that some contain large amounts. The content of manganese of one sample, which contained free acid when it was analyzed was 56 parts per million. All the samples of mine drainage contained large amounts of dissolved mineral matter, but none except that from Harrisburg contained free acid. No report of such large amounts of manganese in mine water has come to the writer's attention. No trace of manganese could be found even in one-gram samples of pyrite, marcasite, and shale from mines in the Streator district. A sulphide shale, which occurs with the coal in the stripping mine at Danville, where water containing 17 parts per million of manganese was found, contained 1.10 per cent of manganese. Manganese probably is leached from minerals by mine drainage in a manner similar to the removal of iron.

[1]Mason, W. P., The manganese waters of Excelsior Springs: Chem. News, 61, 123 (1890).

TABLE 25.—CONTENT OF MANGANESE, IRON, AND DISSOLVED SOLIDS IN WATER FROM LAKES AND STREAMS.

[Parts per million.]

Locality.	County.	Source.	Manganese (Mn).	Iron (Fe).	Dissolved solids.
Anna	Union	Reservoir on Kohler Creek	.0	.6	170
			7.5	1.0	214
Belleville	St. Clair	Mississippi River	0.02	0.1	234
Benton	Franklin	Reservoir on creek	.12	3.5	282
Cairo	Alexander	Ohio River	.00	.1	150
					240
Carlinville	Macoupin	Macoupin Creek	.00	.1	317
Centralia	Marion	Crooked Creek	.20	.1	...
Chicago	Cook	Lake Michigan	.00	.0	151
Danville	Vermilion	Vermilion River	.00	.0	309
			.02	.1	454
Decatur	Macon	Sangamon River	.00	.0	305
				.1	375
East St. Louis	St. Clair	Mississippi River	.02	.1	280
Effingham	Effingham	Little Wabash River	.00	.1	285
Evanston	Cook	Lake Michigan	.00	.0	158
Fort Sheridan	do	do	.00	.0	162
Glencoe	do	do	.00	.0	155
Granite City	Madison	Mississippi River	.02	.1	218
Greenup	Cumberland	Embarrass River	.00	.05	681
Hamilton	Hancock	Mississippi River	.00	.0	160
				.1	274
Harrisburg	Saline	Saline River	.32	.8	671
Highland Park	Lake	Lake Michigan	.00	.05	140
Jacksonville[a]	Morgan	Morgan Lake	.00	1.6	1,041
Kankakee	Kankakee	Kankakee River	.04	.1	877
Kangley[a]	La Salle	Vermilion River	4.00	150.0	2,210
Kenilworth	Cook	Lake Michigan	.00	.0	192
Lake Forest	Lake	do	.00	.0	177
Lawrenceville	Lawrence	Embarrass River	.02	.1	575
					1.054
Lowell[a]	La Salle	Vermilion River	7.50	66.0	2,916
Madison	Madison	Mississippi River	.02	.1	224
Moline	Rock Island	do	.00	.1	191
Mount Carmel	Wabash	Wabash River	.00	.1	300
Mount Vernon	Jefferson	Reservoir	.12	.1	215
			.8	.8	402
Do	do	Casey Fork	.00	.1	155
North Chicago	Lake	Lake Michigan	.00	.0	164
Oblong[a]	Crawford	Creek	.36	1.0	1,358
Olney	Richland	Fox River	.04	.7	145
Oglesby[a]	La Salle	Vermilion River	9.00	46.5	2,825
Pontiac	Livingston	do	.00	.05	447
			.08	.2	557
Pullman	Cook	Lake Michigan	.00	.0	151
Quincy	Adams	Mississippi River	.00	.1	222
			.02		250
Rock Island	Rock Island	do	.02'	.1	224
Staunton	Macoupin	Cahokia Creek	.16	.1	550
Streator	La Salle	Vermilion River	.00	.0	848
Venice	Madison	Mississippi River	.02	.1	234
Waukegan	Lake	Lake Michigan	.00	.0	134
West Hammond	Cook	do	.00	.0	146

[a]Not city supply.

RIVERS AND LAKES

No manganese was found in any of the waters from Lake Michigan (See Table 25), and not more than 0.02 part was found in any of the samples from Mississippi, Ohio, Wabash, and Sangamon. Rivers. Samples from Fox and Embarrass Rivers contained only small amounts. The water of Vermilion River below Streator contains 4 to 9 parts per million of manganese, and much larger amounts of iron, as shown by analyses of samples collected at Kangley, Lowell, and Oglesby. Samples taken at Streator above the dam at the water-works contained no manganese or iron. This river below Streator is heavily polluted with mine drainage containing iron and manganese, a condition that explains the high content of manganese and iron. The presence of 0.32 part per million of manganese in the city supply of Harrisburg which is taken from Saline River, is also due to the entrance above the city of coal-mine drainage of high content of manganese.

Many impounding reservoirs on small creeks in southern Illinois like the supplies at Anna, Benton, Centralia, and Mount Vernon, contain manganese. Such reservoirs are fed partly by springs, which may contribute the manganese. Their content of manganese widely varies. At Anna a variation from 0.2 to 7.5 parts per million from July, 1914 to May, 1915, was observed, and at Mount Vernon from 0.1 to 0.8 part per million during the same period. The occurrence of such amounts of manganese in surface waters nearly saturated with dissolved oxygen is contrary to past conceptions of the occurrence of the element. In fact, much experimental work on the removal of manganese has been based on the theory that aeration oxidizes the manganous salt to an insoluble hydrated oxide, which can be removed by filtration.

SUMMARY

Manganese as a constituent of water supplies in the United States has been overlooked and its importance underestimated. It occurs normally in certain classes of water in Illinois, and amounts sufficient seriously to affect the quality have been found in several waters. This may be said of the water supplies at Mount Vernon, Anna, Centralia, Peoria, Springfield, Freeport, and Harrisburg.

Little manganese is present in water from Potsdam sandstone, St. Peter sandstone, the overlying limestones, Lake Michigan, and the large rivers.

Manganese is usually present and often in very large amounts in coal-mine drainage.

Manganese is present in water from some impounding reservoirs on small streams in southern Illinois, and from some wells entering unconsolidated deposits near rivers.

No apparent relation exists between the content of manganese of a water and any of the other mineral constituents.

REMOVAL OF MANGANESE FROM WATER SUPPLIES

Methods

The experimental work which has been done on the removal of manganese from water has led to the development of three practical methods—aeration and filtration through sand, filtration through permutit, and filtration through pyrolusite. The problem of removing manganese has been attacked by most workers in a manner similar to that of removing iron. The usual method for the removal of iron from water is by aeration followed by filtration through sand, and it is generally and successfully used in many plants in the United States and Europe. Iron occurs in most ground waters in the ferrous condition. When the water is aerated the iron is oxidized to the ferric condition and separates as the hydroxide. This combination of oxidation, hydrolysis, and precipitation is the basic principle of the method though the presence of other substances somewhat affects the results. The occurrence of manganese with iron in many waters and its separation as the hydrated dioxide under certain conditions have led to the assumption that the element in water has chemical properties practically similar to those of iron.

Extensive experiments on removal of manganese by this method have been conducted by Thiesing,[1] who worked with a water at Pommerensdorf, Germany. He has concluded that manganese occurring in water as the bicarbonate can be successfully removed by aeration and filtration. Trickling through beds of coke or spraying through nozzles were used as methods of aeration. The removal of carbon dioxide as well as solution of oxygen was found to be important in the process of aeration. Subsequent filtration through sand gave an effluent containing very little manganese, sedimentation effected little removal.

In this country extensive experiments along similar lines have been conducted by R. S. Weston[2] with several waters containing iron and manganese in Massachusetts. Mr. Weston's problems have dealt chiefly with the removal of iron. A well water containing 0.73 part per million of iron and 0.23 part per million of manganese was treated at Cohasset by being sprayed through nozzles followed by passage through a coke trickling filter and mechanical filters. Satisfactory results were obtained in the experiments and arrangements have been made for construction of a large plant. In experiments at Brookline

[1]Thiesing, [Experiments on the removal of manganese from ground water]: Mitt. kgl. Prufungsans. Wasserversorgung, 16, 210-96 (1912).

[2]Weston, R. S., The purification of ground waters containing iron and manganese: Trans. Am. Soc. C. E., 64, 112-81 (1909); Some recent experiences in the deferrization and demanganization of water: J. N. E. Water Works Assoc, 28, 27-59 (1914).

sprinkling through nozzles followed by passage through a coke trickling filter and slow sand filters decreased the content of iron from 0.6 to 0.2 part per million. The content of manganese of the untreated water was 0.26 part per million, though Weston published no figures concerning the efficiency of the removal of manganese he stated that he found it roughly proportional to that of the removal of iron. A plant for removal of iron and manganese, which has been installed at Middleboro, treats 335,000 gallons a day of water. The water, after it has been sprayed over a coke trickling filter 10 feet deep, flows into a settling basin and through slow sand filters operating at a rate of 10,000,000 gallons p.er acre per day. The content of iron was decreased from 1.5 to 0.2 part per million and the content of manganese from 0.67 to 0.27 part per million during the first run from September 26, 1913, to January 12, 1914. The efficiency of the removal of manganese increased as the plant was operated longer, and the effluent on January 22 contained 0.10 part per million of manganese.

Barbour[1] performed a similar series of experiments on the well-water supply of Lowell, Mass. The waters of the wells differ in content of manganese, the strongest containing 2.0 parts per million. Aeration, sedimentation, and sand filtration were tried on an experimental scale. The efficiency of the plant was at first rather erratic, but it finally became possible to reduce the content of manganese to 0.01 part per million. A dark coloration due to precipitated oxides of manganese was observed in the sand bed, and this extended in diminishing amounts to the bottom of the bed. On the basis of this study a plant was erected at a cost of $180,000 for the removal of manganese and iron.

Practically all students of removal of manganese by aeration and filtration have concluded that manganese is much more difficult to remove than iron. The details of the process, such as the amount of aeration and the rate of filtration, differ with the character of the water.

The permutit process for removal of manganese has come recently into the field. Permutit, the artificial zeolite[2] first produced and patented by Gans of the Prussian Geological Institute of Berlin, has come into somewhat common use in softening water. Its use for removing calcium and magnesium from water has been studied by

[1]Barbour, F. A., Removal of carbonic acid, iron, and manganese from the Lowell (Mass.) well-water supply: Eng. Record, 70, 78-9 (1914).

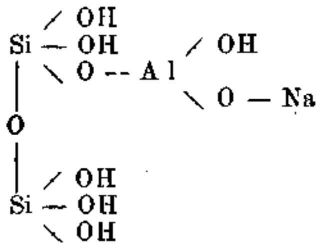
[2]Gans, Robert, [Manufacture of artificial zeolite in crystalline form]: U. S. pat. 914, 405, March 9, 1909, Chem. Rev. Fett-Harz-Ind., 16, 302-3 (1909).

Duggan, T. R., Zeolites, natural and artificial (Abstract): Orig. Com. 8th Intern Congr. Appl. Chem. (Appendix), 26, 125-9 (1912).

Gans, Robert. Ueber die technische Bedeutung der Permutite (der künstlichen zeolithartigen Verbindungen): Chem. Ind., 32, 197-200 (1909).

numerous investigators. Gans, however, has adapted it to the removal of manganese from water. The principles involved in this latter process are decidedly different from those involved in ordinary processes of softening water.

Sodium permutit is made by fusing together 3 parts of kaolin, 6 parts of sand, and 12 parts of soda. The melt, after cooling, is leached with water. Gans[1] proposes the following to represent sodium permutit.



The sodium in this compound is replaceable by other metals. For example, when a solution of a compound of calcium percolates through the crushed material, the calcium replaces the sodium in the silicate, is removed from the solution, and is in turn replaced in the water by an equivalent of sodium. On the other hand, when a solution of a a compound of sodium is filtered through the calcium permutit the calcium is forced out by the sodium. The process may be simply represented by the equilibria:

$$\overset{++}{Ca} + 2Na\text{-permutit} = 2\overset{+}{Na} + Ca\text{-permutit.}$$
$$\overset{++}{Mg} + 2Na\text{-permutit} = 2\overset{+}{Na} + Mg\text{-permutit.}$$

Thus, if a hard water percolates through sodium permutit, the calcium and magnesium in the water are replaced by sodium. If, after this change is complete, a solution of sodium chloride percolates through the used permutit the calcium and magnesium therein are replaced and removed by sodium. The permutit is thus regenerated, or restored, to its original condition without loss. The series of reactions constitutes an apt application of the law of mass action. Permutit is not lost unless the water contains free carbon dioxide, which has on the permutit a solvent action that results in the formation of bicarbonate.

Gans[2] noted that manganese can be removed with compounds of

[1] Gans, Robert. Ueber die technische Bedeutung (der Permutite der künstlichen zeolithartigen Verbindugen): Chem. Ind., 82, 197-200 (1909).

[2] Sans, Robert, Reinigung des Trinkwassers von Mangan durch Aluminatsilicate: Chem. Ztg., 31. 355-6 (1907).

calcium and magnesium when a manganese-bearing water is filtered through the zeolite. Usually, however, it is desired to remove only the manganese without the extra expense of softening the water. To accomplish this, Gans[1] treated permutit with a strong solution of manganous chloride or sulphate, and then with a strong solution of a permanganate. He found that if a water containing manganese or iron is filtered through this medium, the manganese and iron could be removed without the accompanying softening action. After a time the filter medium no longer effected removal, but its efficiency was restored by regenerating it with permanganate. The chemistry of this process is explained by Gans.[1] Treatment with manganous chloride gives a manganese zeolite.

$$2SiO_2 \cdot Al_2O_3 \cdot CaO + MnCl_2 = 2SiO_2 \cdot Al_2O_3 \cdot MnO + CaCl_2$$

When this zeolite is treated with permanganate, the following reactions may take place:

(a) $2SiO_2 \cdot Al_2O_3 \cdot MnO + CaMn_2O_8 \; 2SiO_2 \cdot Al_2O_3 \cdot CaO + MnO \cdot Mn_2O_7$.

(b) $2(SiO_2 \cdot Al_2O_3 \cdot MnO) + H_2O + CaMn_2O_8 = \left\{ \begin{array}{l} 2SiO_2 \cdot Al_2O_3 \cdot CaO \\ 2SiO_2 \cdot Al_2O_3 \cdot H_2O \end{array} \right\} + 2MnO \cdot Mn_2O_7$.

(c) $3(SiO_2 \cdot Al_2O_3 \cdot MnO) + 2H_2O + CaMn_2O_8 = \left\{ \begin{array}{l} 2SiO_2 \cdot Al_2O_3 \cdot CaO \\ 2SiO_2 \cdot Al_2O_3 \cdot H_2O \\ 2SiO_2 \cdot Al_2O_3 \cdot H_2O \end{array} \right\} + 3MnO \cdot Mn_2O_7$.

The precipitation of manganese by these zeolites, which depends on the action of the oxides of manganese, is represented by the following reactions:

(a) $2(MnO \cdot Mn_2O_7) + 3Mn(HCO_3)_2 = 5MnO \cdot 2Mn_2O_7 + 6CO_2 + 3H_2O$

(b) $2MnO \cdot Mn_2O_7 + 3Mn(HCO_3)_2 = 5MnO \cdot Mn_2O_7 + 6CO_2 + 3H_2O$

(c) $2(3MnO \cdot Mn_2O_7) + 9Mn(HCO_3)_2 = 15MnO \cdot 2Mn_2O_7 + 18CO_2 + 9H_2O$

Gans[2] successfully applied the process at Glogau to a water that contained 1.5 to 2.0 parts per million of manganese. The free carbon dioxide was first removed by passing the water through crushed marble. The treated water was free from manganese and neutral. The hardness was slightly increased by solution of calcium in the neutralization of free carbon dioxide. Iron is removed with the manganese in the process. As the cost of installation of a permutit plant is high it has been introduced in only a few places for large-scale operations.

[1]Gans, Robert, Die Mangangefahr bei der Benutzung von Grundwasser zur Trinkwasser. versorgung und deren Beseitigung: Chem. Ind., 33, 48-51, 66-9 (1910).
[2]Oeaterr. Chem. Tech. Ztg. 26, Bohrtechnicker section 16, 178.

The oxide, Mn_2O_7, is considered the basis of the removal process in a pamphlet distributed by The Permutit Co. entitled "The chemistry of permutit." The reactions presented are as follows, the letter p representing permutit:

$$p\text{-}Na_2 + MnCl_2 = p\text{-}Mn + 2NaCl$$
$$p\text{-}Mn + 2KMnO_4 = p\text{-}K_2MnO:Mn_2O_7$$
$$p\text{-}K_2MnO.Mn_2O_7 = p\text{-}K_2 3MnO + 5O$$

The question of whether the reduction is to MnO, MnO_2, or Mn_2O_3 is considered in this discussion to be undecided.

Another method of removing manganese was patented by Pappel[1] who filtered the manganese-bearing water through granular pyrolusite. The material finally may lose its power of removal, but the power is restored by washing it with ordinary tap water. Though this process was investigated experimentally at Dresden by Schmeitzner[2] it was not adopted there for use on a large scale. Manganese is removed from the city supply of Breslau by this method. A natural sand containing pyrolusite is used as the medium.

Tillmans and Heublein,[3] who studied the theory of removal of manganese by this method, found that when pieces of pyrolusite were allowed to stand suspended in tubes containing a solution of manganous sulphate solidified with gelatin, after which ammonia was poured on the surface, the Liesegang rings in the vicinity of the pieces of pyrolusite were absent. The power of this substance to absorb and remove manganous salts from solutions was thus shown. When pure manganese dioxide was allowed to react with a dilute solution of manganous sulphate the free acid formed was equivalent to the manganese removed. They consider the reaction to be:

$$MnO_2 + MnSO_4 = Mn_2O_3 + SO_3$$

Tillmans,[4] reviewing his former work in a later article states that manganese dioxide is the essential medium which removes manganese in the permutit process.

Other methods for the removal of manganese have been proposed, in which chemicals to precipitate the element are added to the water. Lührig and Blasky,[5] who were among the first to experiment on this

[1]Pappel, Alfred, Entmanganen von Wasser, German pat. 241, 571: Chem. Ztg. Rep., 36, 7 (1912).

[2]Schmeitzner, E., [The removal of manganese from ground water]: Techn. Gem. bl., 15, 343; Wasser u. Abwasser, 7, 376-7 (1914); through C. A. 8, 974 (1914).

[3]Tillmans, J., and Heublein, O., Versuche zur Theorie der Entmanganung von Grundwasser: Z. Nahr. Genussm., 27, 253-64 (1914).

[4]Tillmans, J., Über die Entmanganung von Trinkwasser: J. Gasbel., 57, 713-24 (1914).

[5]Lührig, H., and Blasky, A., Mangan im Grundwasser der Breslauer Wasserleitungen und die Frage der Abscheidung des Mangsnsulfates aus demselben: Chem. Ztg., 31, 255-7 (1907).

problem, suggested the addition of potassium permanganate or lime to precipitate the manganese. These chemical methods have not come into practical use. A study of them was undertaken by the writer to determine the chemistry of the processes and especially that in which the water is treated by aeration.

Manganese Permutit

Specimens of manganese permutit, kindly furnished by The Permutit Co. for the study, consist of irregular black grains 2 or 3 millimeters in diameter. When these are crushed, a white core is noted in the center of each. A specimen of the permutit was ground, dried at 105°C., and analyzed. Manganese was determined as the pyrophosphate. Available oxygen was determined by distilling the chlorine evolved on treatment with hydrochloric acid into potassium iodide and titrating the liberated iodine. The analysis is as follows:

TABLE 26.—ANALYSIS OF MANGANESE PERMUTIT.

Potassium oxide (K_2O)	4.00
Sodium oxide (Na_2O)	4.37
Calcium oxide (CaO)	1.87
Magnesium oxide (MgO)	.17
Ferric oxide (Fe_2O_3)	.42
Alumina (Al_2O_3)	22.72
Silica (SiO_2)	38.28
Manganous oxide (MnO)	10.37
Available oxygen (O)	1.94
Water	15.34
	99.48

This specimen of permutit had been prepared by treating sodium permutit with manganous salt and afterward with potassium permanganate. The determined content of manganese, calculated as MnO, is 10.37 per cent; the amount of available oxygen, which should determine the degree of oxidation of the manganese, was found to be 1.94 per cent. The theoretical percentage of available oxygen which should have been obtained if the manganese had been present in each form is as follows:

	Available Oxygen (O).
MnO_2 for 10.37 per cent of MnO as—	2.37
Mn_2O_3	1.17
Mn_3O_4	.78
MnO	none.

As 1.94 per cent of available oxygen was found, the oxide is higher than MnO, Mn_3O_4, and Mn_2O_3, but not so high as MnO_2.

In order to determine what compounds of manganese effected the removal specimens of ground manganese permutit were regenerated to the greatest possible degree, and exhausted to the least possible degree. One portion was treated with a saturated solution of potassium permanganate and agitated in a shaking machine, for several days. It was then allowed to stand for two weeks, at the end of which time the solid material was removed by filtration, washed free from permanganate, dried, and analyzed. The composition was as follows:

TABLE 27.—ANALYSIS OF SPECIALLY TREATED MANGANESE PERMUTIT.

Potassium oxide (K_2O)	10.26
Sodium oxide (Na_2O)	1.00
Calcium oxide (CaO)	1.28
Magnesium oxide (MgO)	trace
Ferric oxide (Fe_2O_3)	.66
Alumina (Al_2O_3)	22.62
Silica (SiO_2)	39.09
Manganous oxide (MnO)	12.30
Available oxygen (O)	2.49
Water	10.83
	100.53

The empirical formula calculated from the above analysis is $3R_2O \cdot 3MnO_x \cdot 4Al_2O_3 \cdot 12SiO_2 \cdot 11H_2O$, in which R_2O represents the oxides of the alkalies and alkaline earths. After regeneration the amount of manganese calculated as MnO was found to be 12.30 per cent, and the available oxygen, 2.49 per cent. The theoretical quantity of available oxygen, if all the manganese had been in the form of MnO_2, would have been 2.77 per cent. This shows that regeneration has increased the available-oxygen ratio, or the degree of oxidation of the manganese, but that it is still somewhat lower than the theoretical for manganese dioxide.

There are several reasons why a quantity of available oxygen smaller than the theoretical might be obtained. The treatment may not have been continued sufficiently long to complete the reaction. All the manganese which is present in an insoluble silicate of this character probably can not be reached and attacked by the permanganate because of the physical structure of the material. Moreover, Morse, Hopkins, and Walker[1] have shown that manganese dioxide loses a

[1]Morse, H. N., Hopkins, A. J., and Walker, M. S., The reduction of permanganic acid by manganese superoxide: Am. Chem. J., 18, 401-19 (1896).

small quantity of its oxygen on drying in the air and that compounds like $MnO \cdot 5OMnO_2$ are obtained. For this reason a content of available oxygen slightly lower than actually present would be found by analysis.

The large percentage of potassium and the small percentages of sodium, calcium, and magnesium compared with the smaller percentage of potassium and the larger percentages of sodium, calcium, and magnesium found before regeneration in this specimen are particularly interesting. This is explained by the fact that these metals are replaceable, and that treatment with potassium permanganate has not only brought about oxidation of the manganese, but has at the same time effected replacement of the other metals with potassium. The effect of replacement can be represented graphically by the reaction:

$$(K, Na, Ca)\ \text{Permutit} + 3\overset{+}{K}\,\overset{-}{MnO_4} = K_x\ \text{Permutit} + \overset{++}{Ca}(\overset{-}{MnO_4})_2 + \overset{+}{Na}\overset{-}{MnO_4}$$

Oxidation of the manganese in the zeolite takes place with the replacement, giving manganese dioxide as the limit of oxidation and not such higher oxides as $MnO \cdot Mn_2O_7$ and $2MnO \cdot Mn_2O_7$, as suggested by Gans.[1]

A portion of this regenerated sample was then shaken with a strong solution of manganous sulphate in the same manner. After washing and drying it was found to have the composition shown in Table 28.

TABLE 28.—ANALYSIS OF SPECIALLY TREATED REGENERATED MANGANESE PERMUTIT.

Potassium oxide (K_2O)	3.15
Sodium oxide (Na_2O)	2.20
Calcium oxide (CaO)	.54
Magnesium oxide (MgO)	Trace
Ferric oxide (Fe_2O_3)	.50
Alumina (Al_2O_3)	23.05
Silica (SiO_2)	37.37
Manganous oxide (MnO)	15.05
Available oxygen (O)	2.00
Water	14.76
	99.62

The empirical formula calculated from this analysis is, $3/2\ R_2O \cdot 4MnO_x \cdot 4Al_2O_3 \cdot 12SiO_2 \cdot 16H_2O$.

[1]Gans, Robert, Die Mangangefahr bei der Benutzung von Grundwasser zur Trinkwasserversorgung und deren Beseitigung: Chem. Ind., 33, 48-51, 66-9 (1910).

The determined content of available oxygen was 2.00 per cent. The theoretical content of available oxygen for Mn_2O_3, the oxide next lower than MnO_2, is 1.70 per cent. It was subsequently found, however, that in the analysis of the reduced material, oxygen was taken up while the substance was being dried in the air. The content of 2.00 per cent, therefore, is probably too great, and little significance should be attached to it.

The low percentages of sodium and potassium, and the high percentage of manganese are interesting, especially when they are compared with corresponding figures for the regenerated specimen. A replacement as well as a reduction again has taken place. The replacement is the substitution of manganese for the sodium and potassium of the permutit, which can be represented by the reaction:

$$K_2\,\text{Permutit} + \overset{++}{Mn}\overset{--}{SO_4} = Mn\ \text{Permutit} + \overset{+}{K_2}\overset{--}{SO_4}$$

The extent to which this reaction takes place is governed by the concentration of manganese in the solution. As the concentration is usually very low this reaction is relatively unimportant and it must take place to only very slight extent. Coincident with this reaction the manganese dioxide is reduced to a lower oxide by the manganous salt thus: $MnO_2 + MnSO_4 = > Mn_2O_x + SO_3$. This is the basic reaction involved in the permutit process.

The acid which is formed when the manganese is removed is undoubtedly neutralized by the alkaline silicate, for Gans[1] has shown that free acid, even carbonic acid, has a solvent action on permutit.

Manganese permutit consists of a zeolite with which a layer of manganese dioxide is incorporated. When a manganese-bearing water is filtered through this medium the manganese is removed from the water by the formation of a lower oxide of manganese by reaction between the manganese in the water and the manganese dioxide in the permutit. At the same time the alkali or alkaline-earth of the silicate is replaced by the manganous compound of the water. The replacement is of minor importance, and the slight extent to which it takes place is dependent on the concentration of manganese in the water. Manganese is added to the permutit not only when manganese permutit is regenerated by potassium permanganate but also when manganese is removed from water by the regenerated permutit; therefore, the content of manganese dioxide increases and the filter medium approaches in composition pure manganese dioxide with each successive regeneration and reduction. As the zeolite can not increase in amount

[1] Idem.

with successive reductions and regenerations the replacement effect must become less and less as the substance is used. These conclusions are in entire accord with that reached independently by Tillmans[1]—that the action of manganese permutit is really the action of manganese dioxide.

Sand Filtration

Some preliminary experiments made by filtering an aerated artificially prepared manganese-bearing water through a small sand filter showed that no removal of manganese was effected. A mechanical filtration plant has been installed at Mount Vernon, Ill., however, for the

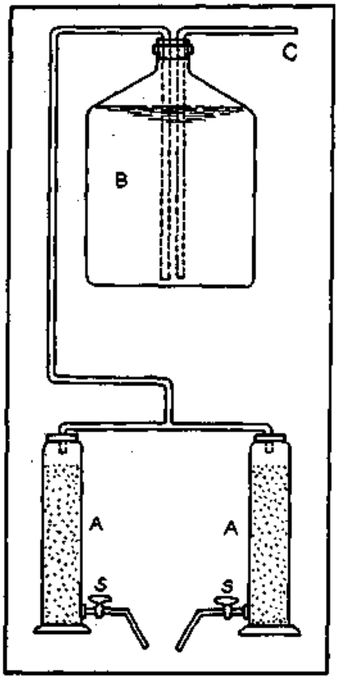


Figure 2.—Experimental sand filters for the removal of manganese.

purpose of removing manganese as well as effecting hygienic purification of a surface water, and analyses of the water some months after installation of the mechanical filters showed that manganese was being removed by this plant. Manganese is also removed in a filter plant at Anna, Ill., designed for hygienic purification of a surface-water supply. These results seemed contradictory to the negative results obtained on a small scale. Yet, as manganese dioxide had been used

[1]Tillmans, J., Über die Entmanganung von Trinkwasser: J. (Gasbel., 57, 713-24 (1914).

successfully for removal of manganese and as this compound is the basic part of manganese permutit it was concluded that manganese dioxide was the principal factor in the removal of manganese in successful sand filtration.

Two filters were, therefore, prepared for experimental use. The apparatus (See Figure 2) consisted of. two gas-washing cylinders (A, A) connected at their tops by a siphon to a large carboy (B) holding the water to be treated. The rate of filtration could be so adjusted by two stopcocks (S, S) that both filters would deliver their effluents at the same rate. A glass tube (C) extending to the bottom of the carboy provided means for admitting compressed air for aeration.

Bach filter was filled with one liter of clean high-grade filter sand, having an effective size of 0.50 millimeter and a uniformity coefficient of 1.32. One filter was treated successively with solutions of manganous sulphate, sodium hydroxide, and potassium permanganate. After two or three treatments a thin film of black oxide of manganese had formed on the grains of sand. The filter was then washed with water until an effluent free from manganese was obtained. The other filter was used without such treatment. The apparatus consisted, therefore, of two filters working in parallel, one containing sand only, and the other containing sand which had been slightly coated with manganese dioxide. As the depth of sand in each was 35 centimeters the filtering area of each was 28 square centimeters.

The removal of manganese in a manganese-removal filter, depends on the contact of the manganous compound with manganese dioxide; consequently, the rate of filtration should be expressed in terms of volume of water filtered per volume of filter medium and not per area of filter surface. The rate varied slightly in these experiments, but it was so adjusted that a volume of water equal to the volume of the filter medium was filtered in twenty minutes. The waters used were prepared by dissolving compounds of iron and manganese in tap water, distilled water, and a mixture of the two. The tap water is a bicarbonate, iron-bearing water from drift wells. The determinations in Table 29 represent the character of the tap water used in reference to a discussion of removal of manganese.

TABLE 29.—CHARACTER OF TAP WATER USED IN EXPERIMENTATION ON REMOVAL OF MANGANESE.

	Parts per million.
Turbidity	5
Color	15

Residue on evaporation	370
Chloride	3
Alkalinity as $CaCO_3$ in presence of methyl orange	355
Free carbon dioxide	40
Iron	2.0
Manganese	none
Total hardness	300
Dissolved oxygen	none
Oxygen consumed	4.8

The first artificial water was prepared by adding 5 parts per million of manganese as $MnSO_4 \cdot 4H_2O$ to a mixture of about equal parts of tap water and distilled water. The water was aerated by blowing air through it for one hour and allowing to stand for two hours. It was then filtered through the apparatus, and manganese, iron, carbon dioxide, dissolved oxygen, and alkalinity, were determined in samples taken at two-hour intervals. The results are shown in Table 30.

TABLE 30.—REMOVAL OF MANGANESE BY AERATION AND FILTRATION OF A MIXTURE OF TAP WATER AND DISTILLED WATER CONTAINING 5 PARTS PER MILLION OF MANGANESE.

[Parts per million.]

Determinations.	Unfiltered water.	Water filtered through—	
		Sand.	Sand coated with manganese dioxide.
AT START			
Manganese	4.8	4.4	.0
Iron	.4	.05	.0
Alkalinity	200	200	196
Dissolved oxygen	7.4	7.2	6.2
Carbon dioxide	4.0	2.0	2.0
AFTER 2 HOURS' OPERATION			
Manganese	4.8	4.8	.0
Iron	.4	.05	.0
Alkalinity	200	200	194
Dissolved oxygen	7.2	7.4	6.6
AFTER 4 HOURS' OPERATION			
Manganese	4.8	4.4	.0
Iron	.4	.05	.0
Alkalinity	200	200	194
Dissolved oxygen	7.4	7.4	6.6
Carbon dioxide	2.0	4.0	6.0
AFTER 6 HOURS' OPERATION			
Manganese	4.8	4.0	.05
Iron	.4	.05	.0
Alkalinity	200	200	192
Dissolved oxygen	7.5	7.5	6.8

Aeration decreased the content of free carbon dioxide to 2 to 4 parts per million, and increased the content of dissolved oxygen to 7.4 parts per million. Filtration through sand removed practically all the iron, but caused practically no change in the content of manganese, dissolved oxygen, and alkalinity. Filtration through sand coated with manganese dioxide, on the other hand, removed all manganese and iron, has decreased the content of dissolved oxygen an average of .8 part per million and the alkalinity an average of .4 part per million. These results indicate that aeration and sand filtration do not remove appreciable amounts of manganese. In the manganese-dioxide filter the manganous compound evidently combines with the manganese dioxide to form a lower oxide exactly as in the pyrolusite and the permutit processes. When manganese is removed the equivalent of free acid that is formed causes a corresponding decrease in the alkalinity. This decrease should theoretically be 10 parts per million when 5 parts per million of manganese is removed, whereas the actual decrease was only 4 parts per million. The disappearance of 0.8 part per million of dissolved oxygen in the manganese-dioxide filter is undoubtedly due to oxidation of the lower oxide of manganese to manganese di-

TABLE 31.—REMOVAL OF MANGANESE BY AERATION AND FILTRATION, OF TAP WATER CONTAINING 10 PARTS PER MILLION OF MANGANESE.

[Parts per million.]

Determinations.	Unfiltered water.	Water filtered through—	
		Sand.	Sand coated with manganese dioxide.
AT START			
Manganese	10.5	9.0	0.1
Iron	.8	.0	.0
Alkalinity	356	354	342
Dissolved oxygen	5.3	3.4	5.0
Carbon dioxide	4	6	8
AFTER 2 HOURS' OPERATION			
Manganese	10	10.5	.1
Iron	.8	.0	.0
Alkalinity	358	356	344
Dissolved oxygen	5.6	4.2	4.1
Carbon dioxide	6	8	12
AFTER 4 HOURS' OPERATION			
Manganese	9.5	10.0	.0
Iron	.8	.1	.0
Alkalinity	358	358	342
Dissolved oxygen	5.6	4.0	4.0
AFTER 6 HOURS' OPERATION			
Manganese	10.0	10.0	.0
Iron	.8	.0	.0
Alkalinity	356	354	340
Dissolved oxygen	5.7	4.5	3.5

oxide. If this were quantitative the removal of 5 parts of manganese should reduce the content of dissolved oxygen 1.6 parts; the actual reduction was, however, only 0·8 part.

In another series of experiments (See Table 31) tap water in which 10 parts per million of manganese as $MnSO_4 4 \cdot H_2O$ had been dissolved was used.

These results are generally similar to those in Table 30. Filtration through sand removed iron, but did not detectibly decrease manganese. The content of dissolved oxygen was decreased throughout more than one part per million by passage through the filters, even in the experiment in which no removal of manganese apparently took place. Filtration through sand coated with manganese dioxide removed all manganese and iron, decreased alkalinity 14 parts per million, and decreased dissolved oxygen about the same extent to which it was decreased in the sand filter.

In order to determine the effect of adding a coagulant, 2 grains per gallon of alum was added to the artificial water, the water was then aerated, and allowed to settle one hour as in the other series. The results obtained (See Table 32) indicate that little change is caused

TABLE 32.—REMOVAL OF MANGANESE BY AERATION AND FILTRATION, OF ARTIFICIAL WATER CONTAINING 5 PARTS PER MILLION OF MANGANESE AND 2 GRAINS PER GALLON OF ALUM. ALKALINITY BEFORE TREATMENT 356 PARTS.

[Parts per million.]

Determinations.	Unfiltered water.	Water filtered through— Sand.	Water filtered through— Sand coated with manganese dioxide.
AT START			
Manganese	5.0	4.8	0.0
Iron	.2	.0	.0
Alkalinity	340	340	328
Dissolved oxygen	8.0	6.5	6.5
AFTER 2 HOURS' OPERATION			
Manganese	5.0	4.7	.0
Iron	.2	.0	.0
Alkalinity	338	338	330
Dissolved oxygen	8.0	7.2	6.0
AFTER 4 HOURS' OPERATION			
Manganese	5.0	4.8	.0
Iron	.2	.05	.0
Alkalinity	340	338	328
Dissolved oxygen	8.0	7.0	6.2
AFTER 6 HOURS' OPERATION			
Manganese	4.8	5.0	.0
Iron	.2	.2	.0
Alkalinity	336	334	330
Dissolved oxygen	7.5	7.0	6.0

by addition of the coagulant. Complete removal of manganese was obtained by filtration through sand coated with manganese dioxide but practically no removal by filtration through sand alone.

The action in presence of both iron and manganese was studied by treating a mixture of distilled water and tap water in which 10 parts per million of manganese as $MnSO_4 \cdot 4H_2O$ and 10 parts per million of iron as $FeSO_4 \cdot (NH_4)_2SO_4 6H_2O$ had been dissolved (See Table 33). After this water had been aerated it had a high reddish-brown turbidity caused by precipitated ferric hydroxide. Treatment of this solution by filtration through sand alone resulted in complete removal of iron but no removal of manganese. Treatment of it by filtration through sand coated with manganese dioxide, however, completely removed manganese and iron. The alkalinity was not decreased by passage through either filter; this is not in accordance with the theory as the removal should have decreased the alkalinity by an amount equivalent to the manganese removed. This apparent discrepancy might be accounted for either by the presence of small amounts of substances capable of neutralizing free acid in the sand, or by oxidation of the manganous compound to a marked degree in the aeration and yet to a degree insufficient to form an insoluble compound.

TABLE 33.—REMOVAL OF MANGANESE BY AERATION AND FILTRATION OF A MIXTURE OF TAP WATER AND DISTILLED WATER CONTAINING 10 PARTS PER MILLION OF MANGANESE AND 10 PARTS PER MILLION OF IRON.

[Parts per million.]

Determinations.	Unfiltered water.	Water filtered through—	
		Sand.	Sand coated with manganese dioxide.
AT START			
Manganese	10.0	10.0	0.0
Iron	5.0	.1	.0
Alkalinity	24	26	30
Dissolved oxygen	7.3	7.4	2.9
AFTER 2 HOURS' OPERATION			
Manganese	9.5	10.0	.0
Iron	4.8	.0	.0
Alkalinity	24	24	30
Dissolved oxygen	7.6	7.5	2.8
AFTER 4 HOURS' OPERATION			
Manganese	9.0	10.0	.0
Iron	5.0	.0	.0
Alkalinity	22	24	30
Dissolved oxygen	7.6	7.8	6.0
AFTER 6 HOURS' OPERATION			
Manganese	10.0	9.0	.0
Iron	4.8	.0	.0
Alkalinity	24	24	28
Dissolved oxygen	7.6	7.3	7.0

Though no removal of manganese by filtration through sand could be detected by analysis the upper part of the sand became discolored by a slight deposit of manganese dioxide after the filter had been used for some time. This shows that there must have been some slight but continual removal of manganese by aeration and filtration. This slight deposit would rapidly aid in removal of more and more manganese until sufficient manganese dioxide would have been deposited to remove completely the manganese from water filtered through it; the process might be erroneously considered to be simply one of aeration and filtration through sand when in reality it is a catalysis by manganese dioxide.

Manganese-Removal Plants in Illinois

Manganese is efficiently removed from surface-water supplies by filtration through sand coated with manganese dioxide at two plants in Illinois. One of these filter plants was installed for removal of manganese as well as for hygienic purification of the water, and the other was installed for hygienic purification only, the presence of manganese in the water not being suspected. There was evidence of unsatisfactory removal of manganese for some time after the installation of these plants, but efficient removal resulted after a period had elapsed for the deposition of sufficient manganese dioxide in the filters. As no similar observations' have been reported a description of these two plants with some of the operating results are presented.-

REMOVAL OF MANGANESE AT ANNA.

The waterworks of Anna State Hospital, in southern Illinois, are located about 2 miles from Anna and about 3½ miles from the hospital buildings. The plant was put in operation in January, 1914.

About half the supply is derived from a.2,000,000-gallon impounding reservoir, on Kohler Creek, which is fed by springs which bubble up over the bottom of the reservoir as well as by rainfall on the watershed. The other half of the supply used is taken from Wilson Creek, a near-by stream.

Mineral analyses of these two sources of supply are given in Table 34.

The supply from Wilson Creek contains practically no manganese, but that from the reservoir contains a large amount.

The content of manganese of water from the reservoir varies widely. Turbidity, color, and bacterial content are low compared with those of other surface waters of Illinois. The water contains much

TABLE 34.—MINERAL ANALYSES OF THE WATER SUPPLY OF ANNA STATE HOSPITAL, OCTOBER, 1914.

[Parts per million.]

	Wilson Creek.	Reservoir.
IONS		
Potassium (K)	5.6	4.7
Sodium (Na)	17.8	11.8
Magnesium (Mg)	12.6	7.5
Calcium (Ca)	78.6	43.9
Iron (Fe)	1.0	0.6
Manganese (Mn)	Trace	1.4
Alumina (Al_2O_3)	1.2	3.0
Silica (SiO_2)	18.2	6.3
Nitrate (NO_3)	5.3	4.0
Chloride (Cl)	3.0	1.0
Sulfate (SO_4)	5.2	11.1
HYPOTHETICAL COMBINATIONS		
Potassium nitrate (KNO_3)	8.6	6.5
Potassium chloride (KCl)	6.3	2.1
Potassium sulfate (K_2SO_4)	....	2.4
Sodium sulfate (Na_2SO_4)	7.7	14.5
Sodium carbonate (Na_2CO_3)	35.2	10.8
Magnesium carbonate ($MgCO_3$)	43.6	26.0
Calcium carbonate ($CaCO_3$)	196.2	109.8
Iron carbonate ($FeCO_3$)	2.0	1.2
Manganese carbonate ($MnCO_3$)	Trace	2.9
Alumnia (Al_2O_3)	1.2	3.0
Silica (SiO_2)	18.2	6.3
Bases	2.0	0.0
Total	321.0	185.5

dissolved oxygen and very little carbon dioxide. Determinations showed 9.8 parts per million of dissolved oxygen, which is high, but only 3 parts per million of carbon dioxide when the temperature of the water was 20°C. The water is treated by ordinary mechanical filtration. About one grain per gallon of alum is added, after which the water passes through a sedimentation basin affording retention for 4 hours. Calcium hypochlorite is added at the outlet of the sedimentation basin at the rate of 0.2 part per million of available chlorine, after which the water passes to the filters. There are 3 concrete filter units, each having a capacity of 300,000 gallons per 24 hours. The nominal rate of filtration is 125,000,000 gallons per acre per day. The filters contain 9 inches of gravel and 30 inches of sand, which had, when it was put in place, an effective size of 0.55 millimeter and a uniformity coefficient of 1.43.

The presence of manganese in a surface water containing so much dissolved oxygen was not suspected until complaint was received that the filtered water was causing unsightly stains on white plumbing fixtures and was staining fabrics in the laundry a pale yellow. A content of 12 parts per million of manganese was found in the raw water July 22, 1914. Subsequent tests showed that the untreated water from the impounding reservoir contained 7.5 parts, July 30, and only

1.4 parts, October 5. The water of Wilson Creek contained 0.05 part July 30 and a trace October 5. The effluent from the filters contained 0.05 part July 30 and 0.0 part October 5. The analyses of raw and filtered water indicate an efficient removal of manganese by the treatment which the water received. In order to determine the cause of this removal the plant was visited in December, 1914, and it was arranged to have determinations of manganese made regularly in the laboratory of the waterworks.

It was impossible to obtain representative samples of the raw water, as the supplies from both reservoir and Wilson Creek enter the settling basin through separate inlets in such manner that thoroughly mixed samples can not be obtained until they emerge from the basin. Determinations of manganese in the water from the reservoir were made from December 1 to February 11, and one-half of this value was taken as the true content of manganese of the raw water used. Determinations were made, however, from February 11 to May 4 on the water at the outlet of the settling basin. It was found that the content of manganese of water at this point was about half that of water from the reservoir. As the determinations were made by the persulphate method on 50-cubic centimeter samples only figures in the first decimal place are significant. The results obtained on samples from December 1 to May 4 are shown in Table 35.

Manganese could be detected in the filtered water in only .7 of the 100 tests. The water applied to the filters during this period had a content of manganese of 0.0 to 1.0 part per million; the removal is, therefore, very efficient. The content of manganese of the reservoir supply has been slowly decreasing since the summer of 1914. In March and April, 1915, the content was 0.2 to 0.6 part per million, whereas in December, 1914, it was 1.0 to 2.0 parts per million. In order to determine the effect, if any, of treatment with hypochlorite on the removal of manganese the application of that chemical was omitted from May 1 to 4, 1915. As an effluent free from manganese was obtained during this period as before it seems apparent that as good results were obtained without as with bleach.

The walls of the concrete filter units were covered with a layer of manganese dioxide, which in appearance resembled asphaltum paint.

Samples of the filter sand were collected for examination. The sand was black although the incrustation was not sufficient greatly to increase the size of the grains. The incrustation was somewhat tenacious, but some of it became detached when the sand was stirred with

TABLE 35.—CONTENT OF MANGANESE OF RESERVOIR, RAW, AND FILTERED WATER AT ANNA STATE HOSPITAL.

[Parts per million.]

Date.	Reservoir water.	Raw water.	Filtered water.
1914			
Dec. 1	1.5	0.7	0.2
2	2.0	1.0	.2
3	1.0	.5	.0
5	1.2	.6	.1
7	1.4	.7	.0
9	.8	.4	.0
11	1.2	.6	.0
13	1.4	.7	.0
15	1.2	.6	.0
17	1.8	.9	.0
19	1.9	1.0	0
21	1.7	.8	.0
23	1.1	.6	.0
29	2.0	1.0	.0
31	1.7	.9	.0
1915			
Jan. 1	1.6	.8	.0
3	1.8	.9	.0
5	2.1	1.0	.0
7	2.2	1.1	.0
9	2.1	1.1	.0
11	2.1	1.1	.0
13	1.9	.9	.0
15	1.8	.9	.0
17	1.7	.9	.0
19	1.6	.8	.0
21	1.6	.8	.0
23	1.4	.7	.0
25	1.4	.7	.0
27	1.6	.8	.0
29	1.8	.9	.0
31	1.9	1.0	.0
1915			
Feb. 1	1.6	0.8	0.0
3	1.4	.7	.0
5	1.2	.6	.0
7	1.6	.8	.0
9	.8	.4	.0
11	.5	.3	.0
13	.4	.2	.0
15	.2	.1	.0
*17	.0	0	.0
*19	.0	.0	.0
21	.2	1	.0
23	.2	.0	.0
25	.3	1	.0
27	.3	.1	.0
1915			
Mar. 1	.4	.2	.0
2	.4	.1	.0
3	.5	.2	.2
4	.6	.4	.0
5	.4	.2	.0
6	.4	.2	.1
8	.6	.4	.1
9	.4	2	.0
10	.2	.0	.0
11	.2	.0	.0
12	.2	.0	.0
15	.4	.2	.1
16	.4	.1	.0
17	.6	.2	.0
18	.4	.2	.0
19	.4	.1	.0
20	.5	.3	.0
22	.4	.2	.0
23	.2	.1	.0
24	.2	.1	.0
25	.2	.0	.0
26	.4	.2	0
27	.2	.0	.0
29	.2	.1	.0
30	.3	.2	.0
31	.3	.0	.0
1915			
Apr. 1	0.2	0.1	0.0
2	.2	.0	.0
3	.1	.0	.0
5	.2	.2	.0
6	.3	.1	.0
7	.3	.0	.0
8	.3	.1	.0
9	.4	.2	.0
10	.4	.2	.0
12	.4	.1	.0
13	.3	.1	.0
14	.3	.1	.0
15	.4	.2	.0
16	.3	.0	.0
17	.5	.3	.0
19	.4	.0	.0
20	.5	.3	.0
21	.4	.2	.0
22	.3	.1	.0
23	.4	.2	.0
24	.5	.3	.0
26	.3	.2	.0
27	.4	.3	.0
28	.4	.2	.0
29	.5	.3	.0
30	.3	.1	.0
1915			
May 1	.3	.1	.0
3	.6	.4	.0
4	1.0	.5	.0

*Heavy rains.

water. The results of a soil analysis of the sand are given in Table 36. Microscopic examination of the sediment washed from the sand grains as well as of the sediment from the water used in washing the filters showed the presence of diatoms and algae, but no organisms resembling *Crenohrix* were found. The material consisted chiefly of debris, such as sand, clay, and precipitated hydroxides of manganese, iron, and aluminium.

TABLE 36.—ANALYSIS OF FILTER SAND, ANNA STATE HOSPITAL.

Insoluble in hydrochloric acid	98.25
Soluble in hydrochloric acid	1.75
Loss on ignition	.91
The soluble portion consists of:	
Ferric oxide (Fe_2O_3)	16.8
Alumina (Al_2O_3)	26.5
Manganese dioxide (MnO_2)	12.0
Loss on ignition	54

The presence of manganese dioxide in the incrustation on the filter sand is sufficient to account for the removal of the manganese from the water. Some experiments were undertaken, however, to determine whether manganese dioxide was the only factor in the process. The two experimental filters, one containing sand and the other sand impregnated with manganese dioxide, which had been used in the former experimental work with artificially prepared waters, were used at Anna for filtering the raw water. The raw water contained 9.6 parts per million of dissolved oxygen and 3 parts per million of free carbon dioxide. Its temperature was 20°C. The results obtained are shown in Table 37. Complete removal of manganese was obtained when the filter containing manganese dioxide was used, but only slight removal of manganese was obtained when the filter containing sand alone was used. This filter, however, had been used for similar work previously, and a small amount of manganese dioxide that may have been present on the sand grains doubtless aided the removal.

TABLE 37.—REMOVAL OF MANGANESE BY FILTRATION OF RAW, WATER AT ANNA STATE HOSPITAL THROUGH EXPERIMENTAL FILTERS OF SAND AND OF SAND ARTIFICIALLY COATED WITH MANGANESE DIOXIDE.

[Parts per million of manganese.]

Raw water.	Water filtered through—	
	Sand.	Sand coated with manganese dioxide.
1.0	0.8	0.0
1.0	1.0	.1
1.0	.9	.0
1.0	.9	.0

In order to test the theory more completely the raw water was filtered through another pair of filters, one containing some unused sand like that with which the large filters at Anna are filled and the other containing sand from the filters which had been used nearly a year. The latter sand was coal black due to the coating of manganese dioxide which had formed on the grains. The results of these experiments are shown in Table 38. Complete removal of manganese was obtained with the used sand, and practically no removal was obtained with the unused sand.

TABLE 38.—REMOVAL OF MANGANESE BY FILTRATION OF RAW WATER AT ANNA STATE HOSPITAL THROUGH EXPERIMENTAL FILTERS OF UNUSED SAND AND OF SAND AFTER USE NATURALLY COATED WITH MANGANESE DIOXIDE.

[Parts per million of manganese.]

Raw water.	Water filtered through—	
	Unused sand.	Used sand.
1.0	1.0	0.0
1.0	1.2	.0
1.0	1.0	.0
1.0	1.0	.0

The city of Dresden, Germany, has installed[1] a manganese-removal plant, in which the water is filtered through a growth of manganese-depositing microorganisms that remove the manganese from the water. No microorganisms of this character could be detected by microscopic examination of the filter sand and the sediment in the wash water from the plant at Anna. In order to test the possibility of their significance in the removal, however, some of the black sand which had been in use for several months and was removing the manganese was sterilized in the autoclave. A filter was prepared from

TABLE 39.—REMOVAL OF MANGANESE BY FILTRATION OF A SOLUTION OF 5 PARTS PER MILLION OF MANGANESE IN DISTILLED WATER THROUGH AN EXPERIMENTAL FILTER OF STERILIZED USED SAND.

[Parts per million of manganese.]

Raw water.	Water filtered through—	
	Unused sand.	Used sand sterilized.
5.0	4.8	0.0
5.0	5.0	.0
5.0	5.0	.0
5.0	5.0	.0

[1]Vollmar, D., Die Entmanganung des Grundwassers im Elbtale und die fur Dresden ausgeführten Anlagen: J. Gasbel., 67, 944-8, 956-9 (1914).

this sterilized sand, and after it had been washed until it was free from manganese it was used to filter a solution of 5 parts per million of manganese as $MnSO_4 \cdot 4H_2O$ in distilled water. The results, in Table 39, show that complete removal of manganese was obtained by filtration through the sterilized sand.

The results of these experiments prove conclusively that the deposit of manganese dioxide on the grains of sand effects the removal of manganese. The deposit, however, has been formed gradually by the slow deposition of manganese from the manganese-bearing water assisted by direct oxidation by the dissolved oxygen. The large amount of dissolved oxygen always present in the raw water evidently oxidizes the lower oxide of manganese to the dioxide at the time the manganese is removed. The process is, therefore, catalytic and no regeneration is necessary. When the filter is washed the grains of sand are stirred up, and the friction probably is sufficient to scour off the coating of manganese dioxide sufficiently to prevent difficulty in operation of the plant.

REMOVAL OF MANGANESE AT MOUNT VERNON

Mount Vernon, a city of approximately 8,000 population, is in the central part of Jefferson County, Illinois. The water supply is

TABLE 40.—MINERAL ANALYSES OF THE WATER SUPPLY OF MOUNT VERNON.

[Parts per million.]

	Casey Fork.	Reservoir.
IONS		
Potassium (K)	7.6	8.3
Sodium (Na)	9.8	13.1
Magneisum (Mg)	10.0	17.6
Calcium (Ca)	13.2	23.3
Iron (Fe)	.1	1.6
Manganese (Mn)	Trace	1.15
Alumina (Al_2O_3)	2.0	1.0
Silica (SiO_2)	17.4	7.0
Nitrate (NO_3)	6.0	2.7
Chlorine (Cl)	3.0	5.0
Sulphate (SO_4)	62.1	130.8
Bases	5.4	3.8
HYPOTHETICAL COMBINATIONS		
Potassium nitrate (KNO_3)	9.8	4.4
Potassium chloride (KCl)	6.3	10.5
Potassium sulphate (K_2SO_4)	.9	2.2
Sodium sulphate (Na_2SO_4)	28.7	40.0
Magnesium sulphate ($MgSO_4$)	49.4	87.0
Calcium sulphate ($CaSO_4$)	3.5	45.8
Calcium carbonate ($CaCO_3$)	30.5	24.5
Iron carbonate ($FeCO_3$)	.2	3.3
Manganese carbonate ($MnCO_3$)	Trace	2.3
Alumina (Al_2O_3)	2.0	1.0
Silica (SiO_2)	17.4	7.0
Bases	5.4	3.8
Total	154.1	231.8

TABLE 41.—CONTENT OF MANGANESE OF RAW AND FILTERED WATER AT MOUNT VERNON.

[Parts per million.]

Date.	Raw water.	Filtered water.	Date.	Raw water.	Filtered water.
1914			1915		
Jan. 9	0.4	0.2	Feb. 16	0.4	0.0
Feb. 16	.4	.25	18	.5	.1
Mar. 24	.5	.1	20	.4	.0
July 23	.05	.05	23	.5	.0
Aug. 19	.12	.12	25	.5	.0
Oct. 14	.4	.0	28	.4	.0
Dec. 2	.4	.0	Mar. 2	.4	.1
5	.4	.0	4	.4	.1
7	.4	.0	6	.4	.1
9	.4	.0	15	.4	.0
11	.4	.0	18	.4	.1
14	.6	.2	20	.3	.0
16	.6	.2	23	.3	.0
19	.7	.1	25	.3	.0
21	.7	.2	27	.3	.0
23	.8	.1	29	.3	.0
26	.6	.0	31	.2	.0
28	.6	.1			
31	.6	.1			
1915					
Jan. 4	.6	.1	Apr. 2	.3	.1
6	.6	.1	5	.2	.0
9	.6	.0	6	.2	.0
12	.7	.1	8	.2	.0
13	.7	.2	10	.2	.0
15	.8	.2	12	.2	.0
18	.8	.3	13	.2	.0
22	.8	.3	16	.2	.0
23	.8	.2	17	.2	.0
25	.7	.1	22	.3	.0
27	.7	.0	24	.3	.0
29	.6	.0			
Feb. 1	.6	.1			
3	.6	.2			
6	.6	.1			
9	.4	.0			
12	.4	.0			
15	.4	.0			

obtained chiefly from an impounding reservoir fed by springs in the bottom, but Casey Fork, a branch of Big Muddy River, furnishes an auxiliary supply. Water from an impounding reservoir on Casey Fork is pumped into the reservoir which is fed by springs. The mineral character of these two supplies is shown by the analyses in Table 40. Both supplies have a high percentage of saturation with dissolved oxygen. The water is treated with about one-half grain per gallon of alum. After sedimentation it is treated with calcium hypochlorite at the rate of 0.2 to 0.3 part per million of available chlorine. Three concrete filters, each having a capacity of 500,000 gallons a day, operate at a rate of 125,000,000 gallons per acre per day.

The results of determinations of manganese made in the raw and in the filtered water from January, 1914, to April, 1915, are shown in Table 41. The determinations after December 1, 1914, were made in the laboratory of the waterworks at Mount Vernon. The content of manganese of the untreated water varied rather widely, the range having been from 0.05 to 0.8 part per million during one year. The efficiency of removal of manganese is well shown by comparison of the contents of the raw and filtered waters. The content of manganese of the filtered water has ranged from 0.0 to 0.3 part per million. No manganese was found in the filtered water on 35 of the 65 days on which tests were made.

The filter sand was coated with a dark colored substance, which contained a large amount of manganese. The results of the analysis of the sand are shown in Table 42. When the sand was examined microscopically before being washed no Crenothrix or similar organisms were found. The wash water contained clay, dirt, inert matter, diatoms, chlorophyl-bearing algae, debris, and similar material.

TABLE 42.—ANALYSIS OF FILTER SAND, MOUNT VERNON.

Insoluble in hydrochloric acid	**99.01**
Soluble in hydrochloric acid	**.99**
Loss on ignition	**.43**
The soluble portion consists of:	
Ferric oxide (Fe_2O_3)	**4.8**
Alumina (Al_2O_3)	**27.7**
Manganese dioxide (MnO_2)	**35.0**
Loss on ignition	**43**

The filter medium used at this plant is, therefore, similar to that used at Anna State Hospital. As the incrustation of the sand is not so great its content of manganese dioxide is somewhat smaller. This fact probably explains the somewhat lower efficiency of removal at Mount Vernon compared with that obtained at Anna State Hospital. The removal is effected, however, in exactly the same process as at the hospital, namely, by filtration through sand coated with a layer of manganese dioxide, which effects the removal.

INCRUSTATION OF WATER PIPES BY MANGANESE BEARING WATERS

The fact that water which carries only a small amount of manganese will cause serious incrustation of water pipes has been noted by many investigators. The incrustations consist chiefly of oxides of manganese and iron. Weston[1] gives analyses of three such incrustations, collected from the water mains at Hanover, Germany and analyzed by him. The largest amount of manganese present was 7.15

[1]Weston, R. S., The purification of ground waters containing iron and manganese: Trans. Am. Soc. C. E., 64, 112-81 (1909).

per cent. Raumer[1] found an incrustation in the water supply of Fürth which contained 43.85 per cent of Mn_3O_4, equivalent to 10.52 per cent of manganese. The raw water contained 2 parts per million of manganese. Threadlike organisms resembling Crenothrix were found. Other examples of the clogging of pipes by manganese waters are noted by Bailey,[2] Jackson,[3] Beythien, Hempel, and Kraft,[4] Volmar,[5] and others. Most of these investigators attribute the deposition to the growth of iron and manganese-secreting bacteria which deposit the oxides of these metals in their sheaths.

Similar incrustations, whose composition is reported by Bartow and Corson,[6] have caused serious difficulty in the water supplies of Mount Vernon and Peoria, Illinois. In a microscopic examination of these deposits no organisms resembling Crenothrix could be found. Specimens from the water mains of Mount Vernon, Peoria, Anna, and Springfield contained large amounts of iron and manganese, but none of the oxide-depositing bacteria. These incrustations, moreover, did not present the thread-like, filamentous appearance which is usually characteristic of growths of Crenothrix,

In view of the important catalytic effect of manganese dioxide in processes of removal it seems probable that this substance is responsible for the formation of the incrustations where organisms do not play a part. If a manganese-bearing water containing dissolved oxygen is pumped into the distribution system there is undoubtedly a very slight precipitation of manganese as the hydrated dioxide. This dioxide then reacts with the manganous compound in the water and removes it as a lower oxide. The dissolved oxygen present, however, simultaneously oxidizes this lower oxide to manganese dioxide. The process is, therefore, catalytic, and is exactly the same as that occurring in the removal of manganese in a manganese-dioxide filter. As acid is formed as one of the products of reaction when manganese is removed the hydrogen-ion concentration of the water determines the point at which equilibrium is reached. Free carbon dioxide in solution renders water acid. So-

[1]Raumer, E. von, Ueber das Auftreten von Eisen und Mangan in Wasserleitungswasser: Z. anal. Chem., 42, 590-602 (1903).

[2]Bailey, E. H. S., Occurrence of manganese in a deposit found in city water pipes: J. Am. Chem. Soc, 26, 714-5 (1904).

[3]Jackson, D. D., The precipitation of iron, manganese, and aluminum by bacterial action: J. Soc. Chem. Ind., 21, 681-4 (1902).

[4]Beythien, A., Hempel, H., and Kraft, L., Beiträge zur Kenntnis des Vorkommens von Crenothrix Polyspora in Brunnenwassern: Z. Nahr. Genussm., 7, 215-21 (1904).

[5]Vollmar, D., Die Entmanganung des Grundwassers im Elbtale und die für Dresden ausgeführten Anlagen: J. Gasbel., 67, 944-8, 956-9 (1914).

[6]Corson, H. P., Occurrence of manganese in the water supply and in an incrustation in the water mains at Mount Vernon, Illinois: Illinois Univ. Bull., Water-Survey Series 10, 57-65 (1913).

dium, calcium, and magnesium bicarbonates, on the other hand, render water alkaline because they are hydrolyzed. Both carbon dioxide and bicarbonate are usually present, and whether a water is acid or alkaline depends on the relative amounts of each in the solution. It is clear that the lower the content of free carbon dioxide and the higher the content of bicarbonate, the lower will be the hydrogen-ion concentration, and, therefore, the greater the tendency toward precipitation of manganese.

CONCLUSION

The results of the researches and experimental investigations conducted by the writer on manganese in water and described herein are summarized in the following paragraphs.

The persulphate method is the most convenient and accurate method for the colorimetric determination of manganese in water. Chloride does not interfere. Five-thousandths of a milligram of manganese in a volume of 50 cubic centimeters, equivalent to 0.1 part per million, can be detected.

The standardized bismuthate method is accurate and reliable. The presence of chloride in amounts less than 5 milligrams does not interfere with this determination. By this method 0.01 milligram of manganese in a volume of 50 cubic centimeters, equivalent to 0.2 part per million, can be detected.

The lead-peroxide method gives too low results because of reduction of permanganate in using the Gooch crucible. The presence of chloride interferes in this method more seriously than in either of the others, and if more than 5 milligrams of chloride are present no manganese may be found even if a comparatively large amount is present. This method is at best the least sensitive of the three, and it should be rejected as a standard method.

Manganese occurs normally in certain classes of water in Illinois, and amounts sufficient to affect the quality have been found in several waters.

Little manganese is present in water from "Potsdam" sandstone, St. Peter sandstone, the overlying limestones, Lake Michigan, and the large rivers.

Manganese is usually present in large amounts in coal-mine drainage, in water from some impounding reservoirs on small streams in southern Illinois, and in water from some wells entering unconsolidated deposits near rivers. No apparent relation exists between the content of manganese of a water and any of the other mineral constituents.

The principle underlying all processes for the removal of manganese from water supplies, except those of direct chemical precipitation, is the reaction between manganous compounds and manganese dioxide to form a lower oxide.

The removal of manganese by the permutit process takes place according to this reaction, as the state of oxidation of manganese in the substance is not greater than that in manganese dioxide. This is in agreement with the view of Tillmans. No evidence of the existence of oxides higher than MnO_2 in this substance was found by the writer, contrary to the suggestion of Gans and the Permutit Co.

No appreciable removal of manganese was obtained on an experimental scale by aeration and sand filtration, as reported by Thiesing, Weston, and Barbour. When an artificial coating of manganese dioxide was prepared on the grains of sand, however, complete removal of manganese was obtained. Manganese is efficiently removed from water supplies at Anna and Mount Vernon, Illinois, by this process, a coating of manganese dioxide having formed on the sand. If the water contains dissolved oxygen regeneration of the filter is unnecessary, and the process may be considered catalytic.

The success of the aeration and sand-filtration process used by Thiesing, "Weston, and Barbour is in reality due to the action of manganese dioxide and not to aeration and sand filtration alone. The assumption that manganese may be removed by the same process which removes iron is incorrect.

The formation of incrustations of manganese in water pipes, where manganese-secreting bacteria are not present, is explainable by the catalytic action of manganese dioxide.

THE ARSENIC CONTENT OF SULFATE OF ALUMINIUM USED FOR WATER PURIFICATION[1]

By Edward Bartow and A. N. Bennett.

Specifications requiring arsenic-free sulfate of aluminium or filter alum for water treatment by several European[2] purification plants suggested that it would be advisable to make determinations of the arsenic content of the sulfate of aluminium used in this country and particularly of that used in the State of Illinois.

It is well known that products which are manufactured with the aid of commercial sulfuric acid quite generally contain, more or less arsenic, depending upon the purity of the acid used. The poisonous character of arsenic compounds, even when present in small amounts, makes it of general interest and importance to have definite knowledge of the presence or absence of arsenic in any substance which enters directly or indirectly into foods or drinks. Sulfuric acid is used in the manufacture of sulfate of aluminium and it is, therefore, quite essential, particularly to those who are in public health work, to know whether arsenic in any considerable amounts is being added to drinking water in the process of purification with this chemical.

We have been unable to find any definite published data relating to the arsenic content of sulfate of aluminium. Dr. George A. Soper several years ago made an investigation of this problem, and referred to his results while discussing a paper by Mr. E. E. Wall[3] on "Water Purification at St. Louis, Missouri." Dr. Soper was discussing in particular the use of sulfate of iron in water treatment and spoke in the following manner:

> There is a final point which the speaker hesitates to mention, but, inasmuch as before this society it will probably be taken in the conservative spirit in which it is intended, and may lead to useful inquiries, it may be referred to briefly. It concerns the composition of the sulfate of iron used * * * * What are the impurities in this sulfate? How much arsenic is there in this sulfate? Some years ago the speaker had occasion to examine specimens of sulfate of aluminium from a good many filter plants and found arsenic in nearly all of them. It is true, that usually the arsenic was not present in large quantities, but it was easily discoverable, and in some of the samples it

[1]Abstract of thesis presented in partial fulfillment of requirements for the degree of Master of Science by A. N. Bennett, June 1915. J. Am. W. W. Assoc, 2. 585-93 (1915).
[2]J. Gasbel., 56, 882 (1913).
[3]Trans. Am. Soc. C. E., 60, 202-9.

was present in sufficient amount to be of more than passing interest. The arsenic, of course, came from the sulfuric acid used in making the sulfate of aluminium, the sulfuric acid having been produced from pyrites which contained arsenic.

From Dr. Soper's first remark it is evident he realized that, due to the increasing public prejudice against the use of any material containing arsenic or other similar poison, a great injustice might be worked upon both the manufacturer and the plants that use sulfate of aluminium for water treatment, by giving widespread publicity to this matter; at least, before all phases of the problem had been thoroughly investigated. The writers, too, are of this same opinion and so have refrained from mentioning the names of any manufacturers whose product have been examined and have also omitted the names of all filter plants outside the State of Illinois.

We have found but one other reference to the arsenic content of water-treatment materials. In further discussion of the same paper and relative to sulfate of iron, Mr. E. E. "Wall, in reply to Dr. Soper's statements, said:

The writer has a copy of a report * * * * in which it is stated that no arsenic was found in any of the samples tested and that the small quantity of arsenic in the sulfuric acid used in cleaning steel is, without doubt, removed in the cleaning tubs in the form of arsenureted hydrogen, thus leaving the liquors from which copperas is made, free from arsenic. Even if there should be a minute quantity of arsenic in the sulfate of iron, it is scarcely possible that this could remain in the water after treatment with the quantity of lime used at St. Louis.

The explanation of the absence of arsenic in sulfate of iron due to its loss as arsine is quite feasible but such is not the case with sulfate of aluminium. This material is made by digesting bauxite with the required amount of sulfuric acid, consequently all or practically all of the arsenic present in the acid will remain in the finished product.

We have not been able to learn that anything has been done in this country to regulate the amount of arsenic in sulfate of aluminium. The purification plants, at least in the State of Illinois, have made no effort to obtain an arsenic-free article. The manufacturers keep more or less accurate records of the arsenic content of their product. The writers have found only one producer who advertises "arsenic-free alum." Neither the Government nor any of the States has promulgated legislation regulating this product, although there is a regulation concerning arsenic in other substances entering into foods. The Government has set a limit for arsenic in coal-tar dyes and in baking powder of one part in 700,000. This very low limit, particularly when it is considered that only relatively small amounts of these substances are used in food preparation, shows that considerable importance is attached to the presence of arsenic and its compounds.

MANUFACTURE

Sulfate of aluminium is manufactured by digesting finely ground bauxite, $Al_2O_3,2H_2O$, with the required amount of sulfuric acid. After the reaction is complete the liquor is filtered to remove silica and other insoluble impurities. The clarified solution is concentrated in evaporating pans. When cool and solidified, it is broken or ground to the desired fineness required by the trade. It consists largely of the normal sulfate, $Al_2(SO_4)_3,18H_2O$, with a small amount of a basic sulfate, so that there is an excess of Al_2O_3 over the amount required to combine with the SO_3 present. All specifications for this product call for at least 17% Al_2O_3. The following is a typical analysis. Total Al_2O_3, 17.5% ; Free Al_2O_3, 1.5%; Total SO_3, 38.5%, Fe_2O_3, .5% ; Water of crystallization, 40%.

There is a sulfate of aluminium on the market containing 22% Al_2O_3. This is made by driving off sufficient water of crystallization to make the required percentage of Al_2O_3. To prepare this product approximately 60% of the water of crystallization would have to be driven off to raise the Al_2O_3 content from 17% to 22%. Its chief advantage consists in the saving effected in transportation charges.

It is readily seen from the process of manufacture that practically all of the arsenic present in the sulfuric acid will appear in the finished product. The arsenic content of the sulfuric acid depends upon two factors; first, the amount of arsenic present in the raw material from which it is manufactured and second, the method of manufacture.

Sulfuric acid is manufactured from pyrites (FeS_2), zinc-blende (ZnS) or sulfur by the lead-chamber process or by the contact process. The amount of arsenic in pyrites is variable so that sulfurie acid manufactured from it may vary widely in arsenic content. Zinc-blende and sulfur are comparatively free from arsenic and yield an acid containing but little. Sulfuric acid manufactured from pyrites by the lead-chamber process contains a large percentage of the arsenic of the raw materials unless special means for removing it have been taken. Arsenic interferes with the catalytic action of the platinum in the contact process, so that it must be removed from the gases before they are passed over the catalyser. Thus the contact process furnishes an acid practically free from arsenic.

One water-purification plant* manufactures its own sulfate of aluminium effecting a considerable saving in the cost of the product. In this case it is not necessary to produce the product in the solid form. After the action of the sulfuric acid upon bauxite is complete the mixture is ready for use. In this way the filtration, evaporation and crushing of the product are eliminated.

METHOD OF USING

Sulfate of aluminium is used for the purpose of clarifying turbid waters and for removing the soluble coloring matter. From 1 to 6 grains per gallon are added according to the character of the water treated. Aluminium hydroxide is formed by reaction with alkaline salts present in the water according to the following equations:

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 = 2Al(OH)_3 + 3CaSO_4 + 6CO_2$$
$$Al_2(SO_4)_3 + 3Mg(HCO_3)_2 = 2Al(OH)_3 + 3MgSO_4 + 6CO_2$$
$$Al_2(SO_4)_3 + 6NaHCO_3 = 2Al_2(OH)_3 + 3Na_2SO_4 + 6CO_2$$

On settling, this aluminium hydroxide floc mechanically carries down the suspended matter including many of the bacteria. The coloring matter which is largely organic is precipitated with the hydroxide.

SAMPLES

In order that results might be of greatest value by showing the condition of the material as it is actually used, as many samples as possible were first obtained directly from the water-purification plants in Illinois. Twenty-six plants use sulfate of aluminium in treating water. The purpose of the investigation was explained to the managers of each plant. They were asked to cooperate by furnishing a sample of the sulfate of aluminium used, together with the name of the manufacturer or dealer supplying the same. Twenty-two of the plants very promptly complied with the" request, and in nearly every case expressed decided interest in the subject with a wish to know the results of the investigation.

Owing to expense of transportation practically all of the sulfate of aluminium used in Illinois is supplied by three manufacturers. In order to make our study more complete we have extended the scope of our investigations and have secured samples from practically all of the large manufacturers of sulfate of aluminium in the country.

*Eng. Record, 71, 676.

In some cases the samples came directly from the producer, and in others from the water-treatment plants. The specimens were carefully sampled, ground and analyzed in duplicate by the following methods.

METHODS OF ANALYSIS

The method used in obtaining most of the data given is a modified Gutzeit method, developed by Mr. Claude R. Smith[1] in his work on coal-tar dyes and other food constituents. The results obtained by this method were in several cases checked by the Marsh-Berzelius method[2] and were found to agree. The Gutzeit method has been investigated by Sanger and Black[3] and others for quantitative work, and, when proper care is taken in the manipulation, has been found to give satisfactory results. The chief modification proposed by Smith is the use of paper sensitized with mercuric bromide instead of mercuric chloride, which had previously been generally used. The bromide gives more permanent stains and the standards can be kept longer. The method depends upon the. formation of a dark orange stain when the generated arsine is brought in contact with the sensitized paper. The apparatus used is essentially as described by Smith. The generator is a 50 cc. wide mouth Erlenmeyer flask. This is connected with two upright tubes 8 cm. in length and one cm. in diameter, the lower containing lead acetate paper and the upper filled with cotton moistened with 5 per cent lead acetate solution. Fitted into the upper tube by means of a rubber stopper is a capillary tube 3 mm. in internal diameter and 12 cm. in length. This capillary is constricted at two joints about 3½ cm. from each end. By this means the sensitized paper is held in the center of the tube thus producing stains of equal length on both sides of the paper. Under uniform conditions, the length of the stain varies with the amount of arsenic present. A series of standard stains prepared from known amounts of arsenic is used for comparison. A convenient series is made from 2, 5, 7.5, 10 and 15 micromilligrams. The amount of arsenic in the sulfate of aluminium is determined by matching the stain it produces with the standards; it is then a matter of simple calculation to determine the percentage arsenic content or the parts per million of arsenic. A one gram sample will contain as many parts per million of arsenic as there are micromilligrams of stain obtained. For example, if one gram of sulfate of aluminium produces a stain which matches the 5 micromilligram standard stain, then that sample con-

[1]U. S. Dept. Agr., Bur. of Chem., Circular No. 102.
[2]U. S. Dept. Agr., Bur. of Chem., Circular No. 99.
[3]J. Soc. Chem. Ind., 26, 1115 (1907).

tains 5 parts per million. One part per million is equivalent to 0.0001 of one per cent. A stain representing between 5 and 25 micromilligrams gives the most satisfactory results. A stain between these limits can be obtained by varying the weight of sulfate of aluminium used.

For the analysis of sulfate of aluminium containing more than 30 parts per million As_2O_3, another method proposed by Smith, was used. The generated arsine is passed into mercuric chloride solution (10 cc. of 5 per cent $HgCl_2$ diluted to 100 cc). According to Smith probably several different arsenides of mercury and some free arsenic are formed. These are oxidized by the excess of mercuric chloride, slowly in. the cold and rapidly on heating, forming arsenous acid and mercurous chloride. The mercurous chloride can be filtered off and weighed and the arsenous acid in the filtrate determined by titration with iodine. In this way checks are obtained in the. one determination. The equation used for the calculation of arsenic from the weight of mercurous chloride obtained is:

$$2AsH_3+12HgCl_2+3H_2O=12HgCl+As_2O_3+12HCl$$

Thus $1As_2O_3$ is equivalent to 12HgCl.

As an alternative the conglomerate precipitate can be titrated by means of iodine. Sufficient potassium iodide is added to form the soluble double potassium mercuric iodide and then an excess of standard iodine solution. "When all the precipitate has gone into solution the excess iodine is titrated with standard thiosulfate. The iodine absorption represents the oxidation of arsine to arsenic acid in which 1As is equivalent to 81.

As usual all reagents used were tested to prove their freedom from arsenic.

DETERMINATION OF ARSENIC

Five grams of finely ground sulfate of aluminium are dissolved in the generating flask in 30 cc. of sulfuric acid (1:4) with the aid of heat. Four or five drops of a 40 per cent solution of stannous chloride in concentrated hydrochloric acid are added and the solution cooled. Four or five grams of arsenic-free moss zinc are now added and the lead acetate tubes and capillary containing the sensitized strip are connected. The evolution of gas is allowed to proceed for at least one hour. The stain, after drying, is then compared with the standards. A steady brisk but not violent evolution of gas should be maintained. This can be regulated by varying the acidity, volume of solution, amount of zinc and temperature. After a little experience very uniform results can be obtained. In the determination of larger amounts of arsenic it is necessary to allow the evolution of gas to proceed for two or three hours.

The sensitized paper is made from heavy, close-textured drafting paper, cut into strips 2.5 mm. by 12 cm. These strips are soaked for an hour in a 5 per cent alcoholic solution of mercuric bromide. The excess solution is squeezed off and the strips allowed to dry.

The results from the samples obtained from the Illinois purification plants are given in Table 1, those from outside the State in

TABLE 1.—ARSENIC AS As_2O_3 IN SULFATE OF ALUMINIUM USED IN ILLINOIS.

City.	Arsenic as As_2O_3		Gallons.[a]
	Parts per million.	Per cent.	
Cairo	1.6	0.00016	3213
Carlinville	1.8	0.00018	2856
Charleston	1.2	0.00012	4283
Chicago and Rogers Park	1.4	0.00014	3671
East St. Louis and Granite City	.8	0.00008	6425
Decatur	1.4	0.00014	3671
Elgin	1.6	0.00016	3213
Evanston	1.4	0.00014	3671
Fort Sheridan	1.2	0.00012	4283
Hamilton	1.4	0.00014	3671
Kankakee	.8	0.00008	6425
Kenilworth	1.4	0.00014	3671
Lawrenceville	3.0	0.00030	1713
Macomb	1.6	0.00016	3213
Moline	1.0	0.00010	5140
Mount Carmel	2.0	0.00020	2570
Mount Vernon	1.2	0.00012	4283
Pana	1.2	0.00012	4283
Quincy[b]	1.0	0.00010	5140
Quincy[b]	4.0	0.00040	1285
Rock Island	2.0	0.00020	2570
Rock Island Arsenal[b]	1.6	0.00016	3213
Rock Island Arsenal[b]	1.0	0.00010	5140
Streator	3.4	0.00034	1512

[a]Gallons of water containing a minimum medicinal dose of 2 mgm. when the water is treated with 6 grains of sulfate of aluminium per gallon, provided that all the arsenic remains in solution.

[b]Two samples from different manufacturers.

Table 2. In all cases the arsenic is recorded as arsenic trioxide, As_2O_3. Twenty-four samples from Illinois plants and seventeen from sources outside the State were analyzed.

The results obtained by analyzing sulfate of aluminium used in Illinois clearly show that arsenic in exceedingly small amounts is always present. We find a minimum of 0.8 part per million (0.00008 per cent) and a maximum of 4.0 parts per million (0.0004 per cent) of arsenic as As_2O_3 in the sulfate of aluminium used by Illinois water-purification plants. If a water were treated with sulfate of aluminium containing the maximum amount of arsenic found, at a rate of 6 grains of sulfate of aluminium per gallon, an amount which is very seldom exceeded, and if all the arsenic were soluble and remained in the filtered water, since arsenic is not a cumulative poison, a person must drink 1,285 gallons of the treated water at one time to obtain a medicinal dose of 2 mgms. From this it is readily seen that the arsenic content of sulfate of aluminium used in Illinois is of no significance.

TABLE 2.—ARSENIC IN SULFATE OF ALUMINIUM OBTAINED FROM SOURCES OUTSIDE OF ILLINOIS.

Sample.	Arsenic, As_2O_3. Parts per million.	Arsenic, As_2O_3. Per cent.	Gallons.[a]
1	0.5	0.00005	10280.0
2	1.2	0.00012	4283.0
3	1.2	0.00012	4283.0
4	1.4	0.00014	3671.0
5	2.6	0.00026	1977.0
6	2.6	0.00026	1977.0
7	4.0	0.0004	1285.0
8	4.0	0.0004	1285.0
9	5.0	0.0005	1028.0
10	20.0	0.0020	257.0
11	27.0	0.0027	190.0
12	31.0	0.0031	166.0
13	49.0	0.0049	105.0
14	280.0	0.0280	18.0
15	941.0	0.0941	5.5
16[b]	1240.0	0.124	4.0
17	1240.0	0.124	4.0

[a]Gallons of water containing a minimum medicinal dose of 2 mgm. when the water is treated with 6 grains of sulfate of aluminium per gallon, provided that all the arsenic remains in solution.

[b]Nos. 16 and 17 were obtained from the same plant and are probably from the same lot.

The samples obtained from sources outside the State showed a wider range in arsenic content. In one case there was 0.5 part per million (0.00005 per cent), and in nine cases there was more than in the highest Illinois sample, the maximum being 1,240 parts per million of arsenic as As_2O_3 (0.124 per cent).

If a water were treated with sulfate of aluminium containing 1,240 parts per million As_2O_3, at the rate of 6 grains per gallon and provided all the arsenic remained in solution, 0.13 part per million of arsenic as As_2O_3 would be added and a medicinal dose of 2 mgm. would be contained in four gallons. This would be quite an appreciable amount and is more than should be added in water purification. However, owing to the insolubility of the arsenites and arsenates of calcium, magnesium, aluminium and iron, a large part of the arsenic would be removed with the precipitated aluminium hydrate. To determine the extent of this removal, several experiments were carried out.

Two liters of water were treated at the rate of 6 grains per gallon with sulfate of aluminium containing 941 parts per million of As_2O_3. By this treatment 188 micromilligrams of As_2O_3 were added. Forty micromilligrams of As_2O_3 were recovered from the filtered water and 144 from the sludge. Thus only 22 per cent of the arsenic remained in solution.

Some water was treated at the rate of 20 grains per gallon with sulfate of aluminium containing 1,240 parts per million of As_2O_3. Only 12 per cent remained in solution. A sample of filtered water was obtained from the filtration plant using this latter sulfate of aluminium. It had been treated at the rate of 200 pounds per million gallons or at the rate of 1.4 grains per gallon. From this water only 7 per cent of the arsenic originally added was recovered from the solution. Thus a removal of 93 per cent of the arsenic was effected by the purification process.

CONCLUSION

Sulfate of aluminium used by water-purification plants in Illinois does not contain a significant amount of arsenic. Some sulfate of aluminium used elsewhere contains a much larger amount of arsenic, but since at least 75 per cent of the arsenic added in the treatment of water with sulfate of aluminium is removed with the precipitated aluminium hydrate, there is a strong probability that in no case a sufficient quantity of arsenic would be added to the filtered water to have therapeutic significance. However, since sulfate of aluminium containing an insignificant amount of As_2O_3 can be readily obtained, the manufacturers should make an effort to keep the arsenic content of their product at a minimum and waterworks officials should demand an article practically free from arsenic.

We wish to express our appreciation of the assistance rendered by the manufacturers and waterworks officials who furnished us samples for examination.

BACTERIA IN DEEP WELLS*

By F. W. Tanner and Edward Bartow.

BACTERIA IN THE WATER OF DEEP WELLS

Previous investigations. Deep-well water was formerly considered sterile, and it is stated in many older textbooks that there are no bacteria in deep-seated water. More recently, however, investigators have reported bacteria in deep-well waters, and most bacteriologists now grant that deep-ground water may contain bacteria. Frankland[10] reports 3 to 80 bacteria per cubic centimeter in the water from the Bath Well in Kent, which is sunk in chalk. Monthly tests were made for 30 months, but no information is given in regard to the methods used in securing the results. Breunig[4] found 6 to 30 bacteria per cubic centimeter in the water of some artesian wells at Kiel. The medium used is not reported. Frankland also states that Hueppe found only 4 bacteria per cubic centimeter in the water of a deep well at Wiesbaden and that Egger found the same number in the water of the wells at Mainz. Savage[23] states that deep-well water, having been filtered through layers of earth, should contain few bacteria and.that the number should be subject to little variation—that on gelatin the number of bacteria is usually less than 50 per cubic centimeter and on agar is less than one per cubic centimeter. Prescott and Winslow[22] quote examinations of deep-well and spring waters in the neighborhood of Boston in which the number of bacteria range from 0 to 12 per cubic centimeter, and they conclude that water absolutely free from bacteria is not ordinarily secured from any source. Thresh[25] cites many ground waters containing bacteria, especially of the intestinal flora, which have come under his own observation. The results in Table 1 indicate the number of bacteria found in water from some deep wells of Illinois, according to tests made in the laboratories of the Illinois State Water Survey.

Experimental Studies. With the purpose of procuring more specific information regarding the character of the colonies on some of the platings of water from underground sourees specimens were carefully studied. Those selected are all from deep wells at different points in Illinois and comprise only those that were known to be from

*Abstract of thesis presented in partial fulfillment of requirements for the degree of Master of Science by ¥. W. Tanner, June, 1914.

TABLE 1.—BACTERIAL CONTENT OF WATER FROM SOME DEEP WELLS IN ILLINOIS.

Location.	Depth.	Bacteria per cubic centimeter.	
		Agar.	Gelatin.
	Feet		
Joliet	282	9	55
Champaign	400	0	0
Do	160	1	1
Do	160	28	30
Do	120	...	6
Danvers	211	4	10
Waukegan	895	0	20
Lexington	113	4	3
Fairbury	2,000	1	9
Dwight	126	0	2
Do	126	0	6
Red Bud	270	4	10

wells that had been in use for some time, for it is well known that many waters that appear badly contaminated come from new wells which have not been thoroughly flushed. The work was done on samples that came to the Illinois Water Survey for routine analysis. The water was plated on agar and on gelatin, and the plates were incubated respectively at 37°C and 20°C. After the colonies on the plates had been counted selected colonies were transferred to agar slants. These cultures were later planted in dilution on gelatin in order to procure pure cultures. The cultural characteristics were then determined by means of the different standard media, and the results were recorded on the charts of the Society of American Bacteriologists. Space forbids reporting all the cultural and morphological characteristics of the specimens but sufficient tests were made to identify species that are named.

Sample A is from a well 1,382 feet deep at Odell. The well was comparatively new, but it had been pumped for some time before the sample was collected. It enters St. Peter sandstone, is cased with iron pipe, and has a water-tight cover. The number of bacteria on agar was 26 and on gelatin, 1,000. The high number on gelatin may have been caused by incomplete flushing of the casing before the sample was taken. Two colonies of the same general shape and differing only in size, taken from the gelatin plates, were identified respectively as B. subtilis and B. fluorescens liquefaciens. Neither form is of sanitary significance. B. subtilis is abundant on grass and B. fluorescens liquefaciens is a form common in water.

Sample B was taken from a 90-foot drilled well. The casing is sunk through rock and clay and the water is pumped from the rock by an iron pump. As the cement cover is water-tight no surface water can get into the well. The number of bacteria on agar was 7 and on gelatin 67. The chemical analysis represents normal water from such a source. The tests for B. coli were negative. The colonies on gelatin were evenly distributed and began to liquefy the medium in less than 43 hours. B. vulgatus was isolated and identified. This organism has no sanitary significance and is a rather common form.

Sample C was taken after the well had been pumped for a long time from a 2,500-foot well cased through rock and sandstone. The number of bacteria on agar was 30 and on gelatin 6. Large liquefying fluorescent green colonies were present. The colony studied was identified as B. arborescens. The fact that this bacillus is found in soil might explain its presence in the water.

Sample D was collected from a drilled well which is cased with iron pipe and has a water-tight cement cover. No feed lot, privy, or stable is near the well. The gelatin plates were covered with liquefiers which made large saucer-like depressions in the medium. B. mycoides, which was isolated from this sample of water, is a common bacterium of the soil and might easily get into a water.

It is realized that there are ways in which bacteria might get into ground water. The well might be a new one which was not thoroughly flushed when the sample was taken, or a perforation or imperfection in the casing might permit surface water to enter. Yet it should be recognized that these waters, which apparently are protected against contamination, contained bacteria commonly found in water. Owing to the meagerness of the data no definite conclusions can be drawn. The bacteria isolated occur in shallow-well Water and may not have come from a deep seated water which is perhaps sterile.

BACILLUS COLI IN GROUND WATERS

Previous investigations. The presence of B. coli in water has been accepted by most sanitarians as sufficient indication that the water has received sewage pollution. B. coli was discovered in 1885 by Emmerich in the feces of cholera patients. As it is present in such large numbers in the colon it was named colon bacillus, and it was at first thought to be an inhabitant of only the human intestine. This theory, however, was soon disproved, for Flint,[9] at the Chicago Zoological Garden, found B. coli in excreta from the snake, llama, white rat, bear, and certain other animals. He concluded that the presence of B. coli is an insufficient basis on which to condemn a water. The researches of Belitzer[3] and Dyer and Keith[7] also demonstrated that B. coli is present in the intestines of most warm-blooded animals. Indeed, work on this organism by these and other investigators has practically established its ubiquity in the intestinal excretions of warm-blooded animals. Numerous instances are cited of the occurrence of B. coli in the intestines of cold-blooded animals. Amyot[1] did not find it in 23 fish including 14 varieties. Johnson[12] isolated B. coli in the contents of stomach or intestines of 47 out of 67 different fishes from Illinois and Mississippi rivers. In 41 of these the organism was isolated from the contents of the intestine. He cites the carrying of B. coli by fish as a method by which a pure water could apparently be polluted. Flint[9] proved its presence in the snake. Moore and Wright[19] could not find it in the frog. Eyre[8] reports its presence in fish and also in some warm-blooded animals.

Prescott[21] found an organism similar in all characteristics to B. coli on growing grain with which animal contact seemed improbable. Yet the possibility that birds may distribute B. coli over such areas should not be disregarded. Prescott concludes that judgment should be used in interpreting an analysis of a water in which B. coli has been found. Metcalf[18] reports B. coli on some rice fields of South Carolina. Here too the possibility of introduction of B. coli by the great quantities of water on the fields should not be overlooked. Smith[24] found colon-like bacteria on rye growing in western Massachusetts. Since colon organisms have been found in so many places the questions may well be raised whether its presence should be taken as a certain index of pollution. If it is as widely distributed as the results of study indicate, it is easy to imagine how it might gain access to water.

Kruse,[13] in a paper in which no experimental data are given, advised against the use of this organism for an index of pollution, as the common tests identify a group of bacteria and not a single organism. He believes that, inasmuch as B. coli are found in the air, water, and earth, their presence should not be taken as positive proof of pollution. Beckmann[2] found B. coli in the city supply of Strassburg, which is taken from deep wells, by using large quantities of water for his tests. Maroni,[16] after he had examined water from some deep and shallow wells at Parma, concluded that B. coli had no sanitary significance. Weissenfeld[27] like Kruse stated that B. coli could be found in all waters if large enough quantities of the sample were taken for examination. During his work he studied about thirty samples of a supposedly good water. On the other hand, certain investigators contend that no good water should contain B. coli. Savage[23] states that sufficient evidence has not yet been produced to discard B. coli as an index of pollution and his statement has been confirmed by Chick[5] and Moore.[19]

Many instances are given of contamination of underground waters. Horton[11] found organisms resembling B. coli in the waters from many deep wells and springs in Ohio. He concluded that ground water containing B. coli should be condemned and that an underground source should not be a sole guarantee of the purity of a supply. Nankivell[20] points out that water from wells in chalk are liable to intermittent pollution and should be purified. Microorganisms may get into water through fissures and shallow holes many miles away, and thus contaminate an apparently pure supply. Thresh[25] quotes many instances of finding B. coli in deep-well waters, and concludes that there are few waters in which B. coli cannot be found if a sufficient quantity is taken.

Experimental studies. An investigation was made on a series of 19 tubular wells 80 to 125 feet deep in alluvial sand and gravel near a river, which is the source of supply for a city of 11,000 inhabitants. As the wells are connected to a common suction it was impracticable to obtain a sample of water from a single well. Gas formers were frequently present in one cubic centimeter samples of the supply.

The results of the chemical and bacteriological examinations of the water from June 25, 1906 to May 18, 1914 are given in Table 2. The indicated variation in quality may be caused by intermittent entrance of another kind of water. The content of chloride varies from 35 to 61 parts per million. Similar variations are shown in determinations of total residue, oxygen consumed, and nitrogen. The number of bacteria is not excessive, and the almost constant presence of gas formers is puzzling.

The water of the near-by river is highly polluted. The surface drainage from the surrounding country is toward the river. No special observations have been made to determine the direction in which the ground water moves, but it may be assumed that it moves diagonally downstream toward the river unless the draft on the wells is so excessive as to reverse normal conditions. There is no impervious stratum to protect the ground water from surface water that might enter.

As the alluvium is porous there may be more or less infiltration of surface water. Purification under such imperfect conditions would not always afford the same degree of purity as that afforded by a frequently cleaned and carefully operated sand filter. Old wells, fissures, and cesspools also might pollute the water-bearing stratum.

TABLE 2.—ANALYSES OF WATER FROM TAP AT PUMPING STATION OF MUNICIPAL WATERWORKS.

[Parts per million.]

Date.	Turbidity.	Color.	Odor.	Total residue.	Chloride.	Oxygen consumed.	Nitrogen.				Alkalinity.	Bacteria per cubic centimeter.		B. coli.			
							Free.	Albuminoid.	Nitrites.	Nitrates.		Gelatin.	Agar.	10 cc.	1.0 cc.	0.1 cc.	Indol.
1906																	
Jun. 25	0	0	0	418	47.5	3	0.046	0.092	.000	1.36	262	30	..	1—	2—	2—	..
Aug. 20	0	0	0	546	47.5	2	.028	.052	.003	5.2	260	..	..	..	...	...	..
1911																	
Dec. 5	2	0	1v	485	88	.4	.004	.034	.000	7.6	270	50	..	1+	1+1—	2—	+
Dec. 19	0	0	0	469	35	.4	.000	.000	.000	24.0	272	92	..	1+	1?1—	1+1—	+
1912																	
Jan. 16	0	0	2v	584	56	1.0	.000	.058	.000	10.	278	..	..	1+	2+	2+	..
Jan. 16	0	0	0	534	61	.4	.000	.048	.000	10.8	278	..	..	1+	2+	2+	—
Jan. 24	..	..	..	...	...	...	....	....	...	...	...	73	..	1+	2+	2—	—
Jan. 24	..	..	..	...	...	...	....	....	...	...	...	55	..	1?	2—	2—	—
Jan. 24	..	..	..	...	...	...	....	....	...	...	...	82	..	1+	1—1+	2—	—
Feb. 13	0	0	0	480	41	.5	.012	.016	.000	8.0	272	86	..	1+	2+	2—	—
Apr. 16	0	0	1e	595	40	.3	.000	.000	.000	10.0	288	58	..	1+	2+	2—	+
May 13	0	0	1	487	43	.8	.000	.000	.000	1.04	280	31	..	1+	2+	2—	+
Jun. 10	0	2	1m	537	85	.1	.000	.032	.000	12.00	274	155	..	1+	2+	1—1+	+
Sep. 16	0	0	0	530	48	1.6	.000	.004	.000	6.80	270	..	90	1+	1—1+	2—	—
Sep. 21	0	0	0	483	53	1.4	.040	.016	.000	7.20	352	32	1	1+	2—	2—	—
Dec. 17	0	0	0	472	33	1.4	.000	.082	.000	7.00	270	22	1	1+	2—	2—	—
1913																	
Jan. 29	2	0	0	520	43	.5	.000	.024	.007	9.00	272	52	0	1+	1+1—	2—	—
Feb. 24	0	0	0	507	27	.2	.008	.056	.000	7.60	270	5	15	1+	2—	2—	—
Mar. 18	0	0	0	497	46	1.2	.016	.032	.000	7.20	410	2	3	1—	2—	2—	—
Apr. 15	1	0	0	532	35	.7	.000	.014	.003	6.00	262	4	5	1+	1—1+	2—	—
May 19	0	0	0	580	88	.6	.000	.048	.003	7.20	276	19	4	1+	2—	2—	—
Jun. 17	0	4	0	528	43	.7	.032	.016	.000	8.00	272	7	0	1+	1+1—	1—1+	+
Jul. 14	0	3	0	551	31	1.1	.024	.064	.000	9.2	268	35	210	1+	1—1+	2—	+
Sep. 2	1	3	0	526	36	1.5	.004	.024	.000	12.00	262	30	59	1+	1—1+	2—	+
Sep. 23	0	0	0	518	34	1.5	.028	.052	.000	8.80	268	76	30	1—	2—	2—	+
Oct. 21	0	0	0	505	38	.7	.000	.014	.005	9.20	264	108	9	1+	1+1—	2—	+
Nov. 18	0	0	0	517	38	.9	.000	.024	.000	10.00	260	37	58	1—	1+1—	2—	—
Dec. 29	0	0	1v	482	39	.4	.000	.038	.002	.12	260	9	10	1+	2+	2+	+
1914																	
Jan. 19	0	0	0	502	42	.8	.000	.000	.000	7.20	266	25	14	1—	1+1—	2—	+
Feb. 17	0	0	0	498	43	.8	.000	.000	.000	6.80	268	20	0	1+	2—	2—	—
Mar. 17	0	0	0	496	42	1.0	.000	.024	.000	9.60	270	140	9	1—	2—	2—	0
May 18	0	0	0	515	40	1.0	.000	.028	.000	.28	276	3	0	1—	2—	2—	—

There is possibility of underground infiltration from the badly polluted river. The following table has been prepared to show the relation of the constituents of the river water, the city water, and water from two wells of similar depth about 200 feet from the city wells.

TABLE 3.—ANALYSES OF WATER FROM RIVER AND NEAR-BY WELLS IN ALLUVIUM.

[Parts per million.]

Source.	River.	City wells.	Private well No. 1.	Private well No. 2.
Date (1914)	Apr. 20	Apr. 20	Mar. 28	Mar. 28
Turbidity	50	0	2	0
Color	30	0	0	0
Odor	2 c	1 v	1 e	1 e
Total residue	332.	498.	357.	617.
Chloride	13.6	42.	10.	14.
Oxygen consumed	7.3	.5	1.6	1.5
Ammonia nitrogen	9.52	.024	.000	.000
Albuminoid nitrogen	3.2	.000	.004	.000
Nitrate nitrogen	2.64	7.2	7.2	13.
Nitrite nitrogen	.030	.000	.000	.000
Alkalinity as $CaCO_3$	154.	274.	246.	264.
Bacteria per cubic centimeter on agar	16,000	50	0	6
On gelatin	35,000	80	1	1
Gas formation				
10 cc.	....	1+	1—	1—
1 cc.	1+	2—	2—	2—
0.1 cc.	2+	2—	2—	2—
.01 cc.	2+	....	....	....

The results of analysis show a decided difference in composition between the water of the river and that from the wells. Pollution from this source is improbable although a small amount of river water might account for the variation in the city well water. Gas-forming bacteria have been present in 10 cubic centimeter samples of the water in more than 90 per cent of the analyses made. The one cubic centimeter samples are positive in 43 per cent of the determinations, but in the 0.1 cubic centimeter samples there are only 9 positive tests in 62. Gas formers isolated from 6 samples had characteristics like those of B. coli. Liquefying bacteria were present in a few samples, and fluorescent colonies were identified in many. Some were identified as B. fluorescens liquefaciens and B. flourescens non-liquefaciens.

Isolation by bacteria. The methods of isolation were those recommended by the American Public Health Association. The samples of water sent to the Illinois State Water Survey are packed in ice. Some were collected by representatives of the Survey, in order to be sure that the samples were carefully collected. After the sample reached the laboratory it was plated on litmus-lactose agar, agar, and gelatin. The red colonies developing on litmus-lactose agar were utilized for growing pure cultures by the usual methods. Confirmatory tests according to the chart of the Society of American Bacteriologists were made and Endo's and Russell's media were used. Both gave the characteristic reactions of B. coli.

The characteristics of the gas formers isolated from the deep wells were not always alike. The motility varied somewhat, but gas and acid were produced by all the cultures. The organism has characteristics identical with those of B. coli.

ATTEMPT TO TRACE SOURCE OF POLLUTION

Previous investigation. Different materials such as sodium chloride, salts of lithium, fluorescent, and suspensions of B. prodigiosus, have been used for tracing the source of pollution of ground waters.

Salt was used by McCallie[14] in Georgia for the purpose of demonstrating the effects of discharging sewage into deep wells. A large amount of salt was put into a 124-foot drilled well, and the content of chloride in the water of the surrounding wells was determined. Increased content of chloride showed that there was underground connection between the wells and springs in the vicinity. This demonstrated what might have resulted had the well been used to carry away the sewage.

Dole[6] summarizes his investigations on the use of fluorescein in the following statements:

"1. In determining the sanitary value of a well or spring it is more important to study the underground flow than to analyze the water itself. 2. Foreign substances put into the aquifer and traced from point to point are of great value in this study. 3. With the fluorescope one part of fluorescein can be detected in 10 billion parts of water. 4. Fluorescein is a particularly valuable flow indicator for fissured or cavernized rocks. 5. It is also available in gravels, where it has been used with success. 6. It progresses at a slightly lower rate than the water in which it is suspended. 7. It is not decolorized by passage through sand, gravel, or manure; it is slightly decomposed by calcareous soils. 8. It is entirely decolorized by peaty formations and by free acids, except carbonic acid."

Trillat[26] states and claims that fluorescein can be detected in dilutions of 1 part in 2,000,000,000, but that before the dye is used a study of the soils should be made regarding the presence of matters which might decompose it. Marboutin[15] comes to somewhat similar conclusions. Martel[17] shows that fluorescein even in very concentrated solutions decolorizes rather quickly after being kept in the sunlight. "When it is kept in complete darkness, which would be the case in the earth, it did not change even after long periods of time.

Gehrmann[22] reports that Alba Orlandi and Roudelli, who used a suspension of B. prodigiosus, found that cultures of this organism poured on the ground passed through soil 200 meters, and that Pfulil found that it took the same organism a short time to pass through .24 feet of gravel. Gehrmann also reports a place at which wells 200 to 300 feet deep too near an old canal were subject to entrance of contaminated water; no experimental data are given.

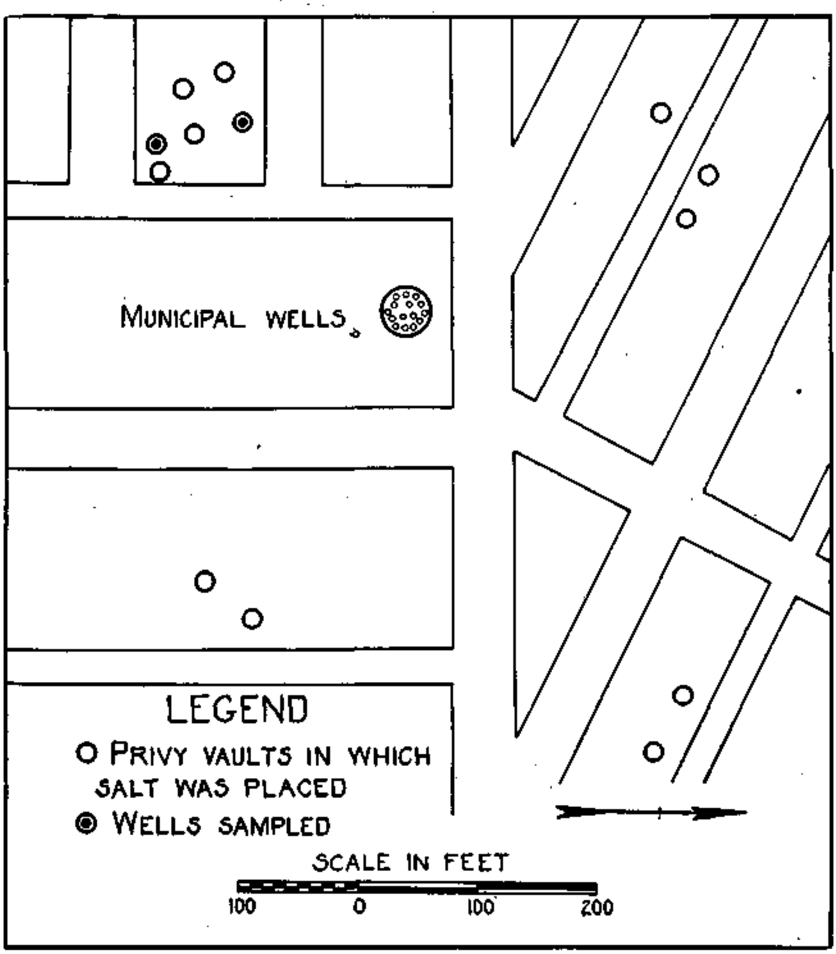


Figure 1.—Location of wells and privy vaults in which salt was placed.

Experimental study. It was thought best not to use fluorescein in the wells on which this work was done because of the possibility of coloring the city supply to an objectionable degree. Salt was, therefore, used in an attempt to determine whether surface seepage entered the wells. One ton of fine salt was evenly divided among 11 privy vaults located near the waterworks (See Figure 1). The salt was all placed during one afternoon, the content of chloride of the water having been determined on the previous day. The content of chloride was determined by titrating 50 cc. with standard silver nitrate in presence of potassium ehromate. At the time the experiment was started the content of chloride was 42 parts per million. From the data given in Table 4 it will be seen that this remained practically unchanged, and it is, therefore, quite apparent that there is no direct connection with pollution from surface sources.

TABLE 4.—THE CONTENT OF CHLORIDE IN THE CITY WATER SUPPLY AFTER ADDITION OF SALT USED TO TRACE THE SOURCE OF POLLUTION.

Date. 1914.	Chloride Parts per million.	Remarks.	Date. 1914.	Chloride Parts per million.	Remarks.
Mar. 16	42	Before salt was added.	Mar. 30	43	Heavy rain night of Mar. 29
17	44	After salt was added.	30	42	
17	43		31	42	
18	44		31	42	
18	45		Apr. 1	42	Heavy rain night of Mar. 31.
19	43		2	42	
19	44	10 gallons of water added to vaults.	3	42	
20	45		4	43	
20	44		6	43	Rained all day.
21	44		7	42	
21	45		8	42	
23	43		9	42	
23	43		10	42	
24	44		11	43	
24	43		13	42	
25	42		14	42	
25	43		15	42	
26	42		16	41	
26	42		17	41	
27	42	Heavy rain during night of Mar. 26.	18	41	Pumped for fire 2 hours. Sample taken 45 minutes after fire was out.
27	43		20	40	
28	43		23	41	
28	42		25	41	

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THE FACTORS WHICH INFLUENCE THE LONGEVITY OF B. COLI AND B. TYPHOSUS IN WATERS*

By M. E. Hinds.

It has long been known that there is a tendency for intestinal bacteria to die out in a natural water. Very little is known of the conditions which govern the death rate. Available data deal mostly with streams[5 3 11] and reservoirs[4] which are influenced by numerous variable conditions. There are few data dealing with pure cultures of bacteria[12] and with known conditions of light, temperature,[1 2] food supply, dissolved oxygen, and the presence of other microorganisms. The effects of drying [7] and disinfectants[1 2 5 8] have been studied and the relation of the death rate to the monomolecular law[1 6 7 8 9] has been discussed. The object of this work was to find the rate and manner of death under starvation conditions.

The culture of B. coli used was isolated from feces and identified by the usual tests. The culture of B. typhosus was strain No. 11, from the American Museum of Natural History. Both cultures were kept fresh by daily transfers in tubes of one per cent lactose broth. The cultures were kept at 20°C.

Smears of the broth cultures were made on lactose agar and incubated from 12 to 24 hours at either 20°C. or at 37°C. The young culture' was emulsified in sterile water and portions of the emulsion used for inoculating the water samples.

The first counts made on lactose-agar plates proved unsatisfactory, so lactose-gelatine plates were adopted. These were incubated at 20°C. until the colonies developed. The time of incubation was constant in each experiment.

For tests with gases the samples were kept in filter flasks arranged to receive a steady though small stream of gas. The gas entered the side tube and passed out at the top. A large tube inserted through the stopper allowed sampling without removing the stopper. All water used was sterilized.

BACILLUS COLI

Three experiments were made with nitrogen-free water at intervals of a week to determine whether the culture could be kept uni-

*Abstract of thesis prepared under the direction of Dr. Otto Rahn, Professor of Bacteriology and Consulting Bacteriologist, Illinois State Water Survey, University of Illinois, and submitted in partial fulfillment of the requirements for the degree of Master of Science.

form by the daily transfers (see Table 1). Miscellaneous samples of water were used at the same time (see Table 2). All tests were made at 27°C. in a dark incubator. The constant K in Table 1 is determined from the formula

$$K = \frac{1}{t} \log_e \left(\frac{N}{n} \right)$$

t is the time in hours, N the original number of cells, and n the number surviving.

TABLE 1.—DEATH OF B. COLI TAKEN FROM CULTURE TRANSFERRED DAILY AND INOCULATED WEEKLY INTO NITROGEN-FREE WATER AND GROWN AT 27°C.

Hours.	Series 1.		Series 2.		Series 3	
	Count.	K.	Count.	K.	Count.	K.
0	1,168,000	...	10,240,000	...	2,180,000	...
2	97,000	(1.243)[a]	6,000,000	.267	1,590,000	(.157)
12	.....	...	....	...	77,000	.278
24	400	.332	1,150	.379	2,000	.291
48	8	.270	....	...	7	.263
72	1	.194	30	.177	....	...
Ave.		.265		.274		.277

[a]Constants in brackets not included in averages.

The constants being very uniform the methods of transfer and inoculation were considered satisfactory.

TABLE 2.—DEATH OF B. COLI INOCULATED IN WATERS OF VARYING CHARACTER AND KEPT AT 27°C.

Hours.	Nitrogen-free water.		Distilled water.		Well water.	
	Count.	K.	Count.	K.	Count.	K.
0	1,104,000	...	212,000	...	1,920,000	...
2	4,000	(2.809)[a]	19,000	(1.205)	500,000	.672
12	1,000	.583	16,000	.215	3,000	.526
24	200	.368	200	.290	200	.381
48	5	.256	....	...	1	.301
72	....	....	3	.159	....	...
96	....	....	....	...	....	...
6 da.	....	....	....	...	....	...
37 da.	....	....	....	...	....	...
Ave.		.399		.221		.470

*Constants in brackets not included in average.

The well water mentioned in Table 2 contained 2,000 parts per million of mineral matter and was especially high in nitrate. The mineral matter had no evident effect on the bacteria. The distilled water used contained rather high ammonia nitrogen.

Three experiments were made using another sample of nitrogen-free water and covering a period of six weeks. At the same time comparative experiments were made in atmospheres of nitrogen and hydrogen (see Table 3).

TABLE 3.—DEATH OF B. COLI INOCULATED IN WATER COVERED BY AIR, NITROGEN, OR HYDROGEN.

Hours.	Air.		Nitrogen.		Hydrogen.	
	Count.	K.	Count.	K.	Count.	K.
Series 1.						
0	650,000	...	700,000	...	490,000	...
1.5	140,000	(1.023)[a]	132,000	(1.112)	350,000	.224
6	42,000	.456	....	...	200,000	.149
11	8,000	.399	....	...	....	...
24	2,000	.241	4,000	.215	....	...
36	11	.305	2	.354	8	.306
48	1	.279	0	.287	0	.272
72	0	...	....	...	....	...
Ave.		.336		.285		.238
Series 2.						
0	4,000,000	...	4,000,000	...	4,000,000	...
1.5	8,100,000	(.169)	2,880,000	.219	2,300,000	.368
6	450,000	.364	1,760,000	.137	760,000	.277
11	50,000	.398	530,000	.184	28,000	.451
24	600	.352	95,000	.155	4,500	.271
36	7	.368	50,000	.121	1,300	.223
48	0	.317	30,000	.102	0	.317
72	....	...	......	...	......	...
Ave.		.359		.153		.318
Series 3.						
0	2,800,000	...	3,350,000	...	2,700,000	...
1.5	1,460,000	.434	2,750,000	(.131)	2,000,000	.200
6	57,000	.649	2,250,000	.066	385,000	.324
11	10,000	.469	1,650,000	.059	170,000	.230
24	8,000	.285	520,000	.077	10,000	.233
36	1,500	.209	320,000	.065	3,600	.184
48	....	...	160,000	.063	700	.172
72	960	.111	64,000	.055	400	.108
Ave.		.359		.064		.207

[a]Constants in brackets not included in averages.

In each set of experiments the death rate in air is higher than in either nitrogen or hydrogen. The variations in the results with nitrogen and hydrogen are high, for which no explanation can be offered.

Several sets of temperature experiments were made by inoculating samples from a new lot of nitrogen-free water (see Table 4).

TABLE 4.—CONSTANTS OBTAINED BY OBSERVATIONS OF THE DEATH OF B. COLI AT VARIOUS TEMPERATURES IN AIR.

Hours.	Series.					
	1	2	3	4	5	6
8°						
0-2	.283	.235	.092	(.556)[a]	.097	...
2-6	.317	.155	.088	.185	.048	...
6-12	.170	.106	.057	.149	.047	...
12-24	.112	.075	.035	...	.030	...
24-36	.112	.046	.023	.053	.021	...
36-48	.089	.058	.019	.043	...	...
48-72	...	.049	.017	.034	...	...
72-96	.061	.038	...	.032	...	...
96-120	...	...	...	...	...	...
120-144	...	.028	...	...	...	...
Ave.	.163	.088	.047	.076	.048	...

20°*

0-2	.713	.143	(.088)	(.270)	.069	.087
2-6	.596	.084	.035	.019	.083	.059
6-12	...	.063	.028	.037	.079	.048
12-24	.184	.036	.019	.021	.071	.025
24-36	.163	.033	.020	.022	.118	.033
36-48	...	.032	.021	.029	.111	.030
48-72	...	.033	.018	.031	.120	...
72-96	.072	.027	...	(.089)	...	...
96-120	...	.025	...	...	...	...
120-144	...	.030	...	...	...	...
Ave.	.345	.052	.023	.026	.094	.047
			37°			
0-2	1.603	1.417	.173	.307	.096	1.721
2-4	...	...	...	...	...	2.184
2-6	.968	...	.155	.225	...	...
4-6	...	...	...	...	.033	2.186
6-12	.858	.369	.291	.474	...	...
12-24	...	.563	...	...	.245	...
24-36	...	...	...	...	.243	...
36-48	...	...	...	...	.275	...
Ave.	1.176	.788	.206	.335	.178	2.033

*Constants in brackets not included in averages.

The experiments were made in the chemical laboratory with the exception of Series 6 which was made in the bacteriological laboratory.

Experiments in air and nitrogen were made at different temperatures (see Tables 5 and 5A).

TABLE 5.—DEATH OF B. COLI IN AIR AT VARYING TEMPERATURES.

Hours.	Count.	K.	Count.	K.	Count.	K.
			Series 5.			
	8°		20°		37°	
0	668,000	...	690,000	...	560,000	...
2	550,000	.097	600,000	.069	462,000	.096
6	550,000	.048	420,000	.083	460,000	.033
9	......	...	......	...	......	...
19	360,000	.047	244,000	.079	......	...
24	328,000	.030	123,000	.071	1,550	.245
36	315,000	.021	10,000	.118	88	.243
48	......	...	3,400	.111	......	...
72	......	...	120	.120	......	...
Ave.		.048		.094		.178
			Series 6.			
	20°		27°			
0	500,000	...	500,000	...		
2	420,000	.087	377,000	.141		
4	......	...	......	...		
6	350,000	.059	258,000	.110		
9	......	...	240,000	.081		
12	280,000	.048	130,000	.114		
24	270,000	.025	20,000	.134		
36	150,000	.033	340	.206		
48	117,500	.030	20	.211		
Ave.		.047		.142		

TABLE 5A.—DEATH OF B. COLI IN AIR AT VARYING TEMPERATURES.

Hours.	Count.	K.	Count.	K.	Count.	K.
			Series 5.			
	8°		20°		37°	
0	600,000	...	640,000	...	550,000	...
2	1,200	3.106	3,800	2.562	520	3.500
4	......	...	......	...	90	.280
6	400	1.052	200	1.345	......	...
13	0	1.023	......	...	......	...
24	......	...	4	.499	......	...
			Series 6.			
	20°		27°		37°	
0	500,000	...	500,000	...	500,000	...
2	285,000	.281	350,000	.178	100*	6.559
6	43,000	.408	......	...	......	...
9	......	...	100,000	.156	......	...
12	......	...	30,000	.234	......	...
24	3,800	.203	17	.428	......	...
36	0	.364	0	.364	......	...
Ave.		.314		.272		

*Less than 100. K figured for 100.

The first two series of experiments using the two different nitrogen-free waters show concordant results. In the first series the three constants .265, .274, and .277 give an average of .272 (see Table 1). In the second the three constants .366, .359, and .359 give an average of .351 (see Table 3). This second average is somewhat higher than the first, possibly because of differences in the nitrogen-free water use.

A comparison of our results with those obtained by others[1 2 7] shows that the proper method of keeping cultures uniform is frequent transference into fresh media.

The first constant of a set is frequently either much too high or too low to agree with the rest of the set. Chick[1] thinks it may be caused by the change of conditions surrounding the bacteria when they are placed in the water and also by incomplete mixing before the first sample is taken. We have omitted the first constant in computing the average in such cases.

The experiments using gases give quite a variation in the death rate (see Table 6).

TABLE 6.—RELATION OF CONSTANTS FOR B. COLI IN AIR, NITROGEN, AND HYDROGEN AT 27°C.

Constants for B. coli.			Ratios of constants		
Air.	Nitrogen.	Hydrogen.	Air / Nitrogen	Air / Hydrogen	Nitrogen / Hydrogen
.336	.285	.238	1.18	1.41	1.2
.359	.153	.318	2.36	1.13	.47
.359	.064	.207	5.60	1.73	.31

The constants with hydrogen are fairly uniform but the constants with nitrogen are very poor. As nitrogen is supposed to be inert toward B. coli we expected its constants to be uniform and are at a loss to explain our results. The only conclusion we are justified in drawing is that B. coli lives longer in the absence of oxygen than in its presence. As nitrogen and hydrogen are supposedly inactive toward bacteria their presence really means the absence of oxygen.

Whipple and Mayer[12] show a higher death rate of B. coli in nitrogen, than in air. The technique was somewhat different from ours in that sterile tap water was used and inoculations were made with quantities of a broth culture thus introducing some food material.

After completing the three series of experiments (see Tables 1, 2, and 3), with cultures kept at 20°C. and grown on agar at 20°C. previous to being used for inoculation, we began growing our agar cultures at 37°C. and failed to obtain any results which checked. It may be that the change from 20°C. to 37°C. was harmful by altering the resistance of the cells. The change was made in order to procure a 12-hour culture in sufficient amount for use.

A comparison of the death rate of B. coli in air and nitrogen at varying temperatures (see Tables 5 and 5A) shows some interesting examples of the change of behavior of the organisms. Some of the nitrogen constants are not uniform enough in a single experiment to allow a fair average, but in all cases the death rate is several times higher in nitrogen than in air. In air there is an increasing death rate with increasing temperature, but in nitrogen the opposite is true except at 37°C. After completing Series 5 it was thought possible that the fumes of the chemical laboratory might have had some deleterious effect on the work, so Series 6 was carried out in the bacteriological laboratory. No improvement could be seen. The ratio of air to

TABLE 7.—TEMPERATURE COEFFICIENTS FOR CONSTANT K FOR 10°C. INTERVALS CALCULATED FROM DATA IN TABLES 4 AND 5.

Series.	Temperature.	Coefficients.
	Degrees centigrade	
1	8—20	1.86
	20—37	2.06
2	8—20	.68
	20—37	4.72
3	8—20	.55
	20—37	3.63
4	8—20	.41
	20—37	4.49
5	8—20	1.75
	20—37	1.45
6	20—27	4.85
	27—37	14.31

nitrogen at 27°C. of Series 6 is .52 which is similar to the ratio of .66 obtained by Whipple and Mayer.[12] On account of the inconsistency of all the data after the change to agar at 37°C. we disregard it and from the preceding data conclude that the presence of oxygen is harmful to B. coli.

With one exception, Series 5, the temperature coefficient (see Table 7) increases with a rise in temperature. This is analogous to a chemical reaction, and agrees with results obtained in experiments upon the death rate of bacteria caused by drying,[7] hot water,[1] and by the use of disinfectants.[1]

BACILLUS TYPHOSUS

Very little work was done with B. typhosus and only two. experiments in gases and two at different temperatures were made. All of the tests made were with samples of the same lot of nitrogen-free water as was used in the comparative temperature tests on B. coli. The experiments were made with cultures kept at 20°C. but grown on agar at 37°C. just before use. This procedure gave poor results with B. coli and may have been the cause for the variation in the results with B. typhosus.

TABLE 8.—DEATH OF B. TYPHOSUS INOCULATED IN WATER COVERED BY AIR, NITROGEN, OR HYDROGEN AT 20°C.

Hours.	Air.		Nitrogen.		Hydrogen.	
	Count.	K.	Count.	K.	Count.	K.
Series 1.						
0	3,000	...	29,000	...	20,000	...
2	2,200	.155	12,400	(.425)*	16,800	.087
6	2,300	.044	14,000	.121	......	...
12	1,600	.052	7,800	.115	17,200	.012
24	175	.118	1,750	.117	17,000	.007
36	40	.119	0	...	10,800	.171
48	10	.119	......	...	6,750	.225
Ave.		.101		.118		.100
Series 2.						
0	315,000	...	220,000	...	266,000	...
2	185,000	.265	87,000	.891	74,000	.639
6	40,000	.344	2,100	.775	8,000	.584
12	937	.485	18	.784	200	.599
24	0	...	0	...	......	...
Ave.		.365		.817		.607

*Not included in average.

In both experiments the constants are erratic (see Table 8) and the average constants do not have the same ratios to each other (see Table 9).

TABLE 9.—RATIOS OF THE CONSTANTS FOR B. TYPHOSUS IN AIR, NITROGEN, AND HYDROGEN.

Series.	Air / Nitrogen.	Air / Hydrogen.	Nitrogen / Hydrogen.
1	.85	1.01	1.18
2	.44	.60	1.35

The death rate is higher in nitrogen and hydrogen than in air, corresponding to the results of Whipple and Mayer.[12] Temperature

TABLE 10.—CONSTANTS OBTAINED BY OBSERVATION OF THE DEATH OF B. TYPHOSUS AT VARIOUS TEMPERATURES IN AIR.

Hours.	Count.	K.	Count.	K.	Count.	K.
	Series 1.					
	8°		20°		37°	
0	195,000	...	118,000	...	110,000	...
2	10,000	1.485	7,500	1.377	500	2.701
4	3,100	1.035	500	1.365	80	1.806
6	1,825	.832	280	1.007	0	1.934
8	950	.665	230	.779	......	...
10	500	.596	150	.666	......	...
12	....	...	80	.689	......	...
14	470	.430	30	.591	......	...
24	60	.336	2	.458	......	...
Ave.		.768		.866		2.147
	Series 2.					
0	93,000	...	83,000	...	Sample Contaminated	
2	......	...	10,000	1.057		
4	2,200	.936	800	1.160		
6	725	.809	1,550	.663		
8	300	.718	370	.676		
10	265	.586	300	.562		
12	130	.548	90	.569		
14	60	.524	35	.555		
24	10	.381	0	.471		
Ave.		.643		.714		

coefficients (see Table 11) have been calculated from the two sets of temperature experiments given in Table 10.

TABLE 11.—TEMPERATURE COEFFICIENTS FOR CONSTANT K FOR 10°C. INTERVALS, CALCULATED FROM DATA IN TABLE 10.

Series.	Temperature.	Coefficients.
	Degrees centigrade.	
1	8—20	1.11
	20—37	1.71
2	8—20	1.09

The coefficients for the interval 8°—20° are nearly equal in both series and all of the coefficients indicate that there is an increase in the death rate of B. typhosus with the temperature.

Ruediger's[11] data show a temperature coefficient of 2.12 for 10°

interval for B. typhosus in winter and summer allowing a 24° difference in temperature. From a comparison of coefficients about half of his higher death rate in summer can be attributed to the temperature difference and the rest to other causes. Whether or not half is really due to temperature would be hard to determine.

On the whole the results of the experiments with B. typhosus are not as satisfactory as those with B. coli. No accurate numerical comparison of the relative death rates of B. coli and B. typhosus has been made because of the variation in the constants for B. typhosus. In general B. typhosus had a somewhat higher death rate as has been found to be true under other conditions by other investigators.

The role of oxygen in these experiments is difficult to understand. B. coli is an aerobe and we would naturally expect a beneficial action when oxygen is present, but in most of the experiments the opposite was the case. It may have been that the excess of oxygen rather than its utter absence was injurious. It is known that aerobes can get too much oxygen and anaerobes require a little oxygen in some form. Another suggestion is that a rapid oxidation may take place in the absence of food.

CONCLUSION

In pure, natural water and in redistilled water B. coli and B. typhosus die from starvation at a regular rate. The rate of death increases with the temperature and is similar to the rate of a chemical reaction, thus following the monomolecular law. The presence of mineral matter had no apparent effect on the organisms. The presence of oxygen under starvation conditions seems to be harmful to B. coli and beneficial to B. typhosus.

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POLLUTION OF VERMILION RIVER AT AND BELOW STREATOR[1]

By Paul Hansen and Ralph Hilscher.

On January 31, 1915, the State Water Survey was informed by Mr. H. S. Turner, superintendent of the Chicago Portland Cement Co. at Portland (Oglesby post office) of foul odors in Vermilion River accompanied by the death of fish. The odor was but slightly noticeable in the cold river water, but the water on being heated became very offensive and men about the cement mill refused to use it for washing purposes. The Marquette Cement Manufacturing Co. at Portland had experienced the same trouble with the odor of the water and also reported a marked rise in the mineralization of the river water during the period in question.

On January 14 and 15, Ralph Hilscher assisted by H. F. Ferguson and J. F. Schnellbach made an investigation of Vermilion River, inspected various sources of pollution, made measurements of the stream flow, collected samples of river water and polluting liquids entering the stream at Streator, and made inquiries concerning objectionable conditions of the river. Assistance was given by H. S. Turner, superintendent and D. R. Fraser, assistant superintendent of the Portland Cement Co. at Oglesby, T. Baumgardner, engineer for the Marquette Cement Manufacturing Co., R. D. Huggans, engineer of the Streator Aqueduct Co., Dr. Hollingsworth, manager of Bailey Falls Dairy Farm, and F. H. Renz, city engineer of Streator.

During December, 1914, and the early part of January, 1915, the stream flow was unusually low, the weather was very cold, and the surface of the river was for the most part covered with a heavy sheet of ice. Sewage pollution enters the stream at Streator and highly mineralized water containing much sulfate of iron enters from mines at Streator and at various points downstream. Thus the river at Streator and points below demanded a very large quantity of oxygen, whereas, the ice on the surface of the stream prevented the oxygenation of the water to an extent that would satisfy this demand. The effect of this lack of oxygen was noticeable for about 25 miles as shown by the deposition of iron hydroxide and the presence of sewage matters. Under ordinary circumstances these evidences of pollution

[1]A report on a previous survey of Vermilion River appears in Bull. 9, 136-46.

disappear within a distance of 5 or 6 miles below Streator. The germieidal activity of the mine wastes was a contributory influence in the persistence of sewage-pollution effects as clearly shown in the bacterial examinations made at various points along the river.

GENERAL DESCRIPTION OF RIVER

Vermilion River has a total drainage basin of about 1,400 square miles and empties into Illinois River just above La Salle. The investigation included that portion of the stream from the mouth to a point about 7 miles above Streator, in all a length of about 32 miles. Above this point there is a tributary drainage basin of about 1,080 square miles.

There are two iarge dams in the river, one at Streator and one at Pontiac, about 40 miles above Streator. These are both used for impounding public water supplies and much of the time the entire flow is held up at both places. All sewage and liquid industrial wastes from both cities are discharged into the river below their respective dams. The Barr Clay Co. recently constructed a low temporary dam to impound for boiler purposes the water wasted at the Streator waterworks. This waste water is principally filter wash water. The Marquette Cement Manufacturing Co. at Portland has a low dam to impound river water for its boilers.

The banks of the lower part of Vermilion River are for the most part high and largely steep limestone bluffs. The surroundings are in many places very picturesque, as at Bailey Falls and at Deer Park near Portland. The river at its mouth has an elevation approximately 480 feet above sea level and land immediately adjoining rises as high as elevation 647. This comparatively rough country extends along the river almost as far upstream as Pontiac. Above that point the drainage basin consists of flat farm land which, originally of a swampy nature, has been extensively ditched and underlain with drain tile. This well-drained flat land and the rolling country at the lower end of the drainage basin both produce rapid run-off, with the result that the flow in Vermilion River is extremely variable, rising rapidly after heavy rainfall and falling to very low stages in a short time.

STREAM FLOW

There had not been typical high water in Vermilion River for two years. During the greater part of the time there had been more or less uncertainty concerning the quantity of water available for Pontiac, Streator, and the cement mills at Portland. At the time of the investigation the Streator reservoir was drawn down about 6 feet below the top of the dam. A weir measurement made above this point showed the flow into the reservoir. to be about 45,000 gallons per day. The daily pumpage from the reservoir was about 1,800,000 gallons. No water has been allowed to flow past the Streator waterworks dam for several months, and, as run-off from the adjoining drainage basin has been but slight, the flow in the river below Streator has consisted almost entirely of sewage and other waste water from that city.

Coal mining has been an important industry at Streator for many years and the city is now almost entirely undermined, with the result that all ground water is drained to a low level and water from drift wells is not obtainable. The operated mines receive much ground water and this is pumped out and thence flows into the river. Abandoned workings are filled with water which continuously seeps out at many points in the bluffs along the river. This flow of mine water is estimated at 2,200,000 gallons per 24 hours.

Because of the absence of drift wells, the water of the Streator Aqueduct Co. is used almost exclusively, the exceptions being a few deep wells which supply a limited quantity of water to some of the factories. Streator has a complete system of sewers and it would probably not be greatly in error to assume that the discharge from this system in dry weather is approximately equal to the normal pumpage of the water company, or about 1,800,000 gallons per 24 hours.

This makes a total discharge of sewage and mine water at Streator of about 4,000,000 gallons per day, or 2,780 gallons per minute. The Marquette Cement Manufacturing Co. at Portland built a 6-foot

TABLE 1.—DISCHARGE OF VERMILION RIVER AT PORTLAND.

Date.	Discharge.	Date.	Discharge.
1914	*Gallons per minute.*		*Gallons per minute.*
Dec. 14	2,085	Dec. 31	3,616
15	2,048	1915	
16	2,042	Jan. 1	3,060
17	994	2	3,060
18	1,279	3	2,360
19	....	4	....
20	2,438	5	2,085
21	3,060	6	2,812
22	3,060	7	3,060
23	2,312	8	....
24	3,060	9	3,208
25	2,438	10	3,616
26	1,583	11	3,409
27	2,085	12	3,409
28	2,438	13	3,409
29	3,060		
30	2,812	*Average*	2,639

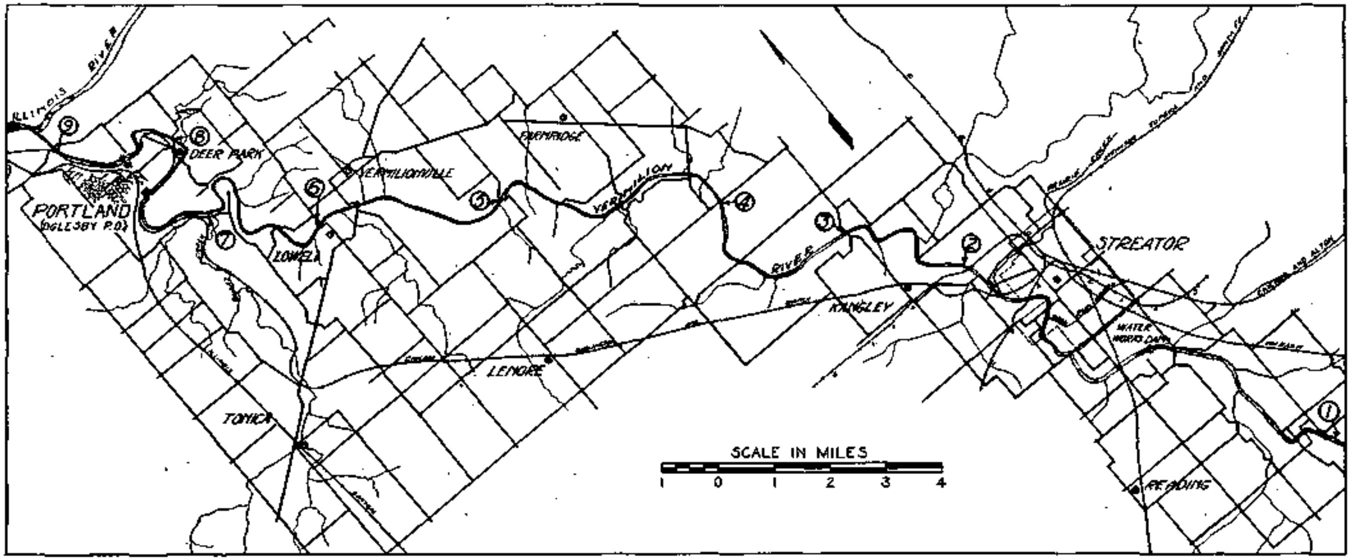

Figure 1.—Map showing sampling and stream-gaging stations on Vermilion River above and below Streator.

weir in the river during the summer of 1914. The daily discharge as recorded (see Table 1) by this weir for the month preceding the investigation agrees quite closely with the estimated discharge at Streator.

The low flow on December 17 resulted from the rapid formation of a heavy coat of ice. The cold weather began about December 14 and continued for several days, the temperature falling to as low as —15°F. The flow was reduced only temporarily and it gradually increased until December 21 when it was again equivalent to the Streator discharge.

OBSERVATIONS

That portion of Vermilion River in question, with numbers to show the various points at which detailed observations were made and samples were collected, is shown in Figure 1.

The wastes which drain into Vermilion River at Streator include domestic sewage from a population of 15,000, mine water, waste from coal washers, and such miscellaneous wastes as are produced at a gas plant, a plant of the Vulcan Detinning Co., and various shops. Other important industries at Streator are a large locomotive and car shop, 3 glass factories, and a number of tile and pottery plants. Probably the only objectionable wastes from these, however, consist of relatively small quantities of engine-room oil.

There are 36 sewer outlets at Streator, 11 of which discharge directly into the river, 15 discharge into Coal Run Creek, which drains the south part of the city and empties into the river near the center of the city's water front, and the remaining 10 discharge into Prairie Creek, which drains the north side and empties into the river at the northwest extremity of the city. All sewers are built on the combined plan and the outlets range from 10 to 30 inches in diameter.

Most of the sewage enters the river directly and more sewage discharges into Coal Run Creek than into Prairie Creek. There have been complaints about the polluted condition, of Coal Run Creek, especially in the vicinity of Bloomingtpn Street. To improve conditions a small branch which enters the creek near Eighth and Bloomington Streets Avas replaced by a closed conduit having its outlet about 600 feet downstream from the mouth of the branch. It has been suggested that Coal Run Creek be covered, especially at its lower end, but this will probably not be done in the near future.

Coal Run Creek at the time of the visit had considerable flow, mostly mine water. Probably two-thirds or more of the estimated

2,200,000 gallons per day of mine water is carried by this creek to the river. A part of the water pumped from the mine of the Harrison Coal Co., about 400 gallons per minute during 8 hours per day, is used to wash coal and the water so used carries with it to the creek a very large amount of finely divided shale and coal giving to the creek a grayish-black color. Although the water from this mine enters the upper end of the creek the gradient and the amount of water are sufficient to carry much of the suspended coal and shale to the river. At the time of the visit the river, but not the creek, was frozen over at the junction and some of the fine material had been deposited on the surface of the ice. On the bed of the creek a short distance above its mouth the fine material had accumulated to a depth of 2 feet. The creek there was about 8 feet wide and the flow was about 6 inches deep. The high turbidity caused by the coal wash water obscured the presence of domestic sewage. There was no disagreeable odor from either the creek water or the deposit. In the summer, however, odors are said to be noticeable, especially near the sewer outlets.

Prairie Creek at Bloomington Street was about 6 feet wide and 6 inches deep. The pumpage from one mine enters it. A very thin coating of oil, the source of which was not ascertained, covered practically the entire water surface. The bed of the creek was soft and sandy for a depth of about one foot and the upper part was black and liberated oil when stirred. Neither the creek water nor material from the bed of the creek had a disagreeable oder.

Besides the water which is pumped from the operated mines, the river receives seepage from abandoned mine workings. This water finds entrance to the river through crevices and jointings in the bluffs. It is more corrosive, and locally is spoken of as being "stronger", than water pumped from the operated mines. This is because of the increased solvent action of the water standing in the abandoned mines in longer contact with the various minerals.

A considerable amount of iron pyrites (FeS_2) in the coal vein at Streator is the basis of the principal objection to the water, when it is oxidized to ferrous sulfate and sulfuric acid. The water as it seeps from the bluffs along the river is clear and colorless, but on exposure to the air much of the iron is converted into the hydroxide in sufficient amount to cause a distinct reddish discoloration of the stream bed and banks (see Figure 2.) It is not uncommon for this water to have a decided acid reaction because of the presence of sulfuric acid.

The gas plant owned by the Public Service Company of Northern Illinois is situated along the river near the center of the city's water front. The amount and the character of the wastes from this plant were not ascertained, but, so far as known, they have not been the source of any complaint.

Acid wastes from the plant of the Vulcan Detinning Co. are discharged into the river northwest of the city. The amount of this waste was not ascertained. The total water consumption at the plant is about 40,000 gallons per day, part of which is consumed in the

Figure 2.—One of the points of mine-water seepage into Vermilion River, Streator.

boilers. The company recovers tin from old tin plate. The exact nature of the waste was not learned, as the process used by the company is secret. Only a very small quantity of water was being wasted at the time the plant was visited and it was freezing almost as fast as discharged. It contained considerable quantities of red and white precipitates.

Following is a detailed description of conditions at various points along the river as observed during the investigation and as described by the persons interviewed.

Station 1 was 4.1 miles above the waterworks dam at Streator and 7.1 miles upstream from the center of town (see Figure 3). A weir was installed in a ditch which the water company had dug in the bed of the river for the purpose of draining pools above into the reservoir. The weir was 18 inches long and the head recorded was 11/16 of an inch, thus showing a flow of about 45,000 gallons per day. The water had no objectionable features. Waterworks officials said there had never been any noticeable ill effects at that point on the stream from Pontiac sewage or any other pollution. No dead fish

Figure 3.—Weir in Vermilion River at Station 1, above Streator.

had been seen. The reservoir and river above were for the most part covered with a heavy coating of ice. The temperature of the water was 36°F.

Station 2 was 4.7 miles below the Streator waterworks, or about 1.7 miles below the center of the city (see Figure 4). All sewage and industrial waste of Streator enter the river between the waterworks and this point. The stream was open with the exception of strips of ice along the banks. The temperature of the water was 41°F. The river had a fairly uniform width of about 70 feet and was little more than one foot deep at any point. The bed of the stream had a decided red color, resembling iron rust, but there were no visible evidences of sewage pollution such as sludge deposits or gas bubbles. Odors were not noticeable. At the time of the visit the river was frozen over at the center of town and the color of the bed could not be observed there. At times the mine waste is said to back up to the plant of the water company and has been reported to have killed fish. Occasionally when a small quantity of water is flowing over the waterworks dam large numbers of fish swarm just below the dam where this fresher water has not been contaminated.

Station 3 was beneath a highway bridge 4.5 miles below the center of Streator. The river with the exception of a single small air hole was covered with ice as far as could be seen in either direction.

Figure 4.—Vermilion River at Station 2, below Streator.

The water was not over one foot deep at this hole and the bottom was a distinct red. The temperature of the water was 33°F.

Station 4 was beneath a highway bridge 7.9 miles below the center of Streator. The water was very shallow and the current rapid, producing a stretch about 100 feet long and 15 feet wide on which there was no ice. Considerable oxygen was no doubt accumulated by the water at this point. The bottom was very red in the open places and a slight red tinge could be distinguished through the ice. There was little foaming as the water flowed over the rocks in the open space. The temperature of the water was 34°F.

Station 5 was 12.6 miles below the center of Streator. Just above the station the river was frozen solidly enough to permit wagons and teams to cross. For a distance of several hundred feet below there was open water, probably not over 2 feet deep at any point. The bed of the stream was red. A farmer living near-by stated that this discoloration had never been seen here prior to this winter. He said that thousands of fish had died in the river during the past month. Some

Figure 5.—Vermilion River from bluff at Bailey Falls.

people had attempted to eat these fish, but the meat had a disagreeable taste. Many cattle drink the river water, but this man knew of no ill effects. A distinct odor was said to have been noticeable in the water a week or two before when the greatest trouble occurred. The temperature of the water was 33°F.

Station 6 was at Lowell 16.2 miles below the center of Streator. Here the river was frozen over as far as could be seen in either direction and samples were collected through a hole made in the ice. Two men stated that dead fish were taken from the river by the wagon load a couple of weeks previous and also that dead fish had frequently been seen earlier in the fall before the river was frozen. Red deposits according to these two men had never been seen at Lowell before this winter. Little red color was seen at the time, but the iron deposits may have existed beneath the ice. The temperature of the water was 33°F.

Station 7 was at Bailey Falls dairy farm, 20 miles below Streator (see Figure 5). Bailey Falls is on a small tributary known as Bailey Creek, the water of which has a fall of about 50 feet just before it enters the main stream. The river is bordered on both sides by high and heavily wooded bluffs and the surroundings are unusually attractive. The Bailey Falls farm is a large stock farm where river water is used entirely for watering. Dr. Hollingsworth, the veterinarian in charge, stated that stock apparently had taken a dislike to

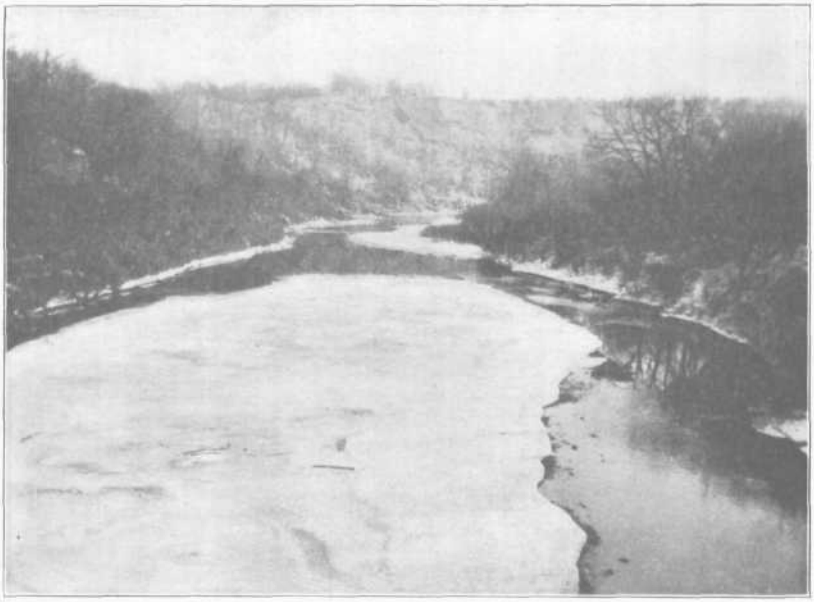

Figure 6.—Vermilion River at Station 8, Portland.

the water. A slight odor in the water could be detected at close range. A red deposit was seen through the ice in places, a condition never known here until recently. Many dead fish were seen at this point before the river was frozen over. The temperature of the water was 33°F.

Station 8 was at Deer Park station, in Portland, 23.1 miles below Streator (see Figure 6). Deer Park, a large private estate of remarkable natural beauty, is on the east side of the river. The Marquette Cement Manufacturing Co. is about one mile above the station. It uses a large quantity of river water, passing it through steam condensers and then back to the stream. The temperature of the river is raised so that the thermometer registered 38°F. at the station at the time the samples were collected. There was open water in the river as far as could be seen in both directions. The river bed was. covered with red deposit and 2 dead fish were seen near the water's edge. At the Marquette mill one fish was seen imbedded in the ice.

Station 9 was just below Portland about one-half mile above the mouth of Vermilion River and about 25.6 miles below the center of Streator. A heavy coat of ice covered the river as far as could be seen in both directions. No red color could be seen, possibly on account of the thick ice covering. Samples were obtained through a hole cut in the ice. The temperature of the water was 33°F.

ANALYTICAL DATA

At the time the investigation was made and samples collected for analysis the disagreeable conditions were less pronounced than they had been a week or so before. A peculiar odor was still slightly noticeable in the cold water and the odor became much more distinct on heating. At the mill of the Chicago Portland Cement Co. treatment of the water with hypochlorite of lime, instituted after the odor developed, diminished the odor.

The hardness of the river water, determined in the laboratory of the Marquette Cement Manufacturing Co., has normally been about 25 grains per gallon, or 430 parts per million, expressed in terms of calcium carbonate. It has sometimes fallen as low as 70 parts per million, and has very seldom risen above 800 parts per million. During this unprecedented condition of the river the mineral content was much higher than usual, and at the time of the investigation was about 1,100 parts per million. Three analyses of the mineral content obtained at the Marquette mill, (see Table 2), show a large amount

TABLE 2.—ANALYSES OF SAMPLES OF WATER FROM VERMILION RIVER COLLECTED AT PORTLAND.

[Parts per million.]

Mineral constituents.	Made by Gulick-Henderson Nov. 11, 1913.	Made by Kennicott Co. Nov. 25, 1914.	Made in Marquette mill Dec. 24, 1914.
SiO_2	1.9	8.1	7.6
Fe+Al	trace	4.0	6.0
$CaSO_4$	427.	595.	854.
$CaCO_3$	87.	120.	100.
$MgSO_4$	382.	643.	968.
$MgCO_3$	8.4	0	....
Na_2SO_4	350.	220.	....
NaCl	103.	170.	180.
Alkalinity	96.	122.	....
H_2SO_4	....	0	....
Hardness	....	1200.	....

of sulfates of calcium and magnesium and give some intimation of what the character of the water has been.

The analyses of the samples collected at the time of investigation (see Table 3) show quite clearly the marked effect of Streator sewage and the mine waters and the persistence of the ill effects for many miles below.

No samples of sewage were taken from the Streator sewer outlet, but samples from Prairie Creek (Station 10) and Coal Eun Creek (Station 11) represent pollution of a similar character. A small quantity of mine water enters Prairie Creek along with the sewage. Much sewage enters Coal Eun Creek, but its influence is obscured by the presence of mine water, especially water from coal washers. The extremely high figures in the Coal Eun Creek sample for residue and oxygen consumed are due to the presence of sewage and a heavy suspension of finely divided coal. The sample from the Stobs mine (Station 12) and the sample of abandoned-mine seepage (Station 13) represent the two types of mine waste. That from the Stobs mine is being pumped out continuously after a comparatively short period of contact in the workings. The other sample is seepage from abandoned-mine workings where water stands for a long time before escaping. Local mine operators state that this seepage water from abandoned mines is much stronger and more corrosive than that from operated mines. This seems to be true in the two samples analyzed especially in one important respect, namely, the content of iron. Conditions no doubt vary widely in different mines and, judging from the amount of iron in the river sample at Streator, there must be mine wastes having much higher iron than either one of the mine-water samples analyzed.

It is difficult to state which is the most important source of pollution at Streator. The municipal sewage and the mine water are both, no doubt, detrimental to fish life when but slightly diluted as was the condition during the period of trouble. Unsightliness is caused by the mine water. The increase of putrescible organic matter is caused by the sewage. The depletion of the oxygen is undoubtedly due to both the unoxidized iron in the mine water and the oxidizable organic matter in the sewage, both of which have an avidity for oxygen which in this case could not be satisfied.

The effect of the pollution is plainly evident from a comparison of the analyses of samples taken above and below Streator (Stations 1 and 2). The increase in turbidity is due principally to the iron added in the mine water between the two stations. This iron, it will

TABLE 3.—ANALYSES OF WATER FROM VERMILION RIVER AND TRIBUTARIES, JANUARY 14-15, 1915.

[Parts per million.]

Station No.	Miles below Streator.	Turbidity.	Color.	Residue on evaporation.						Chloride.	Oxygen consumed.	
				Total.	Fixed.	Dissolved.		Suspended.			Total.	Dissolved.
						Total.	Fixed.	Total.	Fixed.			
1[a]	7.1[b]	20	20	848	582	....	....	....	....	42.	4.0	....
2	1.7	550	30	2,328	1,952	2,210	1,857	118	95	60.	40.0	36.2
3	4.5	150	20	2,070	1,770	1,960	1,725	190	45	80.	40.0	37.0
4	7.9	200	15	2,090	1,965	2,201	1,941	89	24	83.	40.4	38.8
5	12.6	175	30	2,198	1,875	2,147	1,860	51	15	84.	31.4	28.0
6	16.2	175	20	2,371	2,042	2,316	2,027	55	15	108.	30.8	27.4
7	20.0	125	120	2,396	2,083	2,323	2,042	78	41	102.	31.4	30.6
8	23.1	50	10	2,293	1,983	2,211	1,923	82	59	103.	27.0	25.0
9	25.6	5	15	345	255	....	....	....	....	25.	4.4	....
10	...	150	30	1,122	950	876	758	246	192	20.	8.8	7.2
11	....	14,000	5	13,560	11,960	1,970	1,705	11,590	10,255	92.	410.0	27.0
12	...	700	0	2,660	2,290	2,245	2,000	415	290	65.	20.0	2.0
13	...	275	120	1,591	1,407	1,379	1,297	212	110	17.	7.0	5.0

Station No.	Ammonia.			Organic nitrogen.		Nitrites.	Nitrates.	Per cent saturation dissolved oxygen.	Alkalinity.	Non-carbonate hardness.	Sulfates.	Magnesium.[c]	Iron.	Bacteria per cc.
	Free.	Albuminoid		Total.	Dissolved.									
		Total.	Dissolved.											
1	.240	.384	...	.92	...	.000	.48	68.3	460.	216.	209.	329.	0.4	600
2	1.600	1.200	.604	1.88	1.60	.030	1.08	5.3	20.	1072.	1235.	817.	150.	650,000
3	7.68	.800	.604	1.60	1.52	.020	.76	5.5	20.	952.	1188.	366.	86.	1,000
4	10.0	.960	.752	2.00	1.72	.020	.64	7.0	26.	1156.	1336.	304.	90.	2,000
5	6.40	.512	.440	2.20	1.60	.060	1.80	6.9	40.	1004.	1260.	305.	65.	3,500
6	7.20	.592	560	2.56	2.40	.045	1.40	13.8	60.	1128.	1341.	512.	66.	200
7	9.60	.640	.592	1.60	1.20	.050	.60	56.5	90.	1120.	1393.	497.	46.	200
8	7.20	.640	.512	2.56	2.40	.074	.64	42.0	122.	1032.	1299.	633.	4.	0
9	2.56	.288	...	1.68	...	.022	.80	27.6	144.	75.	100.	75.	0.2	100
10	8.20	1.12	.480	2.20	1.08	.100	1.00	...	140.	296.	452.	172.	0.3	10,000
11	5.60	4.00	.800	6.40	1.60	.040	1.08	...	4.	968.	1064.	718.	0.5	15,000
12	1.52	.480	.400	2.00	1.20	.018	.72	...	200.	992.	1315.	478.	57.	300
13	1.28	.224	.128	2.00	1.80	.000	.40	...	92.	752.	878.	569.	126.	100

[a] Samples from Stations 1-9 are from Vermilion River; Station 10, Prairie Creek; Station 11, Coal Run Creek; Station 12, Stobs Mine; and Station 13, seepage from abandoned mine.

[b] Above Streator.

[c] Expressed as calcium carbonate.

be noted, increased from 0.4 to 150 parts per million. The acidity of the mine waters reduces the alkalinity of the river water from 460 to 20. The large increases in residue, hardness, sulfate, and magnesium are also caused mainly by the mine water.

The marked increase in the number of bacteria can be laid entirely to the sewage. Following the sudden rise in bacteria there is a marked reduction at Station 3. This is because of the germicidal action of the iron sulfate of the waste mine water. Increases in chloride, the nitrogens, and oxygen consumed are probably due to both sewage and mine water. The marked reduction in dissolved oxygen is due both to the presence of sewage and to the oxidation of iron in the mine water.

The effects on the river produced by such natural influences as flow, sedimentation, aeration, and ice are shown by the analyses at the various stations between Streator and Portland.

It will be noted that the results of analyses at the point nearest Illinois River (Station 9) are apparently inconsistent. Nearly every determination shows a decidedly different water from that at previous stations. The only explanation of the results seems to be that the sample was in reality Illinois River water. Back water from Illinois River might reach that point because the lower end of Vermilion River broadens out somewhat there and becomes considerably deeper.

The results of all other analyses of Vermilion River appear quite consistent. The turbidity and iron decrease somewhat but, except between Stations 2 and 3, the reduction is only gradual until Station 8 is reached, where a marked drop occurs. The river as far downstream as the Marquette mill at Portland was coated almost completely with ice and lack of air very likely retarded materially the oxidation and deposition of the iron. That this must be true is borne out by the evidence that never before has the iron deposit been observed as far down as Portland. At the Marquette mill a large quantity of river water is pumped through jet steam condensers and then flows back into the river. The result is that for a mile, from the mill to Station 8, the warmer water keeps the river open. Aeration thus being made possible should explain, in part at least, the reduced content of iron at Station 8.

The dissolved oxygen in the water continued very low until Station 7 was reached, where a marked increase was shown. If the assumptions in the previous paragraph are true, it is not quite clear why the iron should not have shown a more marked reduction at Station 7, unless perhaps the combination of the oxygen and iron had not yet had adequate time for completion at that point. The increase in dissolved oxygen at Station 7 is not readily explainable as the stream was heavily coated with ice there and for a long distance above. Possibly, however, there may have been an error in collection or analysis of the sample. Bailey Creek with a small flow of only a few gallons per minute entered just above this point and it probably increased the oxygen somewhat, but so marked a rise could not have been anticipated. At Station 8, as might have been expected, the oxygen was comparatively high.

The general downward trend of the oxygen consumed seems logical in that it illustrates a gradual deoxygenation by both iron and organic matter as the water flowed downstream.

Chloride, alkalinity, and magnesium gradually increase in a downstream direction. This seems to indicate that springs were probably contributing somewhat to the flow. This increase is reflected to a slight degree in the residue determinations. There appears to be no general trend indicated by the hardness or the sulfates.

The nitrogen determinations, most significant of the group as regards sewage pollution, showed very slow improvement in conditions compared with what could be expected in an open stream. The trend of free and albuminoid ammonia was downward, but very slow. The organic nitrogen seems to have had no marked trend, the figures remaining high throughout the entire distance. Nitrite and nitrate likewise showed almost no improvement at the lower end of the stream.

CONCLUSION

During a large part of the time the flow of Vermilion River below Streator consists only of sewage, industrial wastes, and mine water. The mine water causes unsightly conditions in the river at and immediately below Streator during moderately low stages of the stream. Not until the winter of 1914-15 were the effects observed as far downstream as Portland, about 23 miles below Streator, or even more than 5 or 6 miles below that city.

So far as is known the sewage in the river has never caused complaints, but it is very likely in part responsible for bad conditions which prevailed during the winter of 1914-15. During that season the river was unusually low and a heavy coating of ice covered the stream. Shortly after the ice formed, fish died in large numbers, the effects of Streator pollution became plainly apparent as far downstream as Portland and a distinctly disagreeable odor developed in the water.

These objectionable conditions were brought about by three factors which acted together to make the dissolved oxygen in the stream abnormally low causing the long-delayed self-purification of the stream and the suffocation of fish. The contributing influences were the presence of Streator's wastes; the almost total absence of natural flow and hence very low initial oxygen in the stream; and the heavy coating of ice which prevented aeration.

INVESTIGATION OF THE DESTRUCTION OF FISH IN SANGAMON RIVER BELOW SPRINGFIELD

By Paul Hansen and Ralph Hilscher.

At the request of the State Game and Fish Conservation Commission and the Rivers and Lakes Commission an investigation of Sangamon River at and below Springfield was made on January 20-21. The investigation was desired because of a petition to the Game and Pish Conservation Commission, signed by about 200 persons living for 30 miles along Sangamon River. The petition asked that action be taken to relieve the conditions causing the death of large numbers of fish in the river and to prevent a recurrence of the trouble. Deputy game and fish wardens had made inspections and briefly reported to the Game and Fish Conservation Commission.

By the time the Survey was notified and its representatives were ready to make an investigation, objectionable conditions that prevailed during the first week in January had disappeared and all information concerning the objectionable conditions had to be obtained indirectly from those who had observed them. Ralph Hilscher, assisted by H. F. Ferguson and J. F. Schnellbach, inspected the various sources of pollution at Springfield, collected samples of river water, made measurements of the stream flow, and made inquiries as to past conditions at Riverton, Springfield, Salisbury, Petersburg, and Oakford. Assistance was given in obtaining information by James J. Porter, deputy game and fish warden at Springfield, A. E. Estell, deputy game and fish warden at Petersburg, H. M. Levering, mayor of Petersburg, and John L. Burkett, of Salisbury.

Objectionable conditions had existed only downstream from Springfield. At Riverton, 10 miles above the waterworks dam at Springfield, no objectionable conditions accompanied by dead fish had been noted. The engineer at the Springfield waterworks about ¼ mile above the dam had seen no dead fish.

Spring Creek, which receives most of the sewage of Springfield and certain industrial wastes including that from a gas plant and a brewery, discharges into Sangamon River below the dam (see Figure 1). At and for several weeks prior to the time the objectionable conditions prevailed no water flowed over the waterworks dam and the discharge from Spring Creek, therefore, constituted the entire flow of the river below Springfield. At the time of the investigation the flow of the creek as measured with a current meter was 7,360,000 gallons per day below all sewer outlets and 2,000,000 gallons per day above the sewer outlets. The difference, 5,360,000 gallons per day, indicates the waste discharged by the sewers as the ground was frozen and there was no run-off and little seepage augmenting the flow between the two measuring stations. The dry-weather sewage flow of Springfield probably approximates the daily water consumption, which is about 7,000,000 gallons. The difference between this

Figure 1.—Sangamon River below waterworks dam, Springfield.

water consumption and the computed volume of sewage carried by Spring Creek would represent that part of the sewage of Springfield discharged into Sugar Greek, a tributary of Sangamon River above the waterworks dam.

Spring Creek, except during freshets, is malodorous and foul in appearance. The bed at places contains considerable deposits of septic sludge. Near its outlet (see Figure 2) it has been dredged and the gradient there is sufficient to prevent sludge accumulations and also to maintain the channel free of ice except during prolonged cold weather. A small tributary of Spring Creek which carries the waste from the gas plant had a noticeable tar or gas odor. Another tributary, which receives the discharge from one of the sewers, when its ice was broken had a very strong and characteristic odor of sewer gas.

Large numbers of dead fish in Sangamon River were first noticed about January 1 and the destruction continued until about January 12. For some time preceding that period the weather had been very cold and a heavy coating of ice had formed on the river. In places the ice was 15 inches thick. The mean of the maximum and the mean of the minimum daily temperatures for December, 1914, were, respectively, 30.7°F. and 17.7°F. (U. S. Weather Bureau records.) The temperature for the last three weeks of December, 1914, had not risen

Figure 2.—Spring Creek near its mouth, Springfield.

above 38°F. and had fallen as low as —7°F. The ice covering prevented aeration of the river water and as the flow below Springfield consisted almost entirely of sewage the supply of dissolved oxygen in the river water was undoubtedly rapidly depleted.[1]

When the destruction of fish life was noticed the deputy game and fish warden at Springfield walked 5 miles downstream on the ice from a point about 3 miles below the mouth of Spring Creek. In

[1]Similar conditions in Vermilion River below Streator had been investigated a few days prior to this investigation and are described on pages 234-50.

that distance there were few air holes and beneath the ice where it was not covered with snow he estimated he saw 500 dead fish.

At Salisbury, 15 miles below Springfield, hundreds of dead fish were taken from the river, and many still alive though reduced in vitality were readily caught with the hands at holes in the ice where numbers. The trouble was first noticed there on January 2 when they apparently came for air.

At Petersburg, 30 miles below Springfield, fish died in large numbers. The trouble was first noticed there on January 2 when many fish were readily caught through holes in the ice as at Salisbury. For about 3 days fish thus caught were eaten, but those caught later were not used as they had an objectionable taste described as like waste from a gas plant. The deputy game and fish warden at Petersburg estimated that upwards of 3,000 pounds of fish were caught at Petersburg during the few days that the objectionable conditions prevailed. On January 8 he made an inspection for 15 miles above Petersburg and stated that the water had a dark chocolate color and a distinct gas odor. About 4 days later when the stage of the river raised he noticed that the water flowing past Petersburg was similar in character.

At Oakford, 20 miles below Petersburg, conditions similar to those which prevailed upstream were not noticed. There is a dam in the river at Petersburg and citizens there stated that no water had flowed over the dam for several weeks prior to and during the time the trouble lasted. The pollution from Springfield had not, therefore, extended below the Petersburg dam during the time the stream flow was low and the river covered by ice.

On January 12, following a slight rise in temperature and a slight precipitation on the 10th and 11th, the flow of the river increased and large numbers of dead fish were washed downstream beyond Petersburg. After that no more dead fish were noticed.

At the time of the investigation tests for dissolved oxygen were made on water from Spring Creek above and below Springfield sewer outlets and from Sangamon River at two points above and two below the mouth of Spring Creek. Samples were sent in to the laboratories of the Survey for sanitary chemical analysis. The results of these tests and analyses were of little value since they did not represent conditions as they existed during the period the fish were killed. At the time the samples were collected the flow over the Springfield waterworks dam was 285 cubic feet per second, an amount sufficient to dilute the sewage of Springfield and prevent objectionable conditions.

CONCLUSIONS

The sewage from Springfield is of such volume as to pollute objectionably Sangamon River not only under the conditions that prevailed prior to the time of this investigation but during prolonged dry weather. The sewerage conditions in Springfield and the effect of the sewage on Spring Creek and Sangamon River during dry weather are described in a previous bulletin.[1]

The destruction of fish in large numbers in Sangamon River between Springfield and Petersburg early in January was caused by the lack of oxygen in the river water and the toxic effect of polluting wastes from Springfield. The depletion of the oxygen resulted from three causes, (1) the low stage of the river with no flow over the waterworks dam, thus affording no dilution to the sewage from Springfield, (2) the large volume of sewage from Springfield which rapidly used up the oxygen in the water, and (3) the heavy coating of ice which prevented aeration of the river water. The natural purification of sewage under the ice in the absence of sufficient oxygen would be slow and probably the anaerobic decomposition products were detrimental to fish.

[1]Bull. 11, 213-4; 275-80.

QUALITY OF THE DRINKING WATER OBTAINED IN ILLINOIS BY COMMON CARRIERS *

By W. W. Hanford and Edward Bartow.

The Treasury Department has jurisdiction over the health of passengers in interstate traffic. Interstate quarantine regulations were promulgated by the Treasury Department September 27, 1894 in accordance with Section 3, General Regulations, Act of Congress, approved February 15, 1893. Since the publication of the regulations 9 amendments have been passed, Nos. 6-9 concerning water directly. Article 3 is amended by the addition of the following paragraphs:

Pure Drinking Water for Passengers in Interstate Traffic. (Amendment to Interstate Quarantine Regulations No. 6.)

"Paragraph 15.—Water provided by common carriers on cars, vessels, or vehicles operated in interstate traffic for the use of passengers shall be furnished under the following conditions:

(a) Water shall be certified by the State or municipal health authority within whose jurisdiction it is obtained as incapable of conveying disease: *Provided,* That water in regard to the safety of which a reasonable doubt exists may be used if the same has been treated in such manner as to render it incapable of conveying disease, and the fact of such treatment is certified by the aforesaid health officer.

(b) Ice used for cooling such water shall be from a source the safety of which is certified by the State or municipal health authority within whose jurisdiction it is obtained, and washed with water of known safety, and handled in such manner as to prevent its becoming contaminated by the organisms of infectious or contagious disease: *Provided,* That the foregoing shall not apply to ice which does not come in contact with the water which is to be cooled.

(c) Water containers shall be cleansed and thoroughly scalded with live steam at least once in each week that they are in operation.

Franklin MacVeagh, Secretary."

January 25, 1913.

Water for Drinking and Cooking Purposes Furnished Interstate Vessels. (Amendment to Interstate Quarantine Regulations No. 7.)

"Paragraph 16.—No person undertaking to furnish water for drinking or cooking purposes to any vessel in any harbor of the United States, intending to clear for some port within some other State or Territory of the United States or the District of Columbia, shall furnish for such purposes water taken from the

*Abstract of thesis submitted in partial fulfillment of the requirements for the degree of Master of Science by W. W. Hanford, June, 1915.

waters of such harbor or from any other place where it has been or may have been contaminated by sewer discharges. Any person violating this regulation will be liable to a penalty of not more than $500 or imprisonment for not more than one year, or both, at the discretion of the United States district court.

W. G. McAdoo, Secretary."

June 4, 1914.

Pure Drinking Water for Crews and Employees of Common Carriers Engaged in Interstate Traffic. (Amendment to Interstate Quarantine Eegulations No. 8.)

"Paragraph 17.—Common carriers while engaging in interstate traffic shall not furnish to their crews or employees any polluted water for drinking purposes which may contain organisms or materials likely to cause a contagious or infectious disease, nor shall such carriers maintain or permit to be maintained upon their vessels or vehicles, or at or near their stations or their ordinary stopping places over which they may have control, any tank, cistern, receptacle, hydrant, or article with water which may contain such impurities, in such manner that water therefrom may be conveniently obtained by the crews and employees mentioned for drinking purposes, unless such common carriers maintain a notice upon said vessels or vehicles and at, near, or upon every said tank, cistern, receptacle, hydrant, pump, well, stream, brook, pool, ditch, or other place or article, with water therein containing such impurities, forbidding the use of such water for drinking purposes by the crews or employees of the said common carriers or by the general public while engaging in interstate commerce.

W. G. McAdoo, Secretary."

September 16, 1914.

Pure Water for Passengers upon Vessels Operating in Interstate Commerce. (Amendment to Interstate Quarantine Eegulations No. 9.)

"Paragraph 18.—Common carriers operating vessels in commerce between the several States and Territories or the District of Columbia, for passengers in interstate traffic, shall not supply for the use of said passengers any water taken from a lake or stream over which the vessel is being navigated unless the same is certified by the United States Public Health Service or the State or municipal health authority within whose jurisdiction it is obtained as conforming to the bacteriological standard for drinking water promulgated by the Secretary of the Treasury under date of October 21, 1914: *Provided,* That water in regard to the safety of which a reasonable doubt exists may be used if the same has been treated in such manner as to render it incapable of conveying disease, and the fact of such treatment is certified by the aforesaid health authority or by the Surgeon General of the United States Public Health Service or his accredited representative.

W. G. McAdoo, Secretary."

January 12, 1915.

In order to enforce the regulations a commission was appointed to formulate standards.[18] This commission was composed of the following members: John F. Anderson, Edward Bartow, Charles C. Bass, S. J. Crumbine, Edward C. Franklin, Henry Hanson, Charles

Gilman Hyde, Edwin 0. Jordan, Allan J. McLaughlin, William H. Park, Milton J. Rosenau, William T. Sedgwick, George C. Whipple, C-E. A. Winslow, and Wade H. Frost. A bacteriological standard was formulated but, "Pending the preparation of the report recommending specific limits for permissible chemical impurities, it is recommended that water supplies which may be bacteriologically sanitary be excluded from use when, in the opinion of the Surgeon General, they are definitely injurious to health or grossly offensive by reason of chemical impurities or physical properties."

For a drinking water it would be impracticable to require absolutely pure water. The purest on record was obtained by Kohlrausch after ten years of experimenting.[11] It would obviously not be allowable to use a water containing an excessive mineral content or one grossly polluted by organic impurities. There are various opinions concerning the effect of impurities of water on the human body. Rosenau[10] maintains that water is not considered a food except as it enters into the structural composition of all foods as well as all the tissues of the body; it is the one essential element of diet, even though it cannot of itself build tissues, repair waste, or produce heat or energy. A water should be attractive in appearance in order that sufficient will be taken to allow proper performance of its various functions in the body. An unattractive water may indirectly be responsible for much harm. Directly an impure water may cause the biliary or urinary calculi which form around a colon bacillus or a typhoid bacillus or about some pathological particle as a nucleus.

Goiter is a disease supposed to be caused by some poison or infection taken into the system with the water or with some other article of diet. Bircher[4] claims that goiter occurs among people living upon land consisting of marine deposits. Wilms[20] assumes that goiter is due to a substance derived from the bodies of marine animals. Lobenhoffer[13] states that boiling the water seems to remove the goiter-producing properties.

Lead has been known to cause poisoning when present in a water supply. Neisser,[15] and Schwenkenbecher[17], Klut,[10] and Fanconnier[7] have reported cases of lead poisoning. It is doubtful if any authentic cases of poisoning by copper from water have been noted. Tschirch[19] and Lehmann,[12] claimed that copper even in considerable quantity is not harmful. Witthaus[21] records only 3 cases of death caused by ingestion of copper salts. Abel[1] reports copper in nearly all distilled water and Clark[5] reports copper in minute amounts as a natural constituent of reservoirs in Massachusetts.

Bickel[3] experimenting with a water containing a bicarbonate alkalinity of 5,216 parts per million concluded that mineral waters of high alkalinity when taken on an empty stomach cause a diminution of the gastric and pancreatic secretions and cause the mucous of the stomach to dissolve.

Sulfates of potassium, sodium, and magnesium have a marked physiological action. Many waters owe their laxative or purgative effect to magnesium sulfate or Epsom salt, and sodium sulfate or Glaubers salt. It is difficult, however, to place limits as to the allowable mineral constituents in a water. Probably because of these difficulties and because of the minor sanitary importance of chemical impurities the formulation of chemical standards for common carriers has been postponed.

The limits for bacteriological pollution are more important and simpler to formulate. While it is no easy task to prove the presence of disease-producing organisms and practically impossible to specifically prove their absence, yet one can get some idea concerning the purity of the water by the estimation of the number of bacteria and an idea of the possibility of future infection by a determination of the presence or absence of B. coli. The following standards recommended by the Commission and adopted by the Treasury Department on August 1,1914, are based on determinations of the number of bacteria and the presence or absence of B. coli:

The Bacteriological Standard for Water.

1. The total number of bacteria developing on standard agar plates, incubated 24 hours at 37°C, shall not exceed 100 per cubic centimeter. Provided, that the estimate shall be made from not less than two plates, showing such numbers and distribution of colonies as to indicate that the estimate is reliable and accurate.

2. Not more than one out of five 10-cc. portions of any sample examined shall show the presence of organisms of the B. coli group when tested as follows:

(a) Five 10-cc. portions of each sample tested shall be planted, each in a fermentation tube containing not less than 30 cc. of lactose-peptone broth. These shall be incubated 48 hours at 37°C. and observed to note gas formation.

(6) From each tube showing gas, more than 5 per cent of the closed arm of fermentation tube, plates shall be made after 48 hours' incubation, upon lactose-litmus agar or Endo's medium.

(c) When plate colonies resembling B. coli develop upon either of these plate media within 24 hours, a well-isolated characteristic colony shall bo fished and transplanted into a lactose-broth fermentation tube, which shall be incubated at 37°C. for 48 hours.

For the purposes of enforcing any regulations which may be based upon these recommendations the following may be considered sufficient evidence of the presence of organisms of the B. coli group.

Formation of gas in fermentation tube containing original sample of water (*a*).

Development of acid-forming colonies on lactose-litmus agar plates or bright red colonies on Endo's-medium plates, when plates are prepared as directed above under (*b*).

The formation of gas, occupying 10 per cent or more of closed arm of fermentation tube, in lactose-peptone broth fermentation tube inoculated with colony fished from 24-hour lactose-litmus agar or Endo's-medium plate.

These steps are selected with reference to demonstrating the presence in the samples examined of aerobic lactose-fermenting organisms.

3. It is recommended, as a routine procedure, that in addition to five 10-cc. portions, one 1-cc. portion, and one 0.1-cc. portion of each sample examined be planted in a lactose-peptone broth fermentation tube, in order to demonstrate more fully the extent of pollution in grossly polluted samples.

4. It is recommended that in the above-designated tests the culture media and methods used shall be in accordance with the specifications of the committee on standard methods of water analysis of the American Public Health Association, as set forth in "Standard Methods of Water Analysis" (A. P. H. A., 1912).

Since common carriers obtain their water supplies in many instances from municipal supplies, it seems almost necessary that the quality of the municipal water supplies must be made to conform to the standards. McLaughlin[14] secured statistics from a number of large filtration and purification plants in the country. Four of 15 cities furnished a water whose average quality during a year failed to conform to the standard for B. coli. Four others during certain months in the year failed to conform to the standard and it is possible that others on certain days might have furnished water that did not conform to the standard. From this record it would seem that very few large municipal water-purification plants would furnish an effluent at all times throughout the year that could be used by the railroads without further purification. However, the average shows that for the greater part of the time the water is suitable for use.

Director C. C. Young of the Kansas State Water Survey has furnished us with statistics concerning the Kansas supplies. Fifteen of 16 surface-water supplies do not continuously meet the Treasury standards for B. coli. Seven do not meet the standard for count on agar at 37½°C. for 24 hours. Fourteen of 26 ground-water supplies do not continuously meet the Treasury standard for B. coli. Of these 12 have an agar count of over 100 per cc. Only 9 of the 26 supplies meet the requirements in toto. Out of a total of 84 supplies examined 24 or 28.5 per cent met the Treasury requirements in all respects.

Creel[16] examined samples of water from 1,000 railway cars. The methods employed varied somewhat from those of the Commission, since the standard for purity of water on common carriers had not yet been formulated. Of these samples 421 were positive for gas formers in lactose-broth and lactose-bile fermentation tubes and B. coli was present in only 91 instances.

Bartow[2] in 67 samples taken from railway trains and examined according to the rules of the Commission found 49 or 73 per cent which did not conform to the standards of the Commission.

In order to determine whether the contamination was present in the original source or was incurred in handling, and also to study the character of the water supplies furnishing water to the common carriers, samples were collected from sources of water supplies within the State of Illinois.

INVESTIGATION OF SOURCES

In October 1914, circular letters were written to every railroad operating in Illinois, calling their attention to the Treasury regulations and asking them to submit a list of localities from which water was taken for drinking purposes for its trains. The railroads were very appreciative of the work and promptly responded. From the replies received from 64 railroads, 99 sources supplying water for common carriers were found.

Samples of the water were obtained and analyzed (see Table 1). The Standard Methods of the A. P. H. A. have been followed in the chemical analysis and the Treasury standards in the bacteriological examination.

CHEMICAL DATA FOR NINETY-NINE SOURCES

Ninety-nine waters were examined for turbidity; 49 showed a turbidity of less than 5 parts per million; 62, less than 10; 74, less than 15; and only 25 showed a turbidity of 15 or more. A turbidity of 10 parts per million or less would seem a reasonable standard.

Ninety-nine were examined for color. Fifty-three had a color less than 5 parts per million; 71, less than 10; 86, less than 20; and only 13 had a color of 20 or more. A color of 20 parts per million or less would appear to be easy to obtain and would not be noticeable in a glass of water.

In no case was there odor of chlorine or hydrogen sulfide noticeable when the bottle was shaken without heating. It would not be unreasonable to require that odor of chlorine and hydrogen sulfide be absent.

TABLE 1.—ANALYSES OF WATERS FROM WHICH RAILWAY TRAINS ARE SUPPLIED, DECEMBER 30, 1914-MAY 17, 1915.

[Parts per million.]

City.	Railroad.	Source.	Ownership.	Turbidity.	Color.	Odor.	Residue.	Chloride.	Oxygen consumed.	Nitrogen. Ammonia.	Nitrogen. Albuminoid.	Nitrogen. Nitrite.	Nitrogen. Nitrate.	Alkalinity to Methyl Orange.	Bacteria per cc. On Agar.	Bacteria per cc. On Gelatin.	B. coli in lactose broth. 0.1 cc.	B. coli in lactose broth. 1.0 cc.	B. coli in lactose broth. Five 10-cc. Portions. Positive.	B. coli in lactose broth. Five 10-cc. Portions. Confirmed.
Aiken	C.&G.W.	147′ drilled	R.[a]	7	5	0	858	5	.7	.120	.080	.000	.16	352	1	...	2—	2—	0	0
Alton	Mo.&I.,B.B.	Miss. River	..	..	..	..	...	..	..	....	...	....	...	...	50	6	2—	2—	..	..
Bement	Wabash	140′ driven	R.	10	15	1e	574	30	5.6	2.400	.200	.005	.40	474	12	9	2—	2—	0	0
Bloomington	I.C.	150′ drilled	R.	5	75	2v	880	2	7.1	1.600	.264	.000	.00	306	5000	3500	2—	2+	4	3
Bluffs	Wabash	30′ bored	R.	8	15	1v	458	15	1.2	.022	.058	.000	.76	436	1	2	2—	2—	0	0
Do.	"	30′ drilled	R.	0	0	0	488	18	2.0	.000	.040	.015	.72	484	3	0	2—	2—	0	0
Brewer	C.&E.I.	85′ drilled	R.	30	25	1e	582	4	8.1	4.280	.298	.005	.44	426	28	86	2—	2—	0	0
Broadlands	"	49′ dug	R.	3	5	0	504	22	1.2	.008	.056	.000	1.20	230	8	90	2—	2—	3	2
Do.	"	60′ dug	R.	0	0	0	910	17	1.2	.012	.060	.002	4.20	184	44	115	2—	2—	5	2
Bronson	"	20′ dug	R.	0	0	0	767	75	1.0	.000	.060	.003	15.20	136	44	80	2—	2—	..	..
Brighton Pk.	C.&A.	Lake Mich.	..	25	0	2v	179	5	1.3	.026	.102	.000	.28	106	10	111	2—	2—	1	0
Bolton	C.&G.W.	180′ drilled	R.	10	0	2g	294	4	1.6	.600	.120	.000	.24	294	9	180	2—	2—	0	0
Byron	"	75′ "	R.	5	0	2oily	297	5	1.5	.112	.048	.000	.40	302	180	...	1—1+	2+	5	5
Do.	"	481′ d. & d.	R.	0	0	0	395	8	.6	.072	.064	.000	.72	302	0	45	2—	2—	1	1
Cairo	C.&E.I.	....	R.	40	0	2v	156	7	2.2	.084	.072	.000	1.40	28	19	13	2—	2—	..	..
Carbondale	"	600′ drilled	R.	5	0	0	2512	1200	2.9	.048	.064	.000	1.20	378[a]	18	52	2—	1+1—	2	1
Carlinville	C.&A.	18′ dug	R.	10	0	1e	1187	168	.9	.014	.044	.000	5.60	264	13	120	2—	2—	1	1
Centralia	C.&E.I.	....	R.	30	8	1e	169	5	3.2	.078	.252	.000	1.08	42	30	102	2—	2—	0	0
Chester	I.So.	Miss. River	..	30	3	2d	40	2	2.0	.800	.088	.002	.20	16	8	1	2—	2—	..	..
Do.	"	" "	..	35	5	4d	16	2	2.8	.604	.054	.001	.28	12	5	60	2—	2—	..	..
Chicago	Penn.	Hydrant	M.	..	..	..	...	..	..	....	...	....	...	...	5	150	2—	2—	2	2
Do.	"	"	"	..	..	..	...	..	..	....	...	....	...	...	18	260	2—	2—	1	1
Do.	"	Sleeper	..	..	..	..	...	..	..	....	...	....	...	...	650	1300	2—	2—	0	0
Do.	"	"	..	..	..	..	...	..	..	....	...	....	...	...	7	2	2—	2—	1	0
Do.	"	"Edge Cliff"	..	..	..	..	...	..	..	....	...	....	...	...	1100	760	2—	2—	0	0
Do.	"	Coach 7003	..	..	..	..	...	..	..	....	...	....	...	...	750	1600	2—	2—	0	0
Do.	C.&G.W.	....	..	15	5	1m	154	6	1.0	.024	.110	.000	.32	120	2	1	2—	2—	3	0
Chicago Heights	C.&E.I.	Well	R.	2	3	0	700	7	1.0	.224	.080	.004	.72	878	9	4	2—	2—	0	0
Clare	C.&G.W.	14′ dug	R.	..	..	..	...	..	..	....	...	....	...	...	176	210	1+1—	1+1—	5	5
Coaler	C.&E.I.	139′ driven	R.	10	20	1v	376	26	4.8	1.040	.160	.000	32.00	284	30	41	2—	2—	0	0

[a]R.—Railroad, M.=Munieipal, and P.=Private.

[b]Alkalinity to phenolphthalein=8 parts per million.

Crete	C.&E.I.	200′ drilled	..	2	10	0	431	4	1.0	.208	.088	.000	.24	394	125	1600	2—	1—	3	3
Custer	C.&A.	48′ dug	R.	200	15	1v	1185	22	8.0	.728	.240	.017	.12	336	431	9300	1+1—	2+	4	3
Cypress	C.&E.I.	20′ dug	..	0	0	0	309	22	.8	.030	.122	.000	3.20	216	0	500	2—	2—	0	0
Dollville	"	14′ dug	R.	0	0	1d	335	21	1.0	.006	.048	.000	9.20	192	86	580	2—	2+	1	1
Do.	"	16′ bored	R.	3	0	1d	462	19	1.0	.076	.120	.000	6.00	192	250	3000	2—	2—	2	1
Do.	"	16′ dug	R.	3	5	1d	400	28	2.8	.272	.306	.135	11.20	162	14	140	2—	2+	2	2
East Stockton	C.&G.W.	430′	R.	0	0	0	324	12	.8	.120	.144	.000	.60	288	1500	....	2—	2—	0	0
Eldorado	C.&E.I.	Cistern	R.	7	35	1v	1898	220	10.0	.102	.618	2.70	148.0	176	2000	5000	1+1—	2+	5	5
Elgin	C.&G.W.	75′ drilled	R.	0	0	1e	300	4	.5	.032	.086	.003	5.20	242	3	20	2—	2—	0	0
Elizabeth	"	400′	M.	0	5	0	538	85	.7	.048	.088	.015	.44	368	6	17	2—	2—	0	0
Elmhurst	"	Spring	R.	5Fe	0	0	483	4	.8	.276	.096	.000	.28	340	6	3	2—	2—	0	0
Esmond	"	25′ dug	R.	0	10	0	2159	135	3.2	.060	.186	.040	85.00	284	120	870	2—	2—	0	0
"Fan House"	"	Spring	R.	10	0	0	298	8	1.5	.028	.084	.000	.72	234	150	2500	2—	2+	5	3
Findley	C.&E.I.	Dug well	R.	3	5	1a	1881	92	.8	.022	.094	.002	18.80	244	120	880	2+	1+1—	4	4
Flora	B.&O.	22′ dug	R.	0	0	0	1741	130	1.5	.026	.070	.000	5.40	230	9	3	2—	2—	0	0
Do.	"	30′ dug	R.	0	0	0	1806	275	2.8	.012	.108	.000	11.20	850	30	64	2—	2—	4	2
Forest	C.&E.I.	16′ dug	R.	2	5	1v	1660	35	.7	.002	.066	.000	10.00	316	12	90	2—	2—	0	0
Forest Park	C.&G.W.	Artesian Well	M.	0	0	1e	636	85	.7	.216	.112	.020	.32	262	0	2	2—	2—	2	2
Galena Jnc.	"	45′ drilled	R.	7	0	0	341	25	1.3	.026	.090	.000	1.12	342	120	8000	2—	2+	5	5
Galesburg	C.B.&Q.	Reservoir	M.	15Fe	0	0	1004	79	1.2	.400	.144	.030	.64	384	10	80	2—	2—	..	..
Do.	"	Reservoir	M.	10Fe	5	0	1007	79	1.2	.800	.240	.025	.80	384	30	130	2—	2—	..	..
German Valley	C.&G.W.	40′ drilled	R.	0	0	0	321	6	1.8	.020	.088	.000	4.00	260	....	2	2—	2—	0	0
Glenn	C.&A.	90′ "	R.	25Fe	0	1e	861	17	1.2	.324	.088	.000	.20	96	0	0	2—	2—	0	0
Golconda	C.&E.I.	Cistern	R.	5	15	2e	89	4	4.0	.026	.056	.000	.56	24	8	1	2—	2—	0	0
Goodwine	"	60′ drilled	R.	18	15	0	473	7	2.0	1.190	.056	.000	.08	360	6	3	2—	2—	0	0
Gretna	C.&G.W.	150′ "	R.	20	0	1e	825	4	2.1	.320	.048	.000	.16	174	4	0	2—	2—	0	0
Halcomb	"	80′ "	R.	3	0	1e	370	10	1.0	.024	.042	.000	.40	298	2	0	2—	2—	0	0
Hanover	"	Spring	R.	2	0	0	974	85	1.0	.046	.048	.000	11.00	316	60	750	2—	2—	0	0
Henton	C.&E.I.	15′ bored	R.	0	0	0	375	26	.8	.008	.044	.000	6.40	252	0	21	2—	2—	0	0
Ingalton	C.&G.W.	127′ drilled	R.	3	0	0	383	4	.8	.240	.072	.000	.44	352	0	0	2—	2—	0	0
Jacksonville	C.&E.I.	Well "	P.	..	..	..	...	..	..	....	...	....	...	...	2500	1500	2—	1+1—	0	0
Do.	C.P.&St.L.	74′ "	R.	8	10	1v	461	16	1.2	.060	.046	.004	.40	298	2	4	2—	2—	0	0
Joppa	C.&E.I.	80′ driven	R.	2	10	0	220	20	1.2	.036	.048	.000	.80	184	10	1	2—	2—	0	0
Kent	C.&G.W.	....	R.	8	25	1v	244	18	6.0	.056	.144	.000	3.80	138	1700	liq.	2+	2+	5	5
Lockport	....	43′ dug	R.	2	0	0	1469	118	1.8	.034	.158	.010	5.60	280	960	1300	2—	2—	5	3
Lombard	C.&G.W.	125′ drilled	R.	20Fe	0	0	431	4	.9	.200	.040	.000	.20	390	0	38	2—	2—	0	0
Longview	C.&E.I.	700′ "	R.	30	35	1v	1826	500	9.4	9.600	.804	.000	.08	508	9000	5000	2—	2—	3	3
Lindenwood	C.&G.W.	28′ dug	R.	0	0	1v	409	14	1.0	.028	.042	.000	.80	270	9	98	2—	2—	2	1
Lilly Lake	"	80′ drilled	R.	0	0	0	542	11	1.5	.040	.100	.000	7.60	378	4	96	2—	2—	1	0
Do.	"	80′ "	R.	..	..	..	...	..	..	....	...	....	...	...	21	130	2—	2—	0	0
Marion	C.&E.I.	Deep well	M.	2	10	1v	1573	420	1.6	.014	.052	.000	1.12	700	230	700	2—	2—	0	0
Do.	"	400′ bored	M.	2	10	1e	1494	360	2.8	.048	.056	.005	.80	740	1	5000	2—	2—	5	..
Matteson	I.C.	280′ drilled	R.	0	10	0	626	2	1.2	.563	.048	.000	.28	254	180	3000	2—	1—	5	4
Do.	"	280′ "	R.	2	10	0	621	5	1.0	.560	.064	.000	.86	344	3	20	2—	2—	1	0
Mitchell	C.&E.I.	86′ driven	R.	70Fe	0	1e	858	8	1.2	.204	.016	.000	.48	258	1	0	2—	2—	0	0
Momence	"	100′ drilled	R.	2	5	0	531	20	2.5	.024	.088	.004	.60	240	2	2	2—	2—	0	0
Monee	I.C.	190′ "	R.	60	0	1oily	545	2	3.3	.600	.032	.016	.24	454	3	3	2—	2—	0	0
Mount Vernon	C.&E.I.	....	M.	2	20	1e	324	12	3.6	.164	.164	.001	.76	44	85	200	2—	2—	0	0
Do.	So.	....	M.	0	0	1d	266	10	2.3	.080	.140	.000	.76	36	6	200	2—	2—	3	2

TABLE 1.—ANALYSES OF WATERS FROM WHICH RAILWAY TRAINS ARE SUPPLIED, DECEMBER 30, 1914-MAY 17, 1915 (continued).

[Parts per million.]

City.	Railroad.	Source.	Ownership.	Turbidity.	Color.	Odor.	Residue.	Chloride.	Oxygen consumed.	Nitrogen. Ammonia.	Nitrogen. Albuminoid.	Nitrogen. Nitrite.	Nitrogen. Nitrate.	Alkalinity to Methyl Orange.	Bacteria per cc. On Agar.	Bacteria per cc. On Gelatin.	B. coli in lactose broth. 0.1 cc.	B. coli in lactose broth. 1.0 cc.	B. coli in lactose broth. Five 10-cc. Portions. Positive.	B. coli in lactose broth. Five 10-cc. Portions. Confirmed.
Myrtle	C.&G.W.	60′ drilled	R.	0	0	0	442	28	.5	.064	.096	.000	20.00	242	0	69	2—	2—	0	0
North Glen Ellyn	"	60′ d. & d.	R.	3	0	1e	452	4	1.3	.132	.126	.000	.24	334	0	2	2—	2—	0	0
Olney	C.H.&D.	12′ dug	R.	0	0	0	703	55	.8	.040	.062	.000	47.00	76	24	180	2—	2—	4	2
Do.	"	16′ "	R.	3	10	0	577	92	3.6	.040	.344	.000	22.00	68	200	450	1+1—	2+	5	5
Pana	B.&O.	16′ "	R.	0	0	0	1097	52	1.3	.012	.072	.002	8.00	170	45	liq.	2—	2—	0	0
Do.	C.&E.I.	17½′ dug	R.	0	10	0	2379	340	2.2	.000	.190	.013	32.00	269	9	12	2—	2—	1	1
Do.	"	Well	M.	15	5	1e	1054	170	1.4	1.116	.066	.017	.80	404	0	0	2—	2—	3	2
Do.	"	19′ dug	R.	0	5	0	905	130	1.4	.052	.112	.000	15.60	104	12	30	2—	2—	4	4
Do.	"	18½′ dug	R.	0	5	1v	1107	106	1.2	.072	.158	.000	15.20	256	15	69	2—	2—	0	0
Pearl City	C.&G.W.	42′ drilled	R.	12	30	1e	629	66	.7	.836	.108	.012	.88	374	4	6	2—	2—	..	..
Peotone	I.C.	126′ "	R.	10	0	1v	625	5	1.7	.520	.104	.003	.72	322	1	1	2—	2—	0	0
Pinckneyville	C.&E.I.	20′ dug	R.	0	0	0	1466	300	1.0	.022	.082	.000	3.12	280	93	170	2—	2—	0	0
Pittwood	"	120′ drilled	R.	40	30	0	325	25	8.0	2.960	.224	.000	.24	288	0	6	2—	2—	0	0
Roden	C.&G.W.	....	R.	5	0	0	393	12	1.0	.020	.040	.000	1.08	800	20	200	2—	1—	5	3
Roodhouse	C.&A.	Deep well	R.	10	30	0	318	18	1.5	.056	.080	.002	.60	226	42	24	2—	2—	0	0
Do.	"	190′ drilled	R.	120Fe	0	1e	483	9	1.2	1.000	.200	.000	.12	436	1	0	2—	2—	0	0
St. Anne	C.&E.I.	210′ "	R.	45Fe	0	0	902	7	3.3	.800	.080	.023	.24	238	7	3	2—	2—	3	2
St. Charles	C.&G.W.	80′ "	R.	..	..	..	...	..	..	....	...	....	...	...	86	410	2—	2—	1	1
Do.	"	80′ "	R.	0	0	0	473	16	1.0	.014	.086	.000	5.20	284	4	80	2—	2—	5	2
St. Elmo	C.&E.I.	20′ dug	R.	0	0	2m	995	48	1.0	.004	.060	.000	5.00	282	....	....	......	......	..	..
Salem	"	99′ drilled	R.	0	0	1e	2893	49	2.9	.074	.098	.000	.20	448	600	1200	1+1—	1+1—	0	0
Do.	"	20′ dug	R.	30	5	1e	775	7	1.5	.024	.080	.002	2.20	460	570	1450	2—	1+1—	8	1
Shawneetown	B.&O.	40′ driven	R.	..	..	..	...	..	..	....	...	....	...	...	0	4	2—	2—	5	4
Do.	"	40′ driven	R.	0	0	0	560	34	1.2	.008	.026	.005	1.08	260	11	9	2—	2—	5	0
Do.	"	40′ "	R.	0	0	0	490	13	1.0	.006	.090	.000	.56	310	10	9	2—	2—	2	2
So. Freeport	C.&G.W.	310′ drilled	R.	10	0	0	397	6	.9	.560	.064	.000	.00	324	....	....	......	......	..	..
Do.	"	" "	R.	20	0	1e	397	7	1.1	.400	.056	.000	.20	326	370	4000	2—	2—	0	0
So. Holland	C.&E.I.	Lake Mich.	..	2	5	1e	166	4	2.0	.020	.078	.000	.44	120	1	150	2—	2—	0	0
Springfield	B.&O.	City wells	M.	15	5	1e	328	16	2.0	.036	.144	.002	.48	220	9	50	2—	2—	0	0
Do.	C.H.&D.	" "	M.	2	5	1v	357	19	2.8	.038	.132	.000	.80	244	6	15	2—	2—	3	3
Staunton	Wabash	16′ dug	R.	5	15	1v	1752	40	1.7	.120	.110	.246	2.40	316	110	200	2—	2—	0	0
Stillman Valley	C.&G.W.	58′ drilled	R.	0	0	0	376	6	.9	.026	.020	.045	.64	304	1	0	2—	2—	0	0

Steger	C.&E.I.	Well	R.	5	0	0	480	3	.6	.254	.076	.000	.28	398	2	1	2—	2—	0	0
Stockton	C.&G.W.	1500′ drilled	M.	0	0	0	311	2	.6	.040	.056	.000	.60	210	14	99	2—	2—	3	3
Sycamore	"	900′ "	M.	20	0	1e	348	5	1.5	.320	.080	.000	.72	380	5	2	2—	2—	0	0
Thebes	C.&E.I.	Miss. River	..	400	20	2v	687	16	9.4	.240	.400	.015	1.08	158	....	....	......	......	..	..
Do.	"	Water tank	R.	340	10	1e	497	8	9.4	.198	.338	.004	2.40	110	1500	3000	1+1—	2+	0	0
Thornton	"	150′ drilled	R.	0	6	1v	332	6	2.5	.132	.110	.010	8.00	120	6	810	2—	2—	0	0
Do.	"	20′ dug	R.	0	0	0	990	51	1.2	.070	.126	.007	1.92	324	600	5000	1+1—	2—	4	3
Thornton Jnc.	"	30′ dug	R.	7	10	2d	1192	62	.5	.024	.094	.045	1.80	334	34	80	2—	2—	2	1
Villa Grove	"	46′ bored	R.	10	0	1e	1956	73	2.3	.020	.058	.007	15.2	156	9	195	2—	2—	0	0
Virgil	C.&G.W.	12′ driven	R.	35Fe	10	0	896	38	1.4	.074	.114	.000	.20	328	1	3	2—	2—	2	2
Wasco	"	50′ drilled	R.	30	0	1m	1047	118	.7	.044	.076	.000	.36	310	8	150	2—	2—	4	1
Watseka	C.&E.I.	Well	R.	10	40	0	867	15	5.2	3.200	.160	.000	.48	324	2	10	2—	2—	1	..
West Frankfort	"	18′ bored	R.	45	3	1v	1608	36	1.7	.034	.132	.002	6.40	58	800	1200	2—	2—	0	0
Do.	"	35′ dug	R.	8Fe	0	1v	994	44	1.0	.016	.068	.001	80.00	320	90	250	2—	2—	5	5
Winston	C.&G.W.	Spring	R.	0	0	2m	208	4	.9	.044	.094	.000	8.20	176	70	4000	2—	2—	0	0
Woodbine	"	155′ driven	R.	20	20	0	861	110	.6	.048	.056	.010	10.00	280	30	9	2—	2—	0	0

ICES.

Alton	Mo. & I. B. B.			3	0	1hypo	31	3.0	2.0	.632	.126	.015	.48	4	6	0	2—	2—	..	..
Champaign	I. C.			2	5	0	21	4.0	2.5	.666	.122	.007	.20	6	60	180	2—	2—	0	0
Chester	I. So.			2	0	1e	46	4.2	4.8	.392	.246	.015	.48	4	4	9	2—	2—	0	0
Chicago	Penn.			..	..	..	..	..	..	....	...	....	...	...	4	1	2—	2—	0	0
Do.	Penn.			..	..	..	..	..	..	....	...	....	...	...	18	12	2—	2—	0	0
Danville	....			..	..	..	..	..	..	....	...	....	...	...	0	0	2—	2—	0	0
Decatur	....			0	5	1w	10	3.0	1.5	.154	.048	.004	.40	8	10	4	2—	2—	0	0
Effingham	Big 4 & I. C.			0	0	1w	20	.8	1.5	.284	.084	.007	.40	8	4	2	2—	2—	1	0
Flora	....			3	5	0	31	5.0	2.2	.292	.138	.004	.12	8	4	2	2—	2—	0	0
Jacksonville	C. P. & St. L.			0	0	0	34	6.0	1.6	.146	.080	.007	.12	6	30	15	2—	2—	0	0
Kankakee	Big 4 & I. C.			0	0	1w	17	.8	2.2	.112	.236	.007	.92	6	5	2	2—	2—	0	0
Marion	C. I. P. S. Co.			0	0	1m	28	1.	5.4	.132	.310	.008	.16	6	12	36	1+1—	2+	5	5
Do.	C. I. P. S. Co.			0	0	0	12	2.	2.0	.100	.078	.006	.12	14	7	16	2—	2—	0	0
Olney	C. H. & D.			0	5	1oily	21	1.4	2.0	.170	.102	.008	.64	4	0	0	2—	2—	0	0
Papineau	C. & E. I.			10	5	0	353	31.	2.7	.056	.086	.000	.24	290	6	0	2—	2—	0	0
Pekin	....			3	0	0	26	2.0	1.3	.226	.050	.030	.04	4	8	15	2—	2—	0	0
Springfield	C. H. & D.			0	0	0	40	2.0	8.9	.230	.204	.030	.24	8	0	4	2—	2—	0	0
Westville, Ind.	Wabash			3	0	1a	19	4.	2.0	.114	.140	.003	.24	8	12	2	2—	2—	0	0

Ninety-nine waters were examined for residue. Of these, 10 had a residue less than 250 parts per million; 50, less than 500; 78, less than 1,000; and 21 above 1,000. A standard of 1,000 parts per million for residue would seem very reasonable. Owing to the physiological action of some salts, and to the sensitiveness of many people to waters containing salts, it might be advisable to require a residue of less than 500 unless the normal for the line is shown to be greater.

Chloride was determined in 99 waters. Of these, 61 had less than 25 parts per million; 74, less than 50; 84, less than 100; 92, less than 200; 93, less than 250; and only 6 more than 250. It would seem reasonable to set a limit of 50 or even 25 parts per million for chloride, unless it is necessary to use highly mineralized waters of acknowledged hygienic purity.

The alkalinity, using phenolphthalein and methyl orange as indicators, was determined in 99 waters. In but one case was a water found that was alkaline to phenolphthalein. A requirement that the alkalinity to phenolphthalein shall not be greater than one-half the alkalinity to methyl orange would guard against the use of water overtreated with lime. From the results thus far obtained this requirement would work no hardship upon the railroads. Eight waters contained less than 100 parts per million of alkalinity to methyl orange; 21, less than 200; 56, less than 300; 91, less than 400; and 8, more than 400. If a standard of 500 is fixed for residue the same standard may be fixed for alkalinity for, as is sometimes the case, the residue may consist entirely of carbonates.

BACTERIOLOGICAL DATA FOR NINETY-FOUR WATERS

Twenty-seven waters had more than 100 bacteria per cc, growing on agar at 37½°C. and, therefore, did not conform to the Treasury Department standard; 32 did not conform to the B.-coli standard proposed by the same Department; 15 did not conform to either standard; and in all, 44 or 47 per cent of the water, did not meet the Treasury standards.

EXAMINATION OF ICE

Sixteen samples of ice were examined (see Table 1). In but one case was there any difficulty in meeting the Treasury standards. In this single instance the cake was not representative of the whole harvest, as it contained flakes of dirt which might very well envelop B. coli. Another sample was taken and very satisfactory results obtained.

TABLE 2.—CHEMICAL ANALYSES OF RAW AND TREATED WATERS FROM MUNICIPAL FILTER PLANTS IN ILLINOIS.

[Parts per million.]

City.	Turbidity.		Color.		Odor.		Residue.		Chloride.		Oxygen Consumed.		Ammonia Nitrogen.		Albuminoid Nitrogen.		Nitrite Nitrogen.		Nitrate Nitrogen.		Alkalinity.	
	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.	Raw.	Treated.
East St. Louis	70	0	30	25	0	0	295	203	5.6	6.6	7.7	5.2	.128	.056	.360	.198	.015	.000	1.12	1.12	130	130
Hamilton	35	0	30	0	1v	0	189	172	2.8	2.8	7.2	3.5	.104	.108	.360	.148	.010	.003	1.00	1.00	122	112
Granite City	65	10	20	10	1e	1e	300	226	6.2	6.6	7.0	3.5	.120	.108	.320	.186	.024	.001	1.28	1.20	132	126
Warsaw	45	8	20	0	1v	1e	202	170	4.	5.	7.5	4.4	.174	.186	.436	.204	.017	.006	.88	.88	122	108
Alton	85	0	40	10	0	1v	285	259	10.2	9.8	6.0	2.5	.080	.082	.400	.206	.011	.038	1.52	1.28	150	150
Quincy	35	0	35	0	1e	1m	203	189	4.0	8.8	7.6	3.2	.200	.096	.520	.142	.015	.000	.72	.80	124	104
Rock Island	65	0	40	0	1e	0	342	138	1.8	4.0	9.4	4.0	.128	.056	.440	.146	.008	.000	.24	.32	72	52
Cairo	60	25	15	0	1e	1e	210	166	10.	14.	2.0	1.0	.040	.032	.208	.078	.002	.000	.76	.80	74	46
Mount Carmel	35	0	10	0	2a	0	421	390	86.	86.	4.5	2.5	.052	.012	.296	.102	.006	.000	.88	1.00	202	186
Danville	15	2	30	15	1e	1e	328	309	5.	6.	4.2	2.4	.058	.052	.204	.148	.010	.018	.80	.68	210	202
Pontiac	25	0	25	5	2v	1v	421	395	6.	10.	4.6	2.6	.064	.072	.296	.184	.025	.004	1.48	1.72	218	210
Stréator	25	0	20	10	1v	0	371	363	16.	16.	5.2	3.2	.094	.082	.290	.184	.004	.000	.60	.72	178	164
Kankakee	25	0	30	25	1e	0	421	376	2.	4.	5.8	4.5	.064	.040	.246	.202	.000	.002	.88	.80	186	186
Decatur	15	0	10	0	1e	1v	320	315	9.	9.	3.8	2.4	.064	.052	.240	.158	.022	.000	.72	.92	238	232
Macomb	40	0	20	5	1v	0	288	229	8.	8.	5.0	3.0	.102	.054	.370	.180	.002	.000	.08	.08	186	164
Anna	35	5	10	0	1a	0	212	160	5.	5.	8.2	1.4	.042	.064	.240	.106	.022	.001	.56	.76	150	114
Carlinville	35	10	10	10	1m	0	317	316	5.	5.	7.4	3.2	.182	.052	.574	.266	.064	.021	.60	.64	68	60
Mount Vernon	5	0	15	5	1v	1v	374	340	11.	11.	3.8	1.8	.120	.028	.286	.134	.001	.001	.60	.72	60	52
Centralia	..	45	..	20	..	2a	...	149	....	5.	...	3.8	....	.028	...	.234	...	.000	...	1.00	...	30
Breese	20	15	0	0	1e	0	424	411	15.	14.	3.5	3.5	.150	.094	.288	.270	.000	.020	.28	.20	228	228
Fort Sheridan	10	0	10	0	1v	0	159	143	5.	5.	1.6	1.2	.026	.050	.112	.124	.000	.000	.24	.24	116	112
Waukegan	5	5	5	0	1m	2a	147	150	5.	5.	2.2	1.7	.038	.046	.108	.110	.000	.000	.32	.24	114	114
Great Lakes	33	0	0	0	0	0	143	148	5.	5.	1.7	1.6	.048	.048	.150	.098	.000	.000	.24	.32	114	114
Kenilworth	5	0	0	0	1a	0	155	139	5.	5.	1.1	.8	.034	.050	.096	.076	.000	.000	.28	.56	108	100
Lake Forest	5	0	0	0	1a	0	149	149	5.	5.	2.4	2.0	.046	.078	.112	.114	.000	.000	.44	.44	112	114
Winnetka	10	0	0	0	1e	0	145	140	5.	5.	2.1	1.6	.052	.050	.120	.102	.000	.000	.24	.60	114	114
Evanston	7	0	5	0	1a	0	130	142	4.	4.	2.0	.8	.124	.032	.052	.108	.000	.000	.28	.36	114	108

TABLE 3.—BACTERIAL EXAMINATION OF RAW AND TREATED WATERS FROM MUNICIPAL FILTER PLANTS IN ILLINOIS.

City.	Source of supply.	Type of treatment.	Bacteria per cc.				Gas formation in lactose broth.								Confirmation of B. coli.	
			On agar.		On gelatin.		Raw.			Treated.			Five 10-cc. portions.			
			Raw.	Treated.	Raw.	Treated.	Ten cc.	One cc.	Tenth cc.	Ten cc.	One cc.	Tenth cc.	Positive.	Negative.	Positive.	Negative.
East St. Louis	Miss. R.	M. A. H.[a]	1,260	18	5,000	50	1+	2+	1+1—	1+	2—	2—	2	3	0	2
Hamilton	do	M. A.	112	1	930	5	1+	2+	2—	1—	2—	2—	0	5	0	0
Granite City	do	A. H.	175	4	400	90	1+	2+	2+	1—	2—	2—	2	3	0	2
Warsaw	do	M. A. H.	87	14	360	187	1+	2+	2—	1+	2—	2—	4	1	4	0
Alton	do	"	153	8	370	36	1+	2+	2—	...	2—	2—	0	5	0	0
Quincy	do	"	700	0	3,000	4	1+	2+	2+	1—	2—	2—	0	5	0	0
Rock Island	do	"	296	11	560	37	1+	2+	1+1—	1—	2—	2—	0	5	0	0
Cairo	Ohio R.	"	195	6	260	19	1+	1+1—	2—	1+1+	1—	2—	1	4	0	1
Mount Carmel	Wabash R.	"	140	con.	800	75	1+	2—	1+1—	1—	2—	2—	0	5	0	0
Danville	Vermilion R.	"	390	10	45	70	1—	2—	2—	1—	2—	2—	0	5	0	0
Pontiac	do	"	800	8	600	9	1+	2+	1+1—	...	2—	2—	1	3	1	0
Streator	do	"	200	3	1,600	19	1+	2+	1+1—	1—	2—	2—	0	5	0	0
Kankakee	Kankakee R.	"	230	18	5,000	450	1+	2+	1+1—	1+	2—	2—	4	1	3	1
Decatur	Sangamon R.	"	750	25	300	5	1+	2—	2—	1—	2—	2—	0	5	0	0
Macomb	Creek	"	870	7	1,200	120	1+	2+	2—	1—	2—	2—	1	4	1	0
Anna	do	"	63	9	240	13	1+	2+	2—	1+	2—	2—	1	4	1	0
Carlinville	do	M. A.	17	44	130	53	1—	2—	2—	1+	2—	2—	2	3	1	1
Mount Vernon	do	M. A. H.	38	21	65	93	1—	2—	2—	1—	2—	2—	0	5	0	0
Centralia	do	Hypo alone	300	155	50	102	1+	2—	2—	1+	2—	2—	..	..	..	..
Breese	do	S.	950	290	1,300	460	1+	2+	1+1—	1+	2+	2—	5	0	5	0
Fort Sheridan	Lake Mich.	M. A. H.	68	0	90	0	1—	2—	2—	1—	2—	2—	0	5	0	0
Waukegan	do	Hypo alone	40	0	170	0	1+	2—	2—	1—	2—	2—	0	5	0	0
Great Lakes	do	S. S. F.	3	0	6	4	1—	2—	2—	...	2—	2—	0	5	0	0
Kenilworth	do	M. A.	3	5	19	7	1+	1+1—	2—	...	2—	2—	0	5	0	0
Lake Forest	do	M. A. H.	9	0	8	30	1—	1+1—	2—	1+	2—	2—	5	0	5	0
Winnetka	do	Hypo alone	10	0	68	3	1—	2—	2—		2—	2—	0	5	0	0
Evanston	do	M. A. H.	19	3	130	12	1+	2+	1+1—	1—	2—	2—	0	5	0	0

[a]M. A. H.=Mechanical Filter, Alum and Hypochlorite; A. H.=Alum and Hypochlorite; M. A.=Mechanical Filter and Alum; S.=Sedimentation; S. S. F. = Slow Sand Filter.

EXAMINATION OF MUNICIPAL FILTER-PLANT EFFLUENTS

With the assistance of Mr. W. F. Langelier during the month of April, 1915, 26 of the purification plants of Illinois were visited. Samples of the raw and treated water were collected and shipped, packed in ice, to the laboratory, where the analysis was started immediately (see Tables 2 and 3).

It is to be noted that but 5 of the plants were at the time producing an effluent which would be condemned by the Treasury standards. Two towns which do not meet the standards do not have efficient plants. Breese uses coagulation and sedimentation, and at the time of inspection was using no coagulant, and Centralia uses hypochlorite alone. Three plants having filters did not meet the standards. Warsaw is using one of the small wooden tub filters where the rate controller must be changed considerably during the day to meet the demand. Lake Forest has a new filter of an unusual type, and it is doubtful if good results can be obtained consistently. Kankakee has a plant from which fluctuations of quality are to be expected because the apparatus used for adding hypochlorite of calcium does not insure a uniform application. Since the sample was collected, however, a liquid-chlorine apparatus has been installed and a satisfactory effluent may now be expected.

In looking at the analyses of the raw waters from these plants one is impressed by the fact that in many places very little purification was needed. The inspection trip was taken in April after a period in which there had been little or no rain, and it was not surprising that the plants of the State, during times when the number of B. coli in the raw water was not high, could produce an effluent which would conform to the standards. It was expected that another similar trip would be taken after a heavy rain in order that the extremes might be contrasted, but owing to the continued drought such a trip was not possible before the completion of this article. From data of analyses previously made at this laboratory and at the filtration plants where bacteriological control is maintained we would expect very few, if any, of the plants to have an effluent throughout the year which would at all times meet the standards recommended by the Treasury Department.

The confirmation tests for B. coli are not entirely satisfactory. Of 184 positive fermentation tests in lactose broth shown in Table 1, 166 or 90.2 per cent developed red colonies on Endo's medium, and when transplanted into lactose broth, 132 produced fermentation. It is to be expected that B. coli will be missed occasionally owing to their slight motility. They become entangled in the sludge which separates from the medium and presumably are in the bottom of the fermentation tube, thus great care to shake violently must be taken before transplanting into Endo's medium. Also, the fact that not all B. coli colonies are red, but remain white must be taken into consideration. Some white colonies which appear like B. coli, have been found to produce gas when reinoculated into lactose broth.

Based upon the analyses made and upon what is known concerning the physiological effect of the various constituents of water, the following chemical and bacteriological standards seem reasonable.

SUGGESTIONS

Chemical standards may be required as follows:

1. Turbidity not greater than 10 parts per million.
2. Color not greater than 20 parts per million.
3. There shall be no odor of hydrogen sulfide or free chlorine.
4. Eesidue not greater than 1,000, and preferably 500 parts per million.
5. Sulfate not greater than 250 parts per million.
6. Chloride not greater than 50 parts per million.
7. Lead or copper not greater than .2 part per million.
8. The alkalinity to phenolphthalein not greater than one-half that to methyl orange, and the alkalinity to methyl orange not more than 500 parts per million.

The bacteriological standards should be made to conform to those of the Treasury Department (see page 259).

The chemical analysis may be carried on as recommended in the "Standard Methods of "Water Analysis" of the American Public Health Association, 1912, except in the determination of lead or copper and sulfates. The sulfates shall be determined by the ordinary gravimetric method by precipitation with barium chloride or by the benzidene volumetric method.[8 9]

Lead and copper may be determined by the following procedure, except when present in a relatively large amount (i. e. over .3 p. p. m.) in which case Standard Methods are to be followed. To 100 cc. of water add 2 grams of pure crystalline ammonium chloride, 2 cc. of acetic acid and 2 or 3 drops of 10 per cent sodium sulfide solution. Compare immediately with standards containing known amounts of lead nitrate. The standards should contain .01, .02, 03 mg. of lead.

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EPIDEMIC OF TYPHOID FEVER CAUSED BY POLLUTED WATER SUPPLY AT OLD SALEM CHAUTAUQUA[1]

By H. F. Ferguson.

A large and widespread epidemic of typhoid fever resulted from the use of a polluted water supply at the 1915 assembly of Old Salem Chautauqua. Though presenting nothing new from an epidemiological standpoint, it serves to emphasize the danger of incurring typhoid-fever infection at summer camps and picnic grounds where insanitary conditions are allowed to prevail and adequate attention is not given to the quality of the water supply. Sanitarians have realized that there is a tendency for persons to abandon sanitary precautions while camping or on summer vacations in the country, and much has, therefore, been written to warn people of the dangers involved. However, owing to the coming and going of vacationists and the scattered location of their homes it has been difficult to obtain data on any large outbreak coining from a summer camp. The Old Salem Chautauqua epidemic is a striking example of such an outbreak, and it should serve as a warning to vacationists and to the management of summer resorts.

DESCRIPTION OF CHAUTAUQUA GROUNDS

The Old Salem Chautauqua grounds, (Figure 1) comprising about 60 acres, are located in Menard County about a mile south of Petersburg. Sangamon River; flowing in a northerly direction, forms the western boundary. The grounds are rolling and well-drained with the exception of the northern part, where they are very flat and subject to overflow at high stages of Sangamon River. Chautauqua assemblies have been held since 1897, and many buildings, including an auditorium, hotel, bathhouse, memorial and society buildings, and slightly over one hundred private cottages have been constructed. The cottages are occupied by the owners and their friends during the assemblies and many tents are erected to accommodate other campers. The Old Salem Chautauqua assemblies have been remarkably good, and have gained a widespread reputation. This is shown by the fact that in 1905, 4,000 people, coming from 33

[1]Read before the Public Health Section, sixty-sixth annual meeting of the Illinois State Medical Society, at Champaign, May 17, 1916, (Illinois Medical Journal Vol. XXX, No. 4.). Investigation made for the State Board of Health while on leave of absence from the Survey.

States and Territories and five foreign countries, lived on the grounds. Because of the advent of traveling Chautauquas the attendance has fallen off of late years, and the estimated daily attendance during the 1915 assembly varied between 500 and 3,000.

In the early days of the Chautauqua, public water supply and sewer systems were installed. The sewer system serves the greater

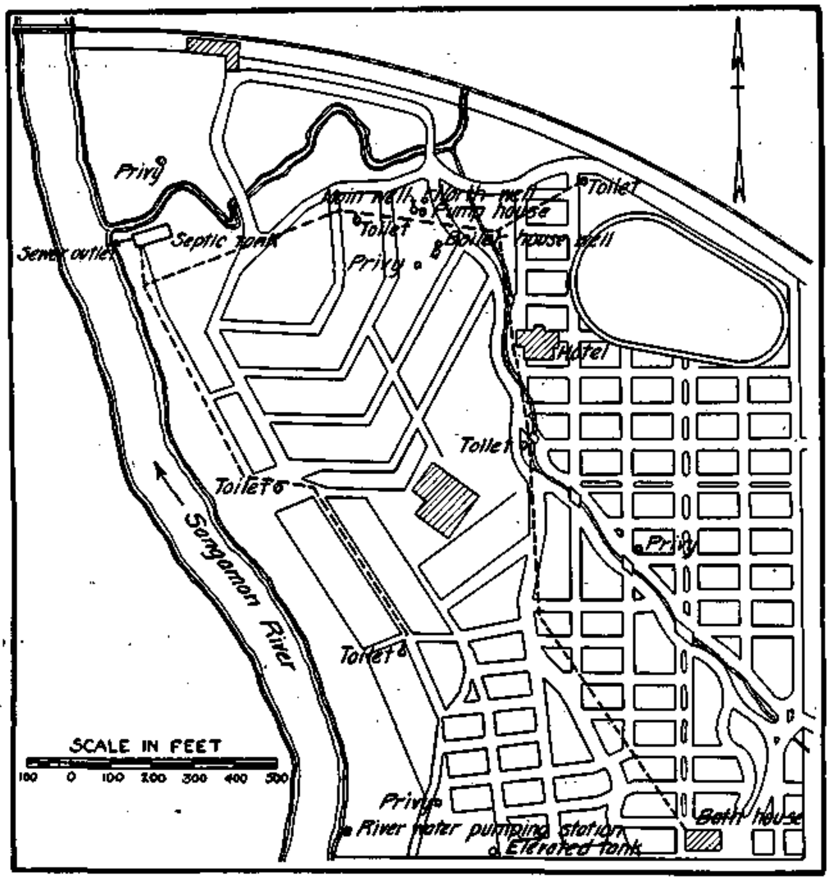

Figure 1.—Plat of Old Salem Chautauqua grounds, showing waterworks and sewer systems.

portion of the grounds and the sewage, after passing through a septic tank, is discharged into Sangamon River at the northwest corner of the grounds.

WATER SUPPLY

There are two separate sources of water supply, a supply from wells for domestic use, and a supply from Sangamon River for the bathhouse, for flushing purposes, and for use in the hotel kitchen. Polluted river water might have caused typhoid, especially as used in a swimming pool at the bathhouse (Figure 2), but since there is no evidence that such was the case the river-water supply will not be described here. It may be noted, however, that between the river-water and well supplies cross-connections, controlled by single valves, existed in a few cottages.

The domestic supply is obtained from three dug wells located on the low land at the northern end of the grounds (Figures 3 and 4).

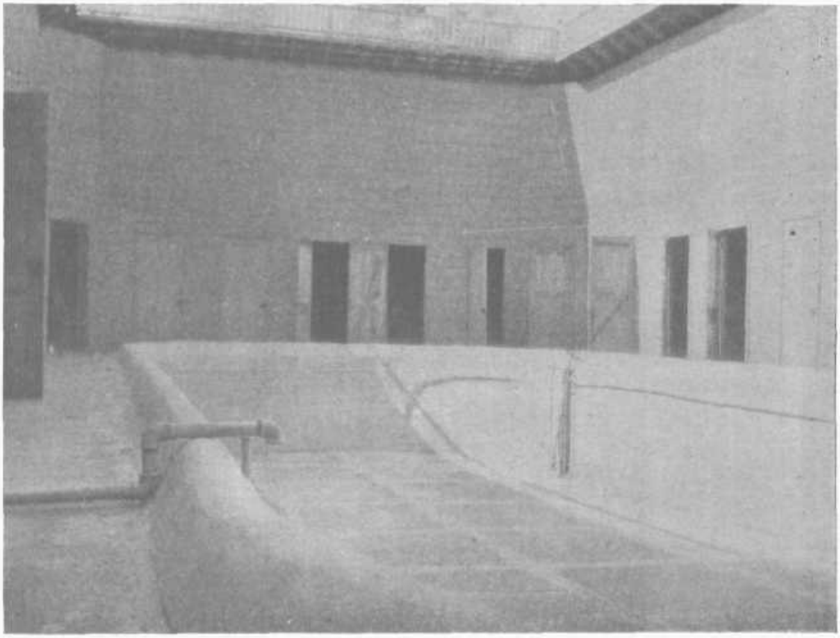

Figure 2.—Interior of bathhouse and swimming pool.

One of these wells, which furnishes most of the water is designated the main well, and the other two the north well and boiler-house well, respectively.

The main well (Figure 5) is about 8 feet in diameter and about 33 feet deep below the ground level. The wall, which consists of two rings of brick laid with horizontal joints cemented, extends about 5 feet above the level of the ground, and is surrounded by an earthen embankment. Surmounting the wall is a conical wooden roof. The wall is not water-tight at any level and where a suction

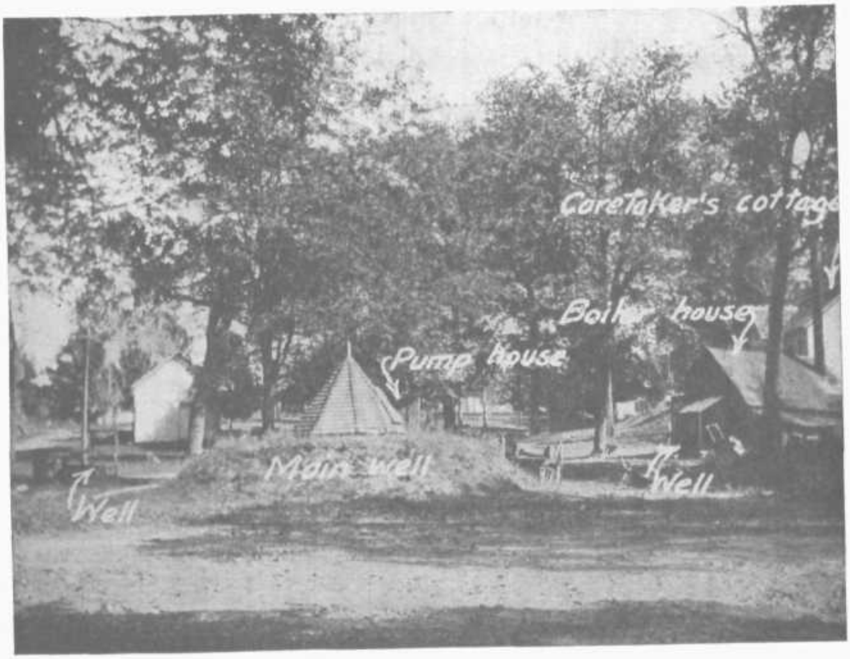

Figure 3.—Waterworks.

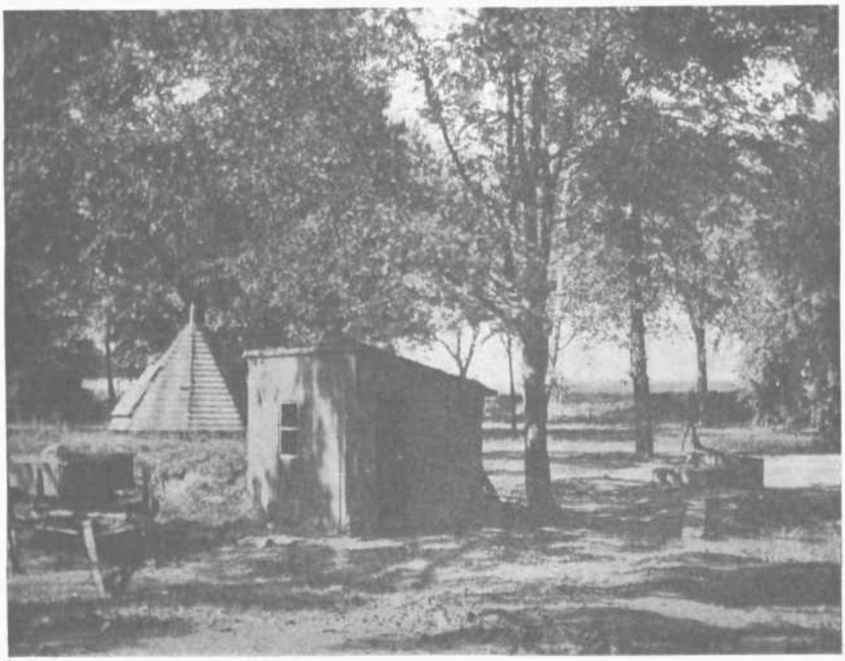

Figure 4.—Pump bouse, main well and north well.

pipe enters the well several bricks have been removed. The earthen embankment is about 6 feet wide at the top and has side slopes of

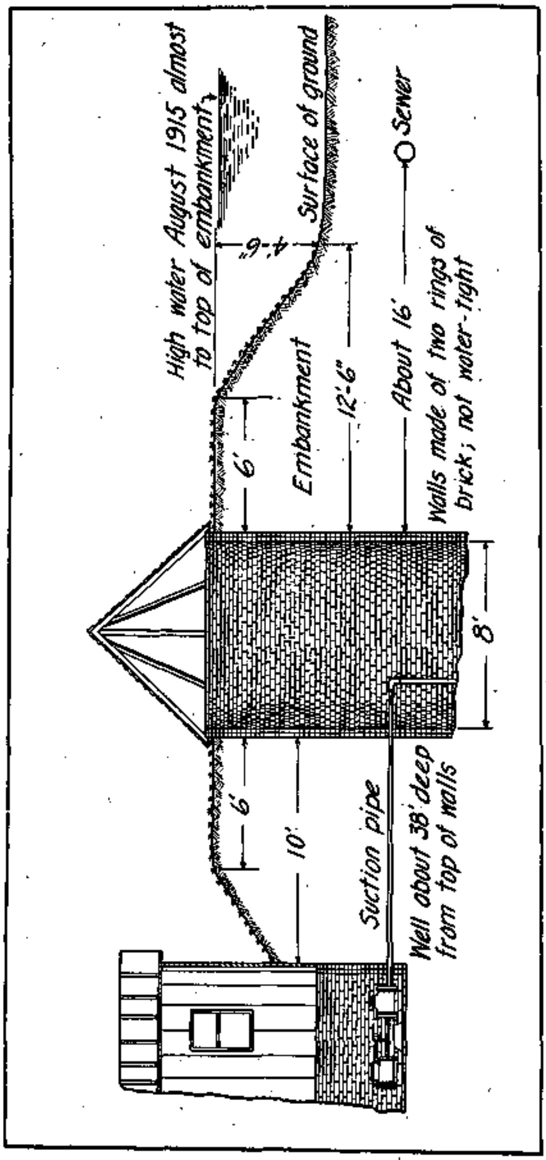

Figure 5.—Sectional elevation of main well.

about 1:1. There is a hole in this embankment along the top of the suction pipe leading to an adjoining pump house and in addition there are several holes on the outside of the embankment evidently bur rowed by field mice or other animals. Water is drawn from this well by means of a steam-driven pump and discharged into a distribution system to which is connected an elevated tank (Figure 6).

The boiler-house and north wells are also dug and walled with brick and are about 25 and 28 feet deep, respectively. The walls of both rise only a few inches above the ground and are surmounted by plank covers which are not water-tight. Both of these wells are pro-

Figure 6.—Elevated tank.

vided with hand pumps, and in addition may be drawn on by a steam pump located in the top of one of them and discharging into the distribution system. This steam pump was not operated during the 1915 assembly, and thus only water from the main well entered the distribution system.

The ground formation at these wells consists of a few feet of top soil, then a layer of clay to about 15 feet below the ground level, and then sand and gravel. The height of the water in the wells is materially affected by weather conditions and by the stage of Sangamon River.

POLLUTION OF WATER SUPPLY

All three wells are subject at all times to more or less contamination. A sewer (Figure 7) passes within about 20 feet of the main well and a privy is located only about 110 feet away and on ground

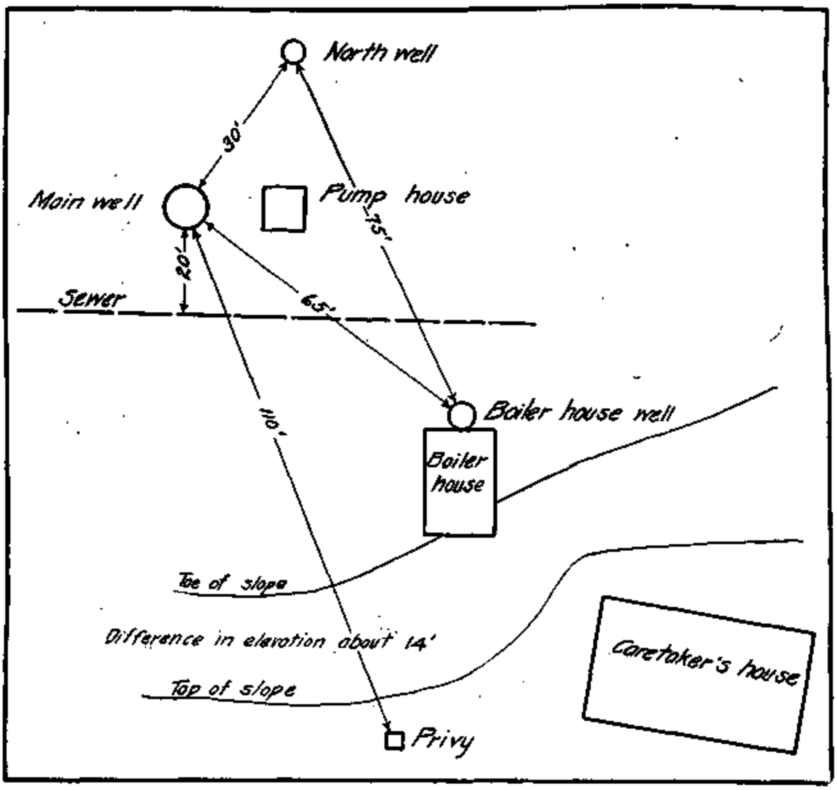

Figure 7.—Sketch showing general layout of waterworks.

about 14 feet higher than that at the wells and draining towards the wells.

The most serious danger of contamination, however, is by flood water of Sangamon River, and it was contamination in this manner that caused the outbreak of typhoid. The pollution carried by Sangamon River, consists of the sewage of Springfield entering 27 miles upstream, possible wash from privies on the watershed between Springfield and the 'Chautauqua grounds, and the sewage from the Chautauqua grounds itself. Assuming a velocity of 3 miles per hour it would take only 9 hours for the sewage of Springfield to reach the Chautauqua grounds.

The wells had previously been flooded during an assembly in 1907, resulting in a large outbreak of diarrhea. The cause of this diarrhea was so apparent at that time that the sickness became locally known as the "Chautauqua Quickstep." Thus the Chautauqua Association was aware of the dangers involved in continuing to use these wells as a source of water supply. Moreover, the State Water Survey, on the basis of analyses, had on three separate occasions notified the Chautauqua management that the water was not safe and should not be used unless boiled.

The 1915 assembly was held from August 11 to 25, inclusive. A few days before the close of the assembly, namely, on August 20 and 21, heavy rains occurred causing Sangamon River to rise rapidly, overflow its banks, and inundate the northern part of the Chautauqua grounds where the wells are located. The flood waters submerged the north and boiler-house wells and entirely surrounded the main well, rising within a few inches of the top of the earthen embankment (Figure 5). Unquestionably, the polluted water seeped through the earthen embankment, aided by the small holes of burrowing animals, for the water became turbid. The pump pit was flooded, but the pump was operated for a while submerged, and since the water is pumped into a distribution system to which is connected an elevated tank, this sewage-polluted water was available for use during the last three or four days of the assembly. The water continued to be served at the hotel dining-room and restaurant.

THE EPIDEMIC

Epidemic of diarrhea preceded epidemic of typhoid.—About a day after the wells became polluted cases of diarrhea began to develop and the first case of typhoid fever occurred on September 1, ten days after the pollution took place. The actual number of cases of diarrhea was not ascertained, but an estimate of 500 would be very conservative. Many of these were severe and prolonged and constituted a serious though non-fatal forerunner of the typhoid outbreak. This relationship of typhoid and diarrheal infection by polluted water has been shown to exist by a study of many water-borne outbreaks. It is clearly stated in the following quotation from page 835 of Preventative Medicine and Hygiene, by Rosenau.

Polluted waters not infrequently cause diarrhea, sometimes as widespread epidemics, sometimes as small outbreaks, or sporadic cases. Whenever there is a water-borne outbreak of typhoid fever there are also a large number of cases of diarrhea and gastro-intestinal disturbances in which the precise etiological factor has not been discovered. Some of these cases may be mild instances of the major disease.

Magnitude of epidemic of typhoid.—The epidemic of typhoid was very explosive in character and involved a large number of cases. Records were obtained of 201 cases and 13 deaths, thus giving a mortality rate of 6.5 per cent. Probably both the morbidity and mortality rates were higher than this since neither cases nor deaths were consistently reported and it was impossible to know or communicate personally with all persons who had been exposed to the infection. The infection was very severe, but in several instances the patients' symptoms were considered unusual by attending physicians. The nature of some of these cases is best described by the following quotation from a physician's report on one of his patients.

This seemed to be what we used to call (30 years ago) typho-malarial fever. She had a fever continuous for about four weeks running from 99° to 103°. She had a clean tongue all the time, no sordes or fissures, no eruption on the abdomen, no diarrhea nor distention of the bowels, no hemorrhages of any kind, no delirium, no trouble of the stomach, and was fed freely on raw eggs, milk and Mellins' Food. No symptoms of typhoid outside of the continued fever.

Chronological distribution of cases.—Figure 8 shows graphically the chronological distribution of the cases, and their relation in point of time to the flooding of the Chautauqua wells. The eases have been numbered in the order of their incidence and this numbering was used in discussing the individual cases in the original report. Many persons that had an attack of diarrhea immediately following the pollution of the Chautauqua wells, apparently fully recovered, and then later developed typhoid fever; other persons experienced similar attacks of diarrhea and did not develop typhoid. Several cases, and these comprise some occurring in the latter part of the outbreak, experienced the preliminary attack of diarrhea and though recovering from the acute character of that illness never felt entirely well and finally developed typhoid. This preliminary illness has been disregarded in selecting the dates of incidence and thus some cases have been relegated to the latter part of the outbreak, which might be placed among the earlier cases. They serve to show, however, that persons may become infected and carry the typhoid germs in their system for a considerable time before actually being taken ill with the disease.

Notation has been made on the diagram of those cases which were of secondary origin, that is, incurred their infection from contact

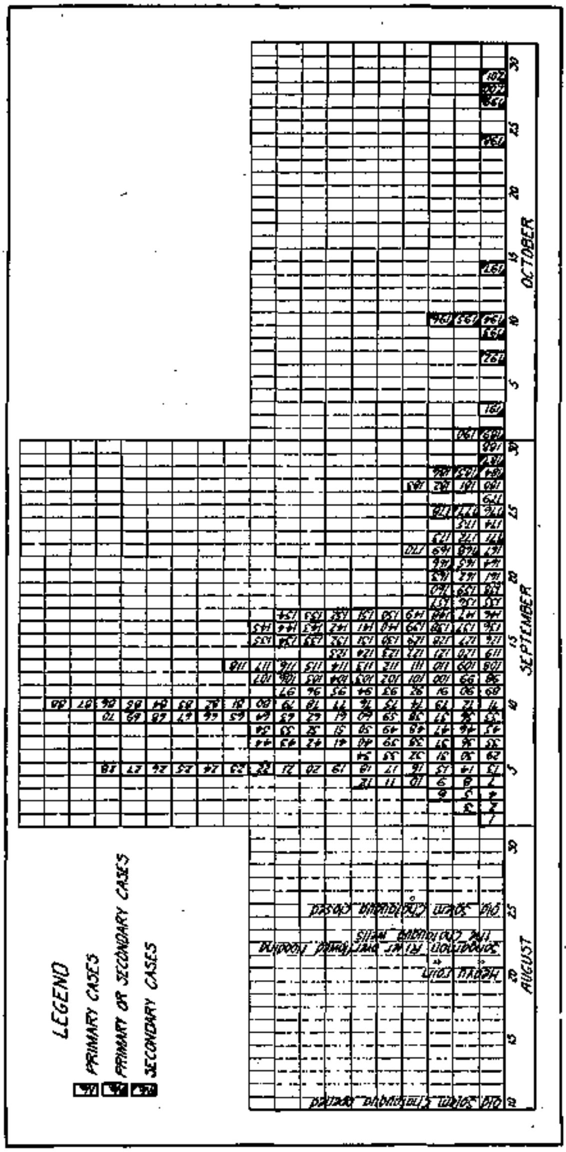

Figure 8.—Diagram showing chronological distribution of cases of typhoid fever.

with earlier cases. There were 14 such secondary cases. Six others who had been exposed to typhoid infection at the Chautauqua grounds and again in their own households, by contact with earlier cases, may have been either primary or secondary cases.

Geographical distribution of cases.—Though the epidemic centered at Petersburg, Illinois, it was widespread in extent. In all 26 incorporated communities were affected, and the most remote cases were two persons who, though residing in Illinois, were taken sick while visiting in California and entered a hospital in San Francisco. The municipalities affected and the number of cases occurring in each are shown in Table 1. For simplification cases residing in the country have been listed under the nearest incorporated community to them, with the exception of the cases near Petersburg which have been separately listed under the heading Petersburg rural free delivery.

TABLE 1.—DISTRIBUTION OF CASES ACCORDING TO PLACE OF RESIDENCE.

Municipality—	No of Cases.	Municipality—	No of Cases.
Ashland	2	Middletown	1
Athens	24	Newmansville	1
Atterberry	3	Oakford	1
Auburn	1	Pekin	1
Chapin	3	Peoria	2
Chicago	2	Petersburg	68
Decatur	3	Petersburg, R. F. D.	32
Fancy Prairie	2	Pleasant Plains	6
Farmingdale	1	Springfield	6
Greenview	16	Tallula	4
Haskins, Iowa	1	Tice	3
Havana	1	Virginia	3
Jacksonville	1		
Lincoln	8	*Total*	201
Mason City	5		

The large number of cases occurring at Petersburg, namely, 68, or 2.8 per cent of the population of that city, was due to the proximity of the Chautauqua grounds, which enabled a large proportion of the residents to attend the Chautauqua assemblies. The same reason explains the fact that 153 of the 201 cases were residents of Menard County. Based upon the population of Menard County of 12,796, as given in the 1910 U. S. Census Report, 1.2 per cent of the population were victims of the epidemic.

The distribution of cases within a community was studied only for Petersburg, and for this purpose a map of that city was prepared showing by means of colored tacks the location of each case of typhoid. Different colored tacks were used to differentiate between cases treated at homes, at hospitals, recovered cases, and fatal cases. The map showed the cases to be more or less evenly distributed over the city with the exception of the eastern edge. This eastern edge comprises the poorer residential section and the people who reside there could not afford to and did not attend the assembly as much as the more well-to-do people. It is interesting to note that although this section of Petersburg was flooded at the same time the Chautauqua wells were flooded, the wells in this part of the city are practically all driven and thus escaped dangerous pollution.

Distribution of cases by family, age, and sex.—The cases were distributed among 154 households having a total membership of about 725. Table 2 shows this distribution among households in detail.

TABLE 2.—DISTRIBUTION OF CASES AMONG HOUSEHOLDS.

119 households contained 1 case each	119 cases
30 households contained 2 cases each	60 cases
3 households contained 3 cases each	9 cases
1 household contained 4 cases	4 cases
1 household contained 9 cases	9 cases
154 households contained a total of	201 cases

In the household containing 9 cases only one was a primary case, the other 8 resulting from it. The sanitary conditions prevailing at this household were very poor and the physician, when he was finally called in, found that little or no precautions were being taken against spreading the infection.

Table 3 shows the age and sex distribution of the cases. Though

TABLE 3.—DISTRIBUTION OF CASES BY AGE AND SEX.

Age. Years—	Male.	Female.	Total
4 or younger	..	..	..
5- 9	8	9	17
10-14	17	24	41
15-19	17	17	34
20-29	23	38	61
30-39	11	12	23
40-49	4	10	14
50 or older	5	6	11
All ages	85	116	201

the cases have been distributed among all ages except the very young, there is a preponderance of cases among the older children and younger men and women. This is more clearly shown by Table 4, in which

TABLE 4.—DISTRIBUTION OF CASES BY AGE.

Age, Years—	Number of cases.	Per cent of total.
9 or younger	17	8.5
10-29	136	67.6
30 or older	48	23.9
All ages	201	100

the cases are grouped under fewer age periods. It will be seen that two-thirds of all the cases were between the ages of 10 and 30 years. This age distribution is characteristic of epidemics where the source of infection is a general one to which persons of all ages are equally exposed, such as epidemics caused by polluted public water supplies. Two examples of such epidemics may be cited from "Typhoid Fever" by Whipple, pages 108 and 142. In an epidemic at Waterville, Maine, caused by a polluted water supply, 64 per cent of all cases were between 10 and 30 years of age. In an epidemic at New Haven, Conn., also caused by polluted water, 50 per cent of all cases were between the ages of 15 and 30 years. The high morbidity rate of the young and middle-aged under such conditions is explainable from the fact that of the total population the percentage of persons at these ages is high.

The very high percentage of cases among young and middle-aged persons in this epidemic even for a water-borne outbreak warrants special mention. Although at normal times the percentage attendance of young men and women at the Chautauqua may not have been unusually high, the prevailing bad weather at the end of the assembly when the Chautauqua wells became flooded tended to restrict the attendance to only the younger and more active people. A ball game with a team from Lincoln, on the last day, was of interest to the younger people and also the Forest Players playing Shakespeare's plays, was a special inducement for school pupils to attend.

Table 3 shows that the number of cases among females was slightly greater than among males. Expressed in percentages of the total number of cases, 58 per cent were females and 42 per cent males. The excess of females is not large enough to be very striking or significant, yet, if anything, it is suggestive of the Chautauqua assembly. There were more female than male campers at the Chautauqua, as the men had to attend to their regular work, especially the farmers taking care of the late harvest, and thus many men were able to attend the assembly only occasionally and for short visits. The baseball games in the afternoons probably attracted more male than females, but the visits of the baseball fans would be short and thus they were not so liable to partake of the Chautauqua water as the campers or those who came and stayed on the grounds all day.

Records of cases showed that Chautauqua water caused the epidemic.—During the first part of the investigation a blank form for recording information about each case was not used, although very complete data was obtained. After obtaining records and information of over 100 cases and sufficient data to indicate that the infection came from the Chautauqua grounds the following blank form was prepared and used to obtain the records of the remaining cases, especially those residing in communities which could not be personally visited.

Blank form used for recording cases

REPORT OF CASE OF TYPHOID FEVER

Note:—Answers to questions should be as *complete* and *accurate* as possible. Wherever possible, give exact dates.

1. Name of patient . . . . Age . . . .
2. Address . . . .
3. Occupation (if student state school and grade) . . . .
4. Patient at home or hospital . . . . Is nurse attending . . . .
5. Date first felt ill . . . .
6. Date physician was first consulted . . . .
7. Name of physician . . . .
8. Dates and results of Widal tests . . . .
9. Number of members in household . . . . Number of cases . . . .
10. Number of members that have been inoculated . . . .
11. Water used at home and at place of business . . . .
12. Milk obtained from whom . . . .
13. Did patient attend Old Salem Chautauqua; state whether staid in cottage or tent or just attended daily . . . .
14. Exact dates patient was at Chautauqua . . . .
15. Did patient use: Chautauqua water . . . . Distilled water . . . . Coffee . . . . Iced tea . . . . Bottled soda . . . . Ice cream . . . .
16. Did patient use milk at Chautauqua and if so from whom was it obtained . . . .
17. Did patient eat at Chautauqua hotel . . . . Where else . . . .
18. Did patient use Chautauqua baths . . . . Swimming pool . . . .
19. How many other members of family attended Chautauqua . . . .
20. Have other members been sick in any way . . . .
21. Additional remarks . . . .

Name of person supplying information . . . .
Name of person obtaining information . . . .

The detailed data relative to milk, water, and food supplies of the patients will not be presented here. In brief it may be stated that there was no food or milk supply common to a large number of people either at their homes or at the Chautauqua grounds. Many people had not eaten on the grounds with the exception of lunches which they brought from home, and over one-half the cases had not used any milk sold on the grounds. At one time rumor spread that distilled water and bottled soda might be a contributory cause, but this rumor was found upon investigation to be absolutely baseless, and as a matter of fact, people who took the precaution to use distilled water in preference to the Chautauqua water supply escaped typhoid infection.

Of the 201 cases of which records were obtained 14 were undoubtly secondary cases. The 187 remaining eases had been on the Chautauqua grounds at the time the water became polluted. Of these, 182 gave definite records of having used the Chautauqua water; 4 others were not sure whether they had drunk the water, but were sure that they had drunk iced tea or coffee made with this water, and also had eaten at the hotel where the water is used. The one remaining case did not remember drinking the water or tea or coffee made with it, but had eaten at the hotel where the water is used.

An effort was made to arrive at an estimate of the number of persons who were exposed to the infection by using the water, but sufficient reliable data could not be obtained. The total attendance at the Chautauqua the last three days, or after the wells were flooded, it is estimated, amounted to about 7,000, but how many persons are counted in this attendance two or three times it is difficult to estimate, and no data obtained makes it possible to draw any conclusion, as to what per cent of the attendance actually used the water.

EPIDEMIC OF TYPHOID FEVER AT PARK RIDGE

By H. F. Ferguson.

INTRODUCTION

At the request of the State Board of Health and the Park Eidge Board of Health the prevalence of typhoid fever at Park Eidge was investigated and all dairy farms supplying milk to that city and all stores handling food supplies were inspected from February 24 to March 5. Mr. A. B. Crowell, president of the Park Eidge Board of Health, Dr. W. M. Friend, health officer, and the other members of the Board of Health, local physicians, and city officials gave generous assistance. Notwithstanding the fact that members of the local Board of Health serve without salary they gave freely of their time and it was fortunate that the city had such an active board at that critical time.

Park Eidge, a residential community, is situated at the northwest corner and just outside the Chicago city limits.. Des Plaines River lies about one mile to the westward. The population is estimated at slightly over 3,000.

A public water supply, installed in 1890, is practically universally used. The water is pumped directly into a distribution system from 2 wells, respectively, 1,425 and 1,806 feet deep. The wells are cased and protected against contamination. Analyses of the water made by the Survey show it to be of excellent sanitary quality and no information obtained during the investigation indicated that the supply had any bearing on the prevalence of typhoid fever.

A combined system of sewers serves the entire built-up area. There are 2 outlets to Des Plaines River about 1½ miles due west of the central part of the city. Only a few houses have not been connected to the sewers, but a recent ruling of the local Board of Health requires that the few remaining privies be abandoned within a limited time. This is an excellent ruling and is being rigidly enforced.

THE EPIDEMIC

Twenty-eight cases of typhoid fever developed from January 9 to February 21. There had been no deaths up to the close of the investigation on March 5 and the cases were then all well or convalescing. That none of the cases ended fatally may be attributed to the general mildness of the disease in this epidemic and to the good nursing that the patients received. Although the epidemic extended over a period of 44 days (see Fig. 1), more than half of the cases developed during the first two weeks. Twenty-four of the cases resided inside the city limits but were not confined to one section (see Fig. 2) and 4 cases resided outside (see Fig. 3).

The 28 cases were distributed among 23 families, one family having 3 cases, each of 3 families 2 cases, and each of 19 families one ease. Only one (Case 27) was a secondary case. This lack of sec-

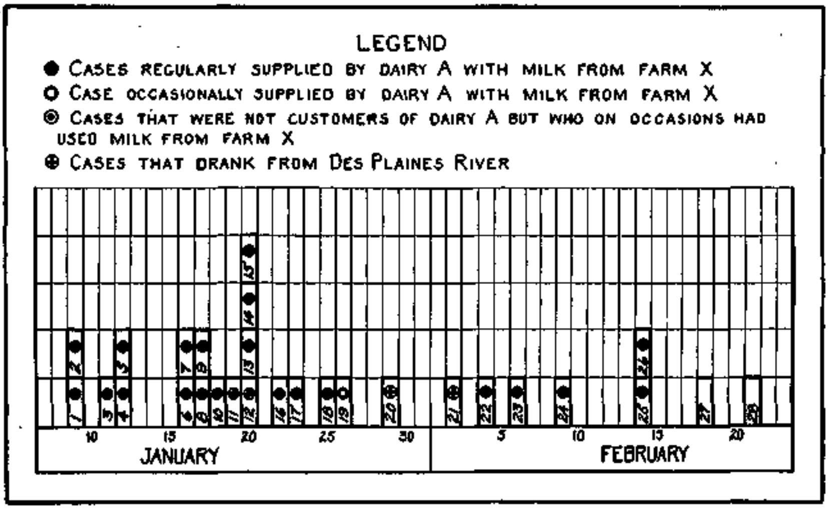

Figure 1.—Diagram showing chronological distribution of cases of typhoid fever at Park Ridge.

ondary cases speaks well for the care in handling the patients and the systematic inoculation of other members of the families. Including servants, who may for this purpose be considered an integral part of the families in which they were employed, the total membership of the 23 families involved was 127 of whom 60 and 67 were, respectively, adults and children. Of this membership 22 per cent had the disease.

Although persons of all ages were involved (see Table 1) the

TABLE 1.—DISTRIBUTION OF CASES BY AGE AND SEX.

Age.	Male.	Female.	Total.
Years.			
4 or younger	2	0	2
5—9	4	5	9
10—19	5	4	9
20—49	2	3	5
50 or older	3	0	3
	16	12	28

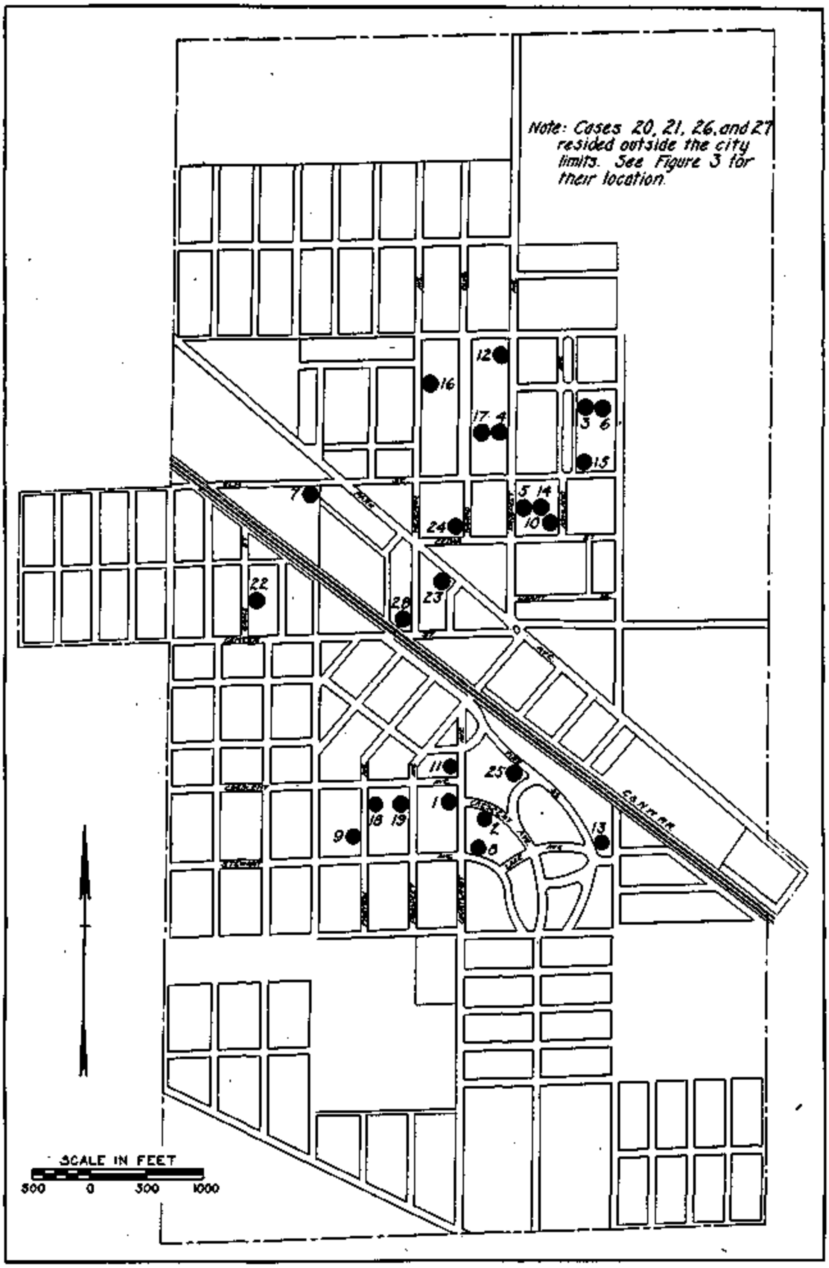

Figure 2.—Map of Park Ridge showing location of cases of typhoid fever.

majority of the cases were children; 71 per cent were under 20 years of age, and 39 per cent were under 10 years of age. Fifty-seven per cent of the cases were males and 43 per cent were females.

There had been no general social gatherings immediately before the epidemic and the occupations of the patients did not bring them together, although a slight majority were school children (see Table 2). The 7 cases employed in Park Eidge and elsewhere were distributed among as many different occupations. The school children were of different ages and attended many different grades in different schools (see Table 3). Main School is the only large school in the city, the others having only a few grades. The schools were closed for vacation December 24, 1914, to January 4, 1915, or during the period in which, judging from the dates of occurrence of the cases, the infection must have taken place.

TABLE 2.—DISTRIBUTION OF CASES BY OCCUPATION.

Attended school	16 cases
Employed in Park Ridge	4 cases
Employed outside of Park Ridge	3 cases
Stayed at home	5 cases

TABLE 3.—DISTRIBUTION OF CASES AMONG SCHOOL CHILDREN BY SCHOOL AND GRADE.

Main School, grade 1	2 cases
Main School, grade 2	1 case
Main School, grade 3	3 cases
Main School, grade 5	1 case
Main School, grade 6	2 cases
Main School, grade 7	1 case
Main School, grade 8	1 case
North Branch School, grade 4	3 cases
German School	1 case
Kindergarten	1 case

The chronological and geographical distribution of the cases indicated that the infection was general and that a number of people must have been exposed. The number of cases was smaller than would have been expected if the infection had been water-borne and analyses of the water and inspection of the waterworks in no way indicated that the city supply had been contaminated. The large percentage of cases among children indicated that milk might have been the cause and a study of the milk used by the cases confirmed this belief.

There are 5 dairies that deliver milk in Park Ridge. Two of these (D and E) have their own dairy farms and the other three (A, B, and C) buy all milk from different farmers. A had 22 cases among its customers, B had 3, C had 2, D had one, and E had none (see Table 4 and Fig..1). Three cases that were customers of A were also customers, respectively, of B, C, and D. Two of these cases generally used only milk from A as the milk from the other dairies was reserved for other purposes in their homes. Cases 20, 21, and 27, all

TABLE 4.—DISTRIBUTION OF CASES BY DAIRIES.

Dairy.	Number of customers.	Number of cases.
A	160	22
B	204	3
C	167	2
D	30	1
E	36	0

of the same family, did not use milk from any of these dairies. The little fresh milk used at their home was obtained from a neighbor who kept one or two cows to furnish milk for his own use and supplied his neighbors occasionally as an accommodation.

Of the 6 cases (Cases 11, 12, 20, 21, 27, and 28) that were not customers of A 2 (Cases 11 and 12) had used milk from that dairy on special occasions and the infection of the other 4 (Cases 20, 21, 27, and 28) was accounted for by means other than milk. Case 11 during a visit at the home of Cases 3 and 6 on December 26 drank milk obtained from A and was taken sick 24 days thereafter, on January 19. This would mean a long prodromal period, but not of unusual length compared with the period of other cases in this epidemic. Case 12 on January 8 drank milk from dairy A that a relative who lives near-by had brought to his home. On January 20, or after a prodromal period of 12 days, Case 12 was taken sick.

Cases 20, 21, and 27 are brothers, 14, 17, and 2 years of age, respectively. They resided outside the city limits (see Fig. 3) and had not come in contact with the cases in the city. The two older brothers were taken sick on January 29 and February 2, respectively. About 2 weeks before their illness while skating on Des Plaines River they became thirsty and breaking a hole in the ice drank the river water. They probably thus were infected for this water is polluted by the untreated sewage from Park Ridge and Des Plaines, which enters the river at points, respectively, one-quarter and two miles upstream. There was special danger at the time the boys drank from the river since the sewage from Park Ridge then contained the discharges of several typhoid-fever patients. The other brother (Case 27) who is only 2 years old and who had not been away from home, was taken sick 16 and 20 days after his brothers, respectively, and undoubtedly was a secondary case. Conditions at home would readily permit of secondary infection as the mother cared for the sick children and also attended to her regular household duties. No disinfectants were used. Case 27 had been given 2 typhoid inoculations before he was taken sick.

Case 28 was employed as a lineman and his work took him about the country. One of the other two men of his party, who does not live in Park Ridge, was taken sick about the same time. The symptoms of both these men, as far as could be learned, were the same although

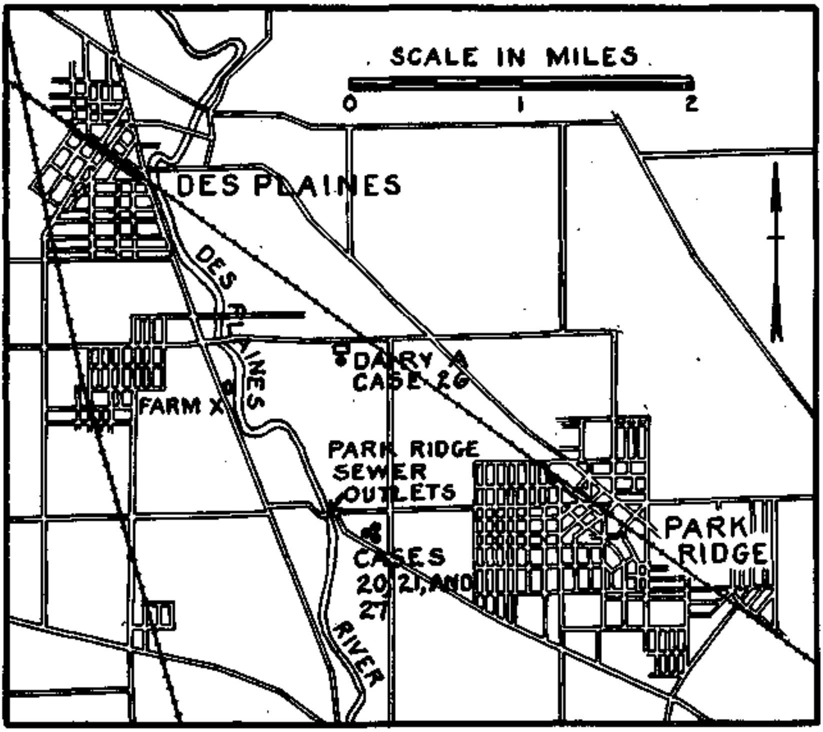

Figure 3.—Map of Des Plaines River near Park Ridge.

the out-of-town man's sickness was diagnosed as grippe. The illness of Case 28 was very mild and may not have been typhoid, or on the other hand, the illness of the out-of-town man may have been typhoid and not grippe. In all probability their illness was of the same character and incurred in the same manner and since one of them neither resided nor had visited in Park Ridge the cause of their sickness lies elsewhere than in that city. Case 28 was, therefore, not strictly speaking part of the epidemic.

Inspection of dairy A and the source of its milk supply corroborated the conclusion, drawn from the study of the cases, that this milk was the cause of 24 cases. Following an investigation on January 22 by Dr. C. E. Crawford, Medical Inspector of the State Board of Health, dairy A was closed although the source of infection of the milk was not then ascertained. Dairy A was allowed to resume business February 6 after all milk bottles and utensils were sterilized. On February 14 dairyman A (Case 26) was taken ill and on February 18 a physician diagnosed his sickness as typhoid fever and the dairy was again closed. The illness of A was suspicious but further investigation showed that he was a victim of the milk he distributed instead of the source of its infection. He had been perfectly well until February 14 and neither he nor any one that worked at his dairy gave any history of ever having had typhoid fever. There were no provisions at this dairy for pasteurizing milk or sterilizing bottles and other utensils. The bottles were simply washed with warm water and soap. The water was obtained from 2 shallow dug wells and a cistern. Although shallow dug wells are not a desirable source of water supply, especially when not far removed from a privy, in this instance there was nothing that indicated that the water supply had become contaminated with typhoid bacilli.

The milk bottled and distributed by A was obtained from 4 farms. On an average 4 cans a day were obtained from farm X, 4 cans from farm Y, 2 cans from farm Z, and one can from farm R. The milk from farm Z was separated for cream. The milk from the other three farms was bottled separately and A regularly supplied certain customers with milk from the same farm. This was done to maintain his trade as the content of cream in the milk from the 3 farms was different. Seventy-eight customers were regularly supplied with milk from farm X, 70 customers were regularly supplied with milk from farm Y, and the remaining customers were supplied with milk from farm R or with whatever milk A had a surplus. With the exception of Case 19 all of the cases among customers of A were regularly supplied with milk from farm X. The milk regularly left at the home of Case 19 was from farm Z, but that family occasionally obtained milk from a store that handled milk from farm X furnished by A. The milk that the two cases (Cases 11 and 12) who were not customers of dairy A had used on special occasions came from farm X. Thus it was only those persons who had used that part of the milk distributed by A that came from farm X who were infected. It was fortunate considering the lack of proper equipment at dairy A that a cross infection to the milk from the other farms did not take place.

Farm X is located on the west bank of Des Plaines River northwest of Park Eidge (see Fig. 3). The river was used as a source of water for the cows. At the approach of winter a channel was constructed along the bank to give the water sufficient velocity to prevent freezing but this was not effective during the very cold weather of the latter part of December, 1914, and early part of January, 1915. Moreover, there must have been days when owing to the severe weather the cows could not go to the river to drink and at such times had to be watered in the barns. Since fall, however, the 3 wells on the farm had been dry and X had been carrying water in milk cans from dairy A and from a well about one-fourth mile from his farm. X denied carrying river water in milk cans, but the hired man at dairy A stated absolutely that he had seen X do so. To haul all water for 24 cows would be a considerable task and the temptation to use Des Plaines River water would be great, especially during cold inclement weather. It is, therefore, believed that the milk cans were rinsed in river water and that water was carried to the cows in them. The farm is located above the sewer outlets of Park Ridge, but below the sewer outlets of Des Plaines and the river is polluted at that point. The milk supply, therefore, probably was infected by milk cans contaminated by the polluted water of Des Plaines River.

RECOMMENDATIONS

The epidemic is a striking example of the need of adequate sanitary supervision of milk supplies and it illustrates the need of having a safe and adequate supply of water at dairy farms. As a result of the investigation of the epidemic and inspection of all dairies distributing milk in Park Ridge it was recommended:

(1). That the milk from farm X be barred from Park Ridge until there is available a safe and adequate supply of water at all times, and until more sanitary conditions are maintained at the farm.

(2). That dairy B be not allowed to resume business until dairyman B is proven to be no longer a typhoid carrier, all milk bottles and other utensils belonging to this dairy shall have been effectively sterilized, the privy vault shall have been cleaned and thoroughly treated with lime, and a new sanitary privy built.

(3). That all dairies operating in Park Ridge be required to pasteurize their milk. That for this purpose suitable equipment be installed and preferably an automatic temperature recorder be used.

(4). That all dairies be required to regularly sterilize all milk bottles and other milk utensils.

(5). That arrangements be made for regular inspections of dairies and milk farms and a score-card used if possible.

THE SIGNIFICANCE OF CHEMISTRY IN WATER PURIFICATION*

By Edward Bartow.

When water purification is mentioned one thinks first of water for drinking purposes. It is a faet, however, that a very small percentage of the water furnished by a municipality to its citizens is used for drinking purposes. "Water purification must include treatment of water for drinking purposes, for domestic uses, for the production of steam, and for manufacturing processes. The value of an abundant supply of pure water for all purposes is becoming more generally realized and many investigators have been and are endeavoring to find the best means for judging the quality of a water and for purifying water. The chemist, the bacteriologist, and the biologist are all busy investigating these problems.

The bacteriologist rightly considers that the presence or absence of disease-producing bacteria is the only absolute means of judging whether a drinking water will cause disease. But, the difficulties in determining absolutely the presence or absence of disease-producing bacteria and the uncertainty which negative results leave with regard to possible later access of pathogenic bacteria make it necessary to use some index other than the disease-producing bacteria themselves by which to judge the purity of drinking water. The bacteriologist has the nearest approach to a reliable index in the bacteria which accompany pollution. Bacteria of the colon group are always present in sewage and their presence or absence in a drinking water is very important since it implies the presence or absence of pollution by sewage. Therefore, finding the colon bacillus the bacteriologist would condemn the water. The biologist, finding organisms that impart an unpleasant taste or odor, would condemn a water. The sanitary inspector from a survey of the territory surrounding the source of a water supply finding unfavorable conditions would condemn a water without further examination. The bacteriological, biological, and inspection approval of a water, is not sufficient. Chemical approval in addition is necessary because of the possibility of unseen underground contamination, because chemical tests reveal the previous history of a water and may

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indicate possible future contamination, and finally because chemical tests determine the therapeutic character of a drinking water.

Chemical tests are used to determine the purity of water and to control the treatment. Chemicals are used in purification and disinfection of water supplies.

When it was first realized that a polluted well water might spread infectious diseases chemical tests alone were relied upon by the water analyst. Because organic waste matter contains nitrogen as an important constituent, Wanklyn in 1868 first suggested the determination of nitrogen as an index of the character of a water supply. He proposed the albuminoid nitrogen (albuminoid ammonia) test and while it has had considerable criticism it has, nevertheless, served a good purpose. The albuminoid nitrogen test and the determination of oxygen-consuming capacity gave the best information concerning the character of a water supply, until the introduction of bacteriological tests. For many years the sanitary examination of a drinking water consisted of purely chemical tests and included the determination of residue, chloride, oxygen-consuming capacity, ammonia nitrogen, albuminoid nitrogen, hardness, dissolved gases and poisonous metals. Later, owing to the demand for a clearer water free from iron and manganese, determinations of alkalinity, carbon dioxide, iron and manganese were added.

When bacteriological tests are made, it is surprising to note the amount of chemistry used by the bacteriologist. Even in determining the number of bacteria, the acidity of the media must be accurately adjusted by chemical analysis. The determination of the colon bacillus, as stated before, the most reliable index of pollution, depends upon the chemical decomposition of sugars in a medium whose acidity is accurately adjusted. Other tests for the colon bacillus depend upon the chemical reaction toward litmus-lactose-agar or Endo's medium. The formation of indol and its recognition are chemical reactions used by the bacteriologist.

At present in the analysis of drinking waters certain chemical tests may be said to supplement the bacteriological tests. These are the tests for organic matter. They include tests "for ammonia, albuminoid, nitrite, and nitrate nitrogen and the oxygen-consuming capacity.

The inorganic constituents must not be overlooked. Some serve as an index of pollution, others have therapeutic significance. Chloride furnishes an example of the usefulness of a chemical test as an index of pollution. It is always present in sewage, hence in regions where the amount of chloride present in normal waters varies with the distance from the sea coast an excess of chloride above the normal arouses suspicion. It must be remembered, however, that in other regions, especially regions which have been covered by the sea, the normal chloride of the water supplies is so high and its variation so great that it is impossible to use it as an index of pollution. The chemical analysis of the soluble inorganic matter indicates the therapeutic value. Waters containing notable amounts of the sulfates of sodium, or magnesium, or waters containing dissolved gases, especially hydrogen sulfide, will have a physiological action on those who drink them, especially on those who are not accustomed to them. Therefore, these waters containing large amounts of sulfates or hydrogen sulfide are valuable mineral waters.

The chemical tests for the troublesome metals, iron and manganese, and the poisonous metals—copper, lead, and zinc must not be overlooked. Copper, lead, and zinc are found in waters in mining regions and many waters will dissolve lead or zinc from pipes. The drinking of these waters will cause serious illnesses. Iron and manganese if present in sufficient quantity to be injurious are usually precipitated on contact with the air and give warning against the use of the water.

To determine definitely the therapeutic value of a water accurate determinations of the chemical composition of the mineral constituents of the water are needed. These accurate determinations serve also to show the value for use in boilers, for manufacturing purposes and for the determination of methods of water purification. The tests ordinarily made are for the positive ions, potassium, sodium, iron, aluminium, calcium, magnesium, and for the negative ions, chloride, nitrate, sulfate, and carbonate. Sometimes rare ions such as lithium, bromide, iodide, and phosphate are determined. For boiler use an excessive amount of calcium and magnesium will cause the formation of scale. Chloride or nitrate ions in excess will cause corrosion and sodium and potassium in excess will cause foaming. Many examples might be given of the injurious action of soluble compounds in water used for manufacturing. Suffice it to say, that compounds of iron and manganese by their color interfere with bleaching processes; calcium and magnesium increase the amount of soap required and form substances that can be with difficulty removed from fabrics thus interfering with laundry processes; calcium and magnesium when present in water used in preparing foods give an inferior product.

Chemists have been working for years to improve methods of analysis and methods of purification. They have been working in cooperation on methods of analysis and individually on methods of purification. In the United States, committees have formulated standard methods of analysis. The first attempt to obtain uniform methods was made by the chemical division of the American Association for the Advancement of Science which presented a preliminary report at the meeting in Cleveland in 1886.[18] This committee gave standards for (1) ammonia, and albuminoid nitrogen (albuminoid ammonia) ; (2) oxygen-consuming capacity; (3) nitrates; (4) nitrites, and implied that residue, chloride, and hardness should also be determined but gave no specific directions for these tests. The American Public Health Association in 1894 took its first step toward the formulation of standard methods.[1] The committee formed at that time made several progress reports and prepared recommendations for bacteriological examination of water. It was not until 1905 that they published the first report on standard methods of water analysis, including both chemical and bacteriological methods. A revised report was published in 1912 and a second revision will appear during 1917. This published report on standard methods has done much to unify the chemical procedure in water laboratories and to promote interest in investigation of methods of analyses.

Having by analysis found a water impure the next step is purification. The method of purification depends upon the proposed use. Turbid drinking water demands filtration to remove turbidity and bacteria. Impure drinking waters, if clear, demand disinfection. Slow sand filters, imitating nature's process, were first used to remove turbidity and bacteria. Owing to the expense of their installation, especially in America, the so-called mechanical filters have been substituted. Chemicals are necessary for the operation of mechanical filters. By means of chemicals a precipitate is formed, which in settling collects colloids and bacteria and permits the water to be filtered at nearly 40 times the rate possible when no chemicals are used. Aluminium sulfate (filter alum), iron sulfate, and lime separately or in combination, are the chemicals added. Aluminium sulfate reacts with the bicarbonates of calcium and magnesium in the water to form a precipitate of aluminium hydroxide. Iron sulfate usually added with lime reacts with the bicarbonates of calcium and magnesium to form a precipitate of iron and magnesium hydroxides, and calcium carbonate. It is necessary to add sufficient lime to neutralize any free carbon dixoide present or set free by the iron sulfate. Lime reacts with magnesium salts forming a sufficient precipitate to allow filtration without aluminium or iron sulfate or with a small amount of either to counteract the excess of lime. Waters with an excessive turbidity like those in Mississippi River valley, cannot be filtered practically by slow-sand filtration and filtration with chemicals is used exclusively.

Each year the public is demanding better water. Standards of purity are being raised. The United States Public Health Service, through a commission, has formulated standards for the purity of drinking water to be used on interstate carriers.[21] A glance at the literature of the last few years shows how investigators are endeavoring to comply with the demand for better water. It is difficult to conform to the improved standards for drinking water without disinfection.

For disinfection, ozone, ultraviolet rays, bleaching powder, liquid chlorine and lime are used. Ozone has been used quite extensively in Europe. Plants are in operation in Europe at Wiesbaden, Schierstein, Paderborn, Oosne, Chartus, Nizza, Dinard, Sulina, Ginnekin,[8] St. Maur,[9] Chemnitz, Florence, Spezia, Genoa, Braila, Paris,[2] Königsberg,[10] Petrograd,[12] and other places.

The plants which have been constructed in the United States[3, 14, 15] have not been very successful and it must be considered that the use of ozone in America is still in the experimental stage.

Disinfection or sterilization with the ultra-violet ray was first proposed by Henri, Helbrunner, and Recklinghausen.[18] Their pioneer work has been followed by many investigators. Plants are in operation in Europe at Luneville, St. Malo, and Rouen.[17] No large installations have been made in the United States but small installations have been used with evident success. Bleaching powder (calcium hypochlorite) was first used in 1908 at the Union Stock Yards in Chicago and at the Boonton reservoir of the Jersey City supply. The process because of its cheapness is being widely used throughout the United States. In 1915 Longley[11] reported that 240 water supplies were being treated with some disinfecting agent; about 80 per cent using bleaching powder and the remainder liquid chlorine.

Within the last few years liquid chlorine has been made available and several forms of apparatus for adding liquid chlorine to water have been successfully used. It is much easier to. handle the liquid chlorine or the gas from it than to handle the bleaching powder. This method will very soon replace the use of bleaching powder.

Investigations by Houston [7] in London have shown that the addition of lime before storage of water removes the bacteria almost completely. Sperry[20] at Grand Rapids and Hoover[5] at Columbus have shown that a slight excess of lime when used as a precipitant removes the bacteria, serving as an excellent disinfectant. For the disinfection of drinking water on a small scale potassium permanganate, bromine, iodine and bleaching powder have been used. Tablets of bleaching powder with tablets of sodium thiosulfate to remove the excess of bleaching powder are quite satisfactory.

For purifying water for the production of steam and for manufacturing processes (water softening) lime and soda, alone or in combination, have been long used. Lime is used for the removal of carbonates; soda for the removal of sulfates, nitrates, and chlorides of calcium and magnesium. Soda may be replaced by other sodium salts so that sodium silicate, sodium phosphate, sodium hydroxide, etc., are used in water softening and boiler compounds.

A new method for softening water was suggested by Gans.[4] It had been known that zeolites would soften water but since a sufficient quantity of the natural material could not be obtained Gans prepared an artificial zeolite by fusing kaolin, feldspar, soda, and potash. This artificial zeolite called by the trade name "Permutit", has the power of removing calcium and magnesium from a hard water, delivering a water with zero hardness. The process is well adapted to soften water for the textile industry, for laundries, etc. Only one municipal plant, at Hooten, England, has been built. As yet it seems too expensive for municipal water supplies but very probably efforts will be made to lessen construction costs so that it can be made available for municipalities.

The use of disinfectants and the invention of Permutit are the most important recent improvements in water purification. Many other improvements of minor importance but having practical value have been recently discovered. Copper sulfate[13] has been found to be an efficient algaecide and is widely used to remove algal growths from reservoirs. Alum has been made from sulfuric acid and bauxite[6] and without refining has been used at Columbus, Ohio, in water purification with a great reduction in the cost of purification. In Omaha[9] the efficiency of filter alum is said to be greatly increased by passing the solution of alum over iron filings before adding it to the water to be purified. Analyses of chemicals and their purchase under specifications has increased the efficiency of water-purification plants.

A summary of this paper on the "Significance of Chemistry in Water Purification" should answer the question often asked:—What does water chemistry do?

It assists in and supplements bacteriological tests.

By determining the mineral constituents of a water it shows the therapeutic character; it shows the presence or absence of troublesome metals, iron and maganese; it shows the presence or absence of poisonous metals, copper, lead, and zinc.

It controls water purification, filtration for use as drinking water and softening for industrial uses.

It formulates standards of purity and improves methods of purification.

Finally, its fundamental purpose is to help furnish and conserve pure water for all purposes.

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THE USE OF BARIUM SALTS IN WATER TREATMENT*

By J. D. Snook and Edward Bartow.

Some municipal water supplies contain so much mineral matter that it is impractical to soften the water with lime and soda.[1] For such waters barium carbonate and barium hydroxide may be suitable. Barium carbonate precipitates any sulfates present in the water as the very insoluble barium sulfate. Barium hydroxide removes the sulfates of calcium and magnesium, and the calcium and magnesium hydroxides formed precipitate the bicarbonates. These reactions may be considered in the reverse order, that is, that the barium hydroxide first reacts with the bicarbonates and the barium carbonate thus formed preciptates the sulfates.[6]

Barium compounds are comparatively rare in nature and the method of preparation of the salts useful in water treatment is complicated, hence they are rather expensive. Barite, or heavy spar, is the principal source of barium compounds. It is the natural sulfate of barium and is commonly called barytes. It is widely distributed, and usually occurs as a gangue material in metallic veins, associated especially with ores of silver, lead, copper, cobalt, manganese, and antimony. It sometimes occurs in veins in limestone with calcite and celestite, or in sandstone with copper ores. Occasionally it is deposited as a sinter by hot springs. Notable localities for the occurrence of crystalline barite are Westmorland, Cornwall, Cumberland, Derbyshire, and Surrey, England; Felsö-Banya and other localities in Hungary; in Saxony, and in Bohemia.[2] In the United States it is found at Cheshire, Connecticut; DeKalb, New York; and Fort "Wallace, New Mexico. Massive barite, occurring usually as veins, nests, and irregular bodies in limestone, is quarried in Nova Scotia, Missouri, and the Appalachian States. In 1913 over 68 per cent of the total output of the United States came from Missouri, while among the Appalachian States, Georgia, North Carolina, Tennessee, South Carolina, and Virginia are in the order of their importance.[3]

Barite is usually a white opaque to translucent crystalline material, with a vitreous luster, about as hard as calcite, but differing from calcite in its greater specific gravity. It has a hardness of 3 to 3.5, and a specific gravity of 4.5, which is heavy for a nonmetallic mineral.[2]

*Abstract of thesis presented in partial fulfillment of requirements for the degree of Bachelor of Science by J. D. Snook, June, 1915.

Natural barite is rarely pure, its most common impurities being silica, lime, magnesia, and the oxides of iron and aluminium. Fine particles of galena are disseminated through many of the deposits in the United States. The commercial grades of the mineral as mined carry from 95 to 98 per cent barium sulfate, and 1 to 3 per cent silica.

A minor source of barium is the natural carbonate, witherite. It is found as fine crystals at Hexham in Northumberland, and Alston Moor in Cumberland. It also occurs at Tarnowitz in Silesia; Leogang in Salzburg; near Lexington, Kentucky; and Thunder Bay, Lake Superior.[2] It does not occur in large enough quantities, however, to be of very great importance.

Barium oxide is made commercially by heating barite and carbon in the electric furnace. When this is dissolved in water the hydroxide is formed. Other salts are made from the oxide and hydroxide.

When any soluble salt of barium is added to a water containing sulfate, barium sulfate is precipitated, since its solubility is only 2.3 milligrams per liter at 19° C.[4] If barium carbonate, which is slightly soluble, is added to a water containing calcium sulfate the very insoluble calcium carbonate is also formed and precipitated.

If barium hydroxide is added to a water containing the bicarbonate and sulfate of calcium, it reacts with the calcium sulfate giving the insoluble barium sulfate and soluble calcium hydroxide, which reacts with the calcium bicarbonate, precipitating the carbonate. An excess of bicarbonate will react directly with barium hydroxide precipitating the carbonates.

Sodium, potassium, or magnesium salts react in a similar manner with barium hydroxide. The sodium hydroxide formed will react with any magnesium salts present, giving the insoluble magnesium hydroxide. When the barium hydroxide reacts with magnesium sulfate both of the products are precipitated. If no sodium or potassium sulfates are present, the barium hydroxide will react directly with magnesium chloride or bicarbonate, precipitating it as the hydroxide. Barium carbonate removes the sulfates only, so that if it is also desired to remove the carbonates, some additional reagent must be used for this purpose. Barium hydroxide, besides precipitating the sulfates, removes an equivalent amount of bicarbonates. When the bicarbonates are in excess of the sulfates, the excess may be removed by using a sufficiently large amount of barium hydroxide, or just enough may be used to precipitate the sulfates, and the excess bicarbonates removed by some other reagent.

EXPERIMENTAL PART

A number of laboratory experiments were made to determine the effect produced by treating a water containing sulfates with barium salts and with lime and barium salts. For each experiment 16 samples of 2 liters each were treated with varying amounts of the reagent. The water chosen for the experiments was taken from a well at the Cunningham Children's Home, one mile northeast of Urbana.

Barium hydroxide was dissolved in distilled water and added to the samples immediately since carbon dioxide from the air will precipitate barium carbonate from this solution. Barium carbonate and lime, on account of their insolubility, were weighed out separately for each sample.

After treatment the samples were allowed to stand in stoppered bottles for several days with frequent shaking. They were then filtered and the efficiency of the reagents determined by determinations of noncarbonate hardness, alkalinity, sulfate, chloride, magnesium, calcium, barium, and residue on evaporation.

Alkalinity, chloride, and residue on evaporation have been determined according to Standard Methods of Water Analysis of the American Public Health Association; noncarbonate hardness and magnesium according to methods described by Jacobson.[5] Calcium was determined by precipitation as calcium oxalate and titration with N/20 potassium permanganate. Sulfate was determined gravimetrically.

For the determination of barium, 500 cubic centimeters of the water which had been acidified with hydrochloric acid was evaporated to about 100 cubic centimeters and 25 cubic centimeters of hot saturated calcium sulfate solution added drop by drop to the boiling water. The precipitate was filtered, washed, ignited, and weighed as barium sulfate.

In order to prove the accuracy of the method from 10 to 30 milligrams of barium (as chloride) were added to distilled water or University tap water, and the amount of barium determined. In only 3 of 30 tests made did the error exceed .2 milligram in 10 milligrams; a result sufficiently accurate for our experiments. A test with the spectroscope showed the absence of barium in the raw water used.

Experiment 1. Sixteen samples of 2 liters each were treated with amounts of a freshly prepared solution of barium hydroxide varying from 0 to 2,000 parts per million of $Ba(OH)_2.8H_2O$ (see Table 1). The noncarbonate hardness and sulfate are removed with 400 parts per million of barium hydroxide. The alkalinity, residue, calcium, and magnesium are further reduced very slowly by additional

TABLE 1.—TREATMENT OF WATER WITH VARYING AMOUNTS OF BARIUM HYDROXIDE.

[Parts per million.]

Sample.	$Ba(OH)_2.8H_2O$.	Non carbonate hardness.	Magnesium.	Alkalinity.		Calcium.	Sulfate.	Barium.	Residue.
				Phenolphthalein.	Methyl orange.				
1	00	86	176	0	411	126	96.6	.0	567
2	100	52	136	0	361	108	57.5	.7	484
3	200	30	124	0	317	90	40.3	1.2	419
4	300	16	104	0	285	78	18.9	1.7	365
5	400	8	92	0	264	71	5.8	6.6	338
6	500	4	88	0	255	68	4.9	19.0	327
7	700	6	92	0	245	63	5.0	18.6	292
8	900	6	88	0	220	65	4.9	12.7	261
9	1100	4	84	2	214	58	4.8	7.7	282
10	1300	0	76	16	195	42	4.5	4.7	187
11	1400	6	64	19	165	34	4.5	4.5	174
12	1500	4	60	20	154	30	4.3	4.3	165
13	1600	4	52	20	140	28	4.5	4.1	145
14	1700	6	48	19	125	25	4.2	4.2	131
15	1800	2	40	20	115	23	4.0	4.1	125
16	2000	4	28	27	105	20	4.1	4.0	118

reagent. Magnesium sulfate and sodium sulfate are eliminated with 400 parts of barium hydroxide. The carbonates are still further removed slowly by the additional reagent as indicated by the decrease in the alkalinity.

Experiment 2. Lime, varying from 0 to 750 parts per million, and barium carbonate, varying from 0 to 375 parts per million, were added to sixteen 2-liter samples of water, each portion of the chemicals being weighed and added in solid form. After treatment as in Experiment 1 it was found (see Table 2) that sulfate was removed by 650 parts per million of calcium hydroxide and 325 parts per million of barium carbonate, and at the same time calcium was reduced to 17 parts per million and magnesium to 36 parts per million. The

TABLE 2.—TREATMENT OF WATER WITH LIME AND BARIUM CARBONATE.

[Parts per million.]

Sample.	$Ca(OH)_2$.	$BaCO_3$.	Non carbonate hardness.	Magnesium.	Alkalinity.		Calcium.	Sulfate.	Barium.	Residue.
					Phenolphthalein.	Methyl orange.				
1	00	00	82	172	0	415	128	96.9	0	572
2	50	25	70	160	0	384	117	84.6	.7	507
3	100	50	62	148	0	357	106	72.6	.8	463
4	150	75	52	136	0	295	82	65.1	.8	396
5	200	100	46	132	0	258	68	58.8	.9	352
6	250	125	40	124	3	191	41	50.5	1.0	261
7	300	150	34	116	9	154	24	44.1	.9	210
8	350	175	24	112	18	159	22	36.5	1.1	207
9	400	200	20	108	20	157	20	30.9	1.1	195
10	450	225	16	104	27	160	19	25.8	1.3	163
11	500	250	16	100	44	174	18	19.3	1.7	152
12	550	275	12	96	71	199	18	16.1	2.6	149
13	600	300	8	60	102	202	18	10.7	7.9	155
14	650	325	4	36	147	264	17	6.2	10.5	170
15	700	350	4	28	198	360	15	3.7	12.0	196
16	750	375	2	24	246	452	14	2.9	12.6	248

continued addition of the reagents further reduced the calcium and magnesium but with increased alkalinity, residue, and barium.

The barium hydroxide and carbonate are satisfactory reagents for removing sulfates from water. Barium salts have a decided advantage over sodium carbonate for the treatment of waters containing large amounts of sulfates because the latter leaves large amounts of sodium sulfate in the treated water. The barium carbonate is a convenient reagent to use because of its slight solubility; a large amount can be put into the softening apparatus and there is no danger of over-treatment. When an excess of hydroxide is used it remains in the water. The action of barium hydroxide is similar to that of calcium hydroxide (lime) so that a mixture of calcium and barium hydroxides properly regulated should be satisfactory for the removal of sulfates and bicarbonates.

An objection has been raised against the use of barium salts for water treatment because of their poisonous properties. These salts do not seem to be cumulative poisons except where there is lack of calcium in the diet.[7] As much as 200 milligrams of barium chloride has been prescribed for children to be taken three times a day when used as a remedy for scrofula. Salts of barium, with the exception of the sulfate, are rapidly acting heart stimulants and when taken in sufficiently large quantities will cause death in a short time. However, the fatal dose of the chloride is 10 to 15 grams and since the largest amount of barium found in any of the samples treated was 19 milligrams per liter it would not seem as if there would be harmful effects if water treated with barium salts was used for drinking purposes. The great objection to the use of barium salts is their cost, so that other salts if obtainable would be used in preference. If a cheaper method could be found for procuring the salts they should be very satisfactory reagents for use in water treatment.

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THE USE OF PERMUTIT IN WATER SOFTENING*

By J. F. Garrett and Edward Bartow.

Permutit is the name chosen to designate an artificial zeolite recently produced and patented by Dr. R. Gans of the Royal Prussian Geological Institute of Berlin. The name is derived from the Latin word "permutare" meaning to exchange.

Natural zeolites were known at an early date, but there had been no scientific investigation of their properties until quite recently.[3] These compounds are usually hydrated forms of silicates of aluminium with sodium and calcium as the important bases. The most important natural zeolites are: thomsonite, natrolite, analcime, apophyllite, desmin, chabazite, and stilbite.[7] They are found in nature[6] in cavities and veins in basic igneous rocks and less frequently in granite, gneiss, and similar formations.

Zeolitic compounds have the property of interchanging their bases, that is, the alkali and alkaline-earth metals may interchange with each other or be substituted by other bases. They play an important part in vegetable life through the delivery of the natural constituents of the earth to the plants, and their restoration by means of artificial fertilizers.[1]

Experiments in the use of the interchanging power of the natural zeolites for technical purposes have failed because of their impurity since they contain only a small amount of the active substances. The crystallized zeolites occur in too small quantities in nature to come into use for technical purposes. The soils which contain the zeolitic compounds are heavy and compact and are little suited for filtration purposes, because in order to do efficient work the filters would have to be too large to be practicable.[7] (Since the above was written success with the natural substance has been claimed by Kinniard.)[9]

Dr. Gans[7] has divided the aluminium zeolites into two classes, (1) "Double earthy silicates," or the zeolites which contain the alkaline earths and alkalies combined with silicic acid. The bases of these zeolites can only be substituted in a small proportion in a given time." (2) "Aluminate silicates," or the zeolites which contain the alkaline earths and alkalies combined with clay. The bases of these zeolites can be almost completely substituted in a very short time.

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Gans was the first to succeed in producing the "aluminate silicates," although several investigators had experimented upon the production of artificial zeolites. Rüempler[8] produced an artificial zeolite before Gans, but it was of the "double earthy silicate" type and accordingly of very little technical importance. Gans prepared his artificial zeolite by smelting together three parts of kaolin, six parts of sand, and twelve parts of soda, and washing out the excess of soda with water. Permutit, in order to be of technical importance, must be of a grainy, leafy, and easily penetrable consistency, hence an excess of alkali must be avoided as it tends to form a more or less slimy product. Gans[8] claims that a part of the soda can be replaced with potash, or cheaper with potassium feldspar or some other potassium-bearing mineral. The grains of the product are in this way made larger and produce an increased porosity which greatly facilitates the reaction. The most difficult part in the manufacture of Permutit[3] is the regulation of the degree of hydration. If the hydration is carried too far it causes decay, and if stopped too soon, products of a feldspar nature are obtained.

Permutit contains alkali and alkaline-earth bases, aluminium, and silica in molecular combination. The bases are easily interchangeable with each other and with other bases by treatment with the appropriate salt solutions. The facility of interchange depends upon the size of the grains of Permutit and to a more or less extent upon the amount of the. bases present. The larger the amount of bases present, the greater the interchanging power of the Permutit. Since one molecule of Al_2O_3 combines with one molecule of Na_2O (or K_2O), the proportion of clay used determines the content of bases. Accordingly Gans devoted his efforts to raising the clay content as high as possible in order that he might obtain the maximum base content. The ideal composition of such a zeolite would approach the formula: $2SiO_2Al_2O_3,Na_2O+6H_2O$. The most important characteristics of this compound are:

(1). Its property of interchanging bases. This property is very significant, for by replacing the sodium base by other bases it is possible to make a Permutit of almost any metallic combination.[5] The exchange of greatest interest, however, is the exchange of sodium for calcium or magnesium by which the hardness of water can be reduced to zero. The iron, manganese, and the salts of other metals can be removed from the water through this property of interchanging bases.

(2). Its property of regeneration. When one of the above processes is carried out for any great length of time, the base content of the Permutit eventually becomes exhausted, hence it is necessary to regenerate it. When the sodium of sodium Permutit has been replaced by the calcium and magnesium of hard water, the Pemutit can be regenerated by passing through it a 10 per cent solution of common salt (NaCl), the interchange taking place in the opposite direction.

(3). Its insolubility. Another important property of Permutit is that all of its salts, including those of the alkalies, are insoluble in water.

(4). Its permeability. The high interchanging facility of Permutit depends upon the fact that the water penetrates the interior of the grains and thus the whole of the substance is brought into action and not merely the external surfaces of the grains.

(5). Its length of life. It is claimed[5] that Permutit can be regenerated an unlimited number of times without loss, hence it is never necessary to renew it.

There are many and varied industrial applications claimed for Permutit. Harm and Rüempler were the first to point out a technical use[8] for the interchanging power of zeolites in the sugar industry. They attempted to exchange the potassium salts of the sugar sap for those of calcium since their experiments showed that the calcium salts hinder the crystallization of sugar much less than do the corresponding potassium salts. The process is a pure interchange and consists simply of filtering the sugar sap through calcium zeolite and regenerating the latter by means of a solution of $CaCl_2$.

Another possible technical application of Permutit is the recovery of gold from dilute solutions.

The manufacture of the salts of bases by double exchange offers still further possibilities for this process. For example, if sodium Permutit is washed with a solution of NH_4C1[3] an ammonium Permutit is produced. Passing waste waters containing potassium salts through this Permutit will produce a potassium Permutit and by regenerating this filter with NH_4C1 the potassium may be recovered.

The greatest possibilities for commercial application of Permutit, however, lie in its use for the purification and softening of water. The use of sodium Permutit for softening water is of vital commercial importance because of the large number of industries that require water free from calcium and magnesium. The sodium-Permutit filter will reduce the hardness of almost any water to zero and at a very low cost. Hence the advantages of Permutit-treated waters for processes in which a soft water is desirable are undoubtedly very great.

The process differs from most water-softening processes in that an excess of an insoluble reagent is used instead of a small amount of a soluble one. When a hard water (i. e. water containing salts of calcium and magnesium) is filtered through sodium Permutit, the sodium is replaced by the calcium and magnesium of the water, forming a calcium-magnesium-Permutit, while the sodium unites with the acid radicles in the water, according to the following reaction.

$$2SiO_2.Al_2O_3.Na_2O+CaH_2(CO_3)_2=2SiO_2.Al_2O_3.CaO+2NaHCO_3.$$

The reactions are similar for all other salts of calcium or of magnesium. The regeneration reaction is as follows:

$$2SiO_2.Al_2O_3.(Ca,Mg)O + NaCl = 2SiO_2.Al_2O_3.Na_2O + (Ca,Mg)Cl_2.$$

This reaction is simply the reverse of the softening reaction.

The following brief abstracts show the possibilities of this method of water softening as applied in several industries.

Basch[2] states that the presence of alkali in waters prevents the corrosion of iron but causes foaming; and that the presence of NaCl counteracts the effect of alkali. Hence waters treated with Permutit cause foaming and yet do not prevent corrosion because of the presence of small quantities of NaCl. However, other writers[12] state that at least 50 boiler plants in Germany and over 1,000 in Germany, France, England, and the United States are employing this system of treatment and none of them have had any trouble with corrosion, scale, or foaming, since this process was introduced.

It is claimed[4] that for dyeing and bleaching purposes, water treated by the Permutit method is equal to distilled water and is much cheaper.

The use of Permutit for laundry purposes has many advantages over the lime and soda process. Water can not be softened to less than 3½ grains per gallon or 60 parts per million ($CaCO_3$) hardness by the lime and soda process,[11] while it can be softened to zero by means of Permutit. The cost of treatment is approximately the same with either method. The Permutit-treated waters also contain a considerable quantity of bicarbonates which aid in cleansing and are ordinarily added to waters used for laundry purposes. Another important advantage of the Permutit filter for laundries is that it automatically adjusts itself to waters of varying degrees of hardness. The mechanical adjusters used on lime and soda softeners are efficient for a short time, although they require constant attention. The action of the lime, however, soon throws the gears out of adjustment and the water is not properly treated. All these difficulties are avoided in using a Permutit softener.[10]

H. G. Anders[1] recently published the results of his investigations of Permutit for use in breweries. His results showed that the complete separation of calcium and magnesium from the water can be made without difficulty. He states in addition that waters treated by this method fulfill all the requirements for boiler-feed waters. However, upon investigating this water for use as mash and soaking water he found that small quantities of sodium carbonate were present, which were very deleterious to the action of malt and hops in sweetening, clarifying, and improving the taste of beer. This sodium carbonate was formed through the action of the CO_2 in the water upon the sodium Permutit.

The author concludes that water treated with Permutit is unsuitable for mash or soaking water because the alkali carbonates of the Permutit-treated waters are less desirable than the calcium salts of the natural waters since these salts are precipitated upon cooking. Also the sodium bicarbonate is broken down by heat to sodium carbonate, which is very undesirable. Thus it seems that Permutit-treated waters can come into use in breweries only for boiler-feed purposes.

EXPERIMENTAL PART

A number of experiments have been made in the chemical laboratory of the State Water Survey to determine the effect produced by filtering hard water through a bed of sodium Permutit.

The filter used in the investigations consists of a steel shell, 12 inches in diameter and 60 inches high. The outlet is covered by an inverted disk slightly raised at the edge to permit the water to flow under it. On the disk is an 8-inch layer of gravel on top of which are placed 80 pounds of Permutit. Supported on a perforated steel plate about 12 inches above the top of the layer of Permutit, is another 3-inch layer of gravel. A single pipe on the outside of the filter is equipped with valves and connections so that it can be used simultaneously for the inlet and outlet for water. By regulating the valves this pipe can also be used to back-flush the filter, and to drain out the salt solution used in the regeneration. A float valve fitted on the inlet pipe regulates the flow. An overflow pipe is provided for use during the back-flushing of the filter. A porcelain-lined iron tank, having a capacity of 80 gallons and elevated above the filter, is used for dissolving the salt and feeding the solution into the filter while regenerating.

Although the filter was designed to soften 33 gallons per hour for 12 hours, it will run at the above rate for about 16 hours without regeneration and will completely soften water containing 280 parts per million of carbonate hardness.

The regeneration of the filter is accomplished by dissolving 8 pounds of common salt in 8 gallons of water, running this solution into the filter and letting it stand for about 6 hours (usually over night). After the salt solution is drained out water is forced upward (back-flushing) through the filter for a short time in order to wash out the dirt which may have collected on the filter. The filter is then started and after the ten to fifteen minutes required to wash out the last traces of salt, the water is ready for use.

The University tap water, which contains no sulfates, has been used for a number of tests with this filter (see Table 1). A well water containing a large quantity of sulfates has been used for one test (see Tables 2 and 3). Samples were taken at intervals during these tests and anlyses were made for noncarbonate hardness, magnesium, alkalinity, calcium, sodium carbonate, and chloride. These determinations can rapidly be carried out and serve very well to show the comparisons between the raw and treated waters and thus the efficiency of the filter. For a more accurate comparison, a complete analysis was made of the content of mineral matter before and after treatment.

TABLE 1.—ANALYSES OF UNIVERSITY TAP WATER BEFORE AND AFTER PERMUTIT TREATMENT.

[Parts per million.]

QUANTITIES DETERMINED	Raw.	Treated.
Residue on evaporation	386.	449.
Silica (SiO_2)	20.5	21.
Sulfate (SO_4)	1.5	0.4
Iron (Fe)	1.3	.0
Alumina (Al_2O_3)	.9	2.2
Calcium (Ca)	70.2	2.5
Magnesium (Mg)	32.2	.37
Sodium (Na)	27.6	156.2
Potassium (K)	4.0	24.3
HYPOTHETICAL COMBINATIONS		
Potassium sulfate (K_2SO_4)	2.7	.7
Potassium carbonate (K_2CO_3)	6.7	42.4
Sodium carbonate (Na_2CO_3)	63.4	359.5
Magnesium carbonate ($MgCO_3$)	11.5	1.3
Calcium carbonate ($CaCO_3$)	175.2	6.3
Iron carbonate ($FeCO_3$)	2.7	.0
Silica (SiO_2)	20.5	21.0
Alumina (Al_2O_3)	.9	2.2
Total	386.6	433.4

A comparison, as afforded by Table 1, of the water before and after treatment shows practically complete removal of calcium and magnesium from a water containing carbonates.

All of the tests made with the University tap water show that the Permutit filter will soften the water which has a hardness of about 300 parts per million of $CaCO_3$, at a rate of 33 gallons per hour for 16 hours before it is necessary to regenerate the filter.

It requires 8 pounds of salt for one regeneration. Thus 8 pounds of salt by using Permutit will soften 16 times 33 or, approximately 500 gallons of water. Assuming the cost of salt to be $3.50 per ton, it costs 2.8 cents per thousand gallons to completely soften the University of Illinois water.

A water containing a large quantity of sulfates of calcium or magnesium (see Table 2) can be softened by means of Permutit (see Table 3) as well as a water that contains only the bicarbonates. A very

TABLE 2.—ANALYSIS OF THE SULFATE WATER BEFORE PERMUTIT TREATMENT.

[Parts per million.]

QUANTITIES DETERMINED	
Residue on evaporation	672
Silica (SiO_2)	11.4
Chloride (Cl)	40.0
Sulfate (SO_4)	138.8
Potassium (K)	6.54
Sodium (Na)	76.24
Iron (Fe)	.255
Alumina (Al_2O_3)	61.4
Magnesium (Mg)	39.46
Calcium (Ca)	83.65
HYPOTHETICAL COMBINATIONS	
Potassium chloride (KCl)	12.4
Sodium chloride (NaCl)	56.1
Sodium sulfate (Na_2SO_4)	166.8
Magnesium sulfate ($MgSO_4$)	31.1
Magnesium carbonate ($MgCO_3$)	114.9
Calcium carbonate ($CaCO_3$)	208.6
Silica (SiO_2)	11.4
Alumina (Al_2O_3)	61.4
Total	662.7

TABLE 3.—THREE ANALYSES OF THE SULFATE WATER AFTER PERMUTIT TREATMENT.

[Parts per million.]

No.	Non carbonate hardness.	Alkalinity to methyl orange.	Magnesium as $CaCO_3$.	Magnesium carbonate.	Calcium carbonate.	Sodium carbonate.	Rate. [*Gallons per hour.*]
1	—310	320	000	000	10	328.6	32
2	—226	231	000	000	6	239.6	34
3	—216	221	12	10.1	5	228.9	33

short run was made because of difficulty in obtaining the water and for this reason not enough experimental data are available to estimate the cost of softening it.

CONCLUSIONS

(1). Calcium and magnesium were completely removed from the University tap water.

(2). Iron was removed from the water.

(3). The normal rate of flow was varied a great deal without affecting the quality of the filtrate.

(4). The filter could be completely regenerated.

(5). There is a small loss of Permutit in washing the filter. This loss is purely mechanical, however, and by exercising a little care in flushing can be reduced to a minimum.

Although there has been, up to the present time, very little investigation of Permutit, the results obtained both in this country and abroad all show high efficiency for this method of water purification and point toward a large industrial application of the process in the future.

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THE ENGLISH INCUBATION TEST FOR THE PUTRESCIBILITY OF SEWAGE AND SEWAGE EFFLUENTS*

By F. W. Mohlman.

The decomposition of sewage is a biological process. Sewage putrefies because of the presence and growth of bacteria and micro-organisms which use the organic matter in the sewage for food. Formerly analysts tried to show the extent of biological activity by determinations of some part of the carbon and nitrogen in organic combination. The value of the concentration of oxygen was also recognized because it was known that sewage did not putrefy until the decomposition became anaerobic. Determinations which show the concentration of oxygen are nitrite and nitrate nitrogen and dissolved oxygen.

The great importance of dissolved oxygen in preventing nuisance in a sewage-polluted stream has been emphasized in the last decade. Adeney[1] in 1908 stated that the most important change which occurs in an unpolluted water when mixed with sewage, is the more or less rapid absorption of the dissolved oxygen. He claimed that the absorption is effected in three ways: (1) by dilution, (2) by oxidation of directly oxidizable substances, and (3) by indirect oxidation of organic substances. The last action may be further subdivided into (a) carbon-oxidizable substances, and (b) nitrogen-fermentable substances and ammonium compounds.

These reactions may be duplicated in the laboratory by mixing sewage with a definite amount of aerated water, keeping the mixture either in sealed bottles or exposed to the air, and making determinations of dissolved oxygen at intervals. The method of using sealed bottles has been used more frequently and is known as the "incubation test."

Frankland[8] in England in 1868 was first to apply this test. He claimed that "if water contaminated with organic matter be excluded from the air in a stoppered bottle, the gradual diminution of the dissolved oxygen indicates exactly the process of the oxidation of the organic matter." He determined dissolved oxygen every day for seven days in mixtures of 5 per cent London sewage and aerated

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water in sealed bottles. He concluded that the oxidation of the organic matter proceeded with extreme slowness.

Incubation tests of surface waters were made by A. Geradin[9] in 1875. He simply determined loss of dissolved oxygen in surface waters kept in sealed bottles for 10-14 days.

Dupre[6] in 1884 stated that when sewage-polluted water was kept for 10 days out of contact with the air, a more or less complete absorption of the dissolved oxygen would take place, and that by a determination of the dissolved oxygen before and after incubation an idea might be obtained regarding the amount of organic matter present.

Adeney[2] in 1895 used the incubation test with determinations of dissolved oxygen. He studied the test very carefully, and his results were given in the reports of the Royal Commission on Sewage Disposal.

Spitta[17, 18] in 1900 in two very exhaustive articles on self-purification of streams stated that the oxygen consumption of a sewage was a measure of its oxidizable substances but that the rate varied with different bacteria.

Pleiszner[16] stated that the rate of oxygen consumption in polluted waters decreases with the time. He expressed results of the incubation tests as "milligrams of oxygen per hour" from the beginning of incubation.

Müller[13] claimed that the rate of oxygen consumption is not uniform, and is best shown by frequent determinations, with expression of results as "milligrams of oxygen per hour" between determinations.

In the Fifth Report of the Eoyal Commission on Sewage Disposal, 1908, the incubation test was used to measure the degree of purification of sewage. Suggested limits of oxygen consumption for effluents provided that, after being filtered, the effluent should not absorb more than 5 parts per million of dissolved oxygen in 24 hours, 10 parts in 48 hours, and 15 parts in 5 days. The loss was to be obtained by multiplying loss in a given sample by the dilution.

The technique and interpretation of the test were given by Fowler.[7] He used a dilution of 1:10 and determined dissolved oxygen after 24 and 48 hours.

Hoover[10] in 1911 reported analyses for 1910 at the Columbus Sewage Works in terms of "oxygen consumed" by potassium permanganate, using the 5-minute boiling test, with periodic addition of permanganate, and also reported analyses in terms of "dissolved oxygen consumed" by the undiluted sample. He found a practically constant ratio between the two determinations for raw, septic, and filtered sewage; the dilutions which he used for the incubation test were determined from the test for oxygen consumed. The dilutions were made so that there would be a loss of about 5 parts per million of dissolved oxygen in 24 hours. The proper dilution was made, the mixture shaken and siphoned into two bottles; dissolved oxygen was determined in one at once, and in the other after it has been sealed with paraffin and incubated at 37° C. for 24 hours. The dissolved oxygen consumed by the undiluted sample was equal to the loss in the diluted sample multiplied by the dilution. The average monthly dilutions used were: crude sewage, 1:23; septic sewage, 1:17; and filter effluent, 1:4. The values of dissolved oxygen consumed by the undiluted samples were, respectively, 118, 85, and 25.5 parts per million.

Phelps[14] investigated the test and although in procedure and technique he used the general method proposed by Fowler and the Royal Commission on Sewage Disposal, he sought to devise a more convenient and more accurate method of reporting results. This is proposed in the report of his work on New York Harbor in which he states "considering the reaction taking place between the organic matter of the sewage and the oxygen dissolved in the water the following relation should hold: $\frac{dO}{dt} = KOC$. O is the amount of oxygen present in unit volume, C the amount of organic matter oxidizable, i. e. the concentration of sewage in per cent by volume, t the time in hours allowed for the reaction to proceed, and K a constant determined by the character of the organic matter and in turn defining the oxidizability of that organic matter. Integrating between the limits O' for the initial and 0 the final amount of oxygen present the formula becomes: $\log \frac{O'}{O} = KCt$ expressed in parts per million.

The value of this formula, if accurate, is apparent, "A value of K = .0030 would indicate a sewage which in 25-per cent admixture with water would reduce the content of oxygen of the mixture 50 per cent in 4 hours. Similarly for K = .0020 the reduction in a 25-per cent admixture in 4 hours would be 37.5 per cent and with K = .0015, 28.5 per cent." This formula simplifies calculations in disposing of sewage in streams or harbors, and deserves further study to prove its reliability.

The formula is derived from the monomolecular law for chemical reactions. The governing conditions of such reactions are that only two molecular species shall be involved, and that one shall be in such excess that its concentration is not changed appreciably during the course of the reaction. Examples of reactions which follow this law are: (1) the inversion of sugar by acids, (2) the reduction of potassium permanganate by a large excess of oxalic acid, (3) the conversion of metaphosphoric acid into phosphoric acid, and (4) the saponification of methylacetate by water. In each of these reactions the concentration of one molecular species is not appreciably changed; in (1) it is the acid, in (2) the oxalic acid, and in (3) and (4) the water which does not change appreciably in concentration.

Certain biological phenomena are also thought to follow this reaction. The commonest example is disinfection or killing of bacteria. H. Chick[4] showed that phenol and other disinfectants killed bacteria in accordance with this law, the number dying in any period being proportional to the number alive at the beginning of that period. In this biological reaction also, the conditions must be such that the concentration of the phenol, or whatever disinfecting agent is used, must not change appreciably.

However, in integrating the differential when applied to sewage, the assumption that the concentration of organic matter remains constant during the test is only approximately true, as was pointed out by Lederer,[12] and later admitted by Phelps.[15] He states that it is necessary in each case to employ a dilution approximately equivalent to that obtained in practice, when disposing of sewage by dilution into a stream or harbor.

The test as used at the Hygienic Laboratory in Washington is made after incubation for 24 hours, using such dilutions as will leave a residual oxygen content of 20 per cent of the original amount present.

Although a short incubation period is desirable, the greatest discrepancies will probably occur during the first 24 hours of incubation, since the reduction is much greater during this time than during any succeeding 24 hours. Reducing gases present in the sewage will be oxidized chemically during the first hours of incubation, and, after these are oxidized, the more purely biological oxidation will take place.

Clark[5] experimented with septic sewage to determine if the absorption of oxygen was caused by the oxidation of organic matter or of oxidizable gases. He sterilized sewage by heat, driving out the volatile gases, and found no rapid oxygen absorption; however, when sterilized with mercuric acetate, thus retaining the gases, a quick absorption of oxygen was noted. He concluded that the rapid absorption of oxygen in septic sewage was either due to oxidation of gases or else to the oxidation of organic matter that sterilization by heat had made resistant to oxidation.

The English test requires incubation for 10 days. The final oxygen consumption should be between 30 and 60 per cent of the amount originally present. A sub-committee was appointed by the Committee on Standard Methods of the American Public Health Association in 1913 to find the most practical and most accurate procedure for this test. The experimental work reported herein was considered in preparing the report of the committee.

EXPERIMENTAL STUDIES

The experimental work consisted of incubation tests at 20°C. with various dilutions of sewage and distilled water. This temperature is generally recognized as most desirable, although 37°C. has been used by Hoover and others. The bacterial flora at 20°C. is different from that at 37°C. and 20°C. is the temperature nearer actual conditions in streams. The use of the higher temperature would necessitate making the dilutions at 37°C. as otherwise much oxygen would be lost by the decreased solubility at this temperature.

The first tests were made with Champaign sewage. It was mixed with distilled water which had been saturated with oxygen at 20°C. by bubbling air through it at that temperature. The mixing was done in a glass cylinder into which the aerated water was siphoned from a large vessel full of water. At the same time a certain quantity of the sewage was added and then aerated water was added to bring the mixture up to a definite volume. The mixture was stirred with a wire spiral, and siphoned into 4 glass-stoppered bottles of 250-cubic centimeter capacity. Dissolved oxygen was determined by the Winkler method[19] immediately in one bottle; in the remaining bottles after 6, 24, and 48 hours incubation at 20°C. Glass-stoppered bottles were found to be satisfactory.

The results (see Table 1) show that the amount consumed and the rate of consumption increases with increasing dilution. The rate of consumption is greatest between 6 and 24 hours. Phelps' coefficient, $K = \frac{1}{Ct} \log \frac{O'}{O}$, remains fairly constant when the per cent reduction is between 30 and 75 per cent. The values of K are higher when the consumption is higher than 75 per cent, and lower when the consumption is below 30 per cent. The values of the hourly rate are also more concordant in dilutions which will give a final absorption between 30 and 75 per cent.

Tests were next made upon raw sewage from Urbana, the effluent from the Urbana septic tank, and raw sewage from Champaign. The procedure was the same as before, except that higher dilutions were used, samples were incubated for 10 days, and daily determinations of dissolved oxygen were made. This procedure necessitated the use of tighter stoppers than glass stoppers, since the incubator varied about 3°C. Several methods of preventing entrance of air have been used.

After considering the bulb pipette of Jackson and Horton,[11] the cover of celluloid or aluminium of Winkler,[20] and the U-shaped

TABLE 1.—OXYGEN DEMAND OF CHAMPAIGN SEWAGE IN VARIOUS DILUTIONS WITH DISTILLED WATER INCUBATED FOR TWO DAYS AT 20°C.

Time.	Dissolved oxygen.		Per cent loss.	Loss per hour.	Oxygen demand.		K.
	Initial.	Loss.			Loss / Dilution.	Loss per hr. / Dilution.	
[Hours.]	[Parts per million.]				[P. p. m.]	[P. p. m. per hour.]	
			TEN PER CENT SEWAGE.				
0	7.46	...	...	...	...	...	.....
6	6.94	.52	6	.086	5.2	.86	.00052
24	.20	7.26	97	.302	72.6	3.02	.00654
48	.00	...	...	...	...	...	.....
			SEVEN PER CENT SEWAGE.				
0	7.70	...	...	...	...	...	.....
6	7.50	.20	3	.036	2.9	.51	.00027
24	1.52	6.18	80	.257	88.3	3.67	.00419
48	.00	...	...	...	...	...	.....
			FIVE PER CENT SEWAGE.				
0	8.00	...	...	...	...	...	.....
6	7.90	.10	1	.016	2.0	.32	.00018
24	3.54	4.46	56	.186	89.2	3.72	.00295
48	.94	7.06	88	.147	141.2	2.94	.00387
			FOUR PER CENT SEWAGE.				
0	8.14	...	...	...	...	...	.....
6	8.00	.14	1	.023	3.5	.57	.00031
24	4.28	3.86	47	.161	96.5	4.02	.00290
48	2.16	5.98	74	.124	149.5	3.10	.00300
			THREE PER CENT SEWAGE.				
0	8.20	...	...	...	...	...	.....
6	8.04	.16	2	.026	5.3	.86	.00047
24	5.00	3.20	39	.133	106.6	4.43	.00298
48	2.94	5.26	64	.110	175.3	3.66	.00309
			TWO PER CENT SEWAGE.				
0	8.40	...	...	...	...	...	.....
6	8.34	.06	1	.010	3.0	.50	.00026
24	5.92	2.48	30	.103	124.0	5.15	.00316
48	4.62	3.78	45	.078	189.0	3.90	.00270

capillary tube of Buswell,[3] the bulb pipette was selected as being the least troublesome. An S-shaped capillary may be even less troublesome.

Four series of three dilutions each were completed using raw sewage from Urbana and four series of two dilutions each of this sewage after it had passed through the septic tank. 'Three series of three dilutions each were completed with sewage from Champaign. Phelps' coefficient and also the actual amount of oxygen consumed in milligrams were calculated for each day of incubation in each dilution.

The mass of data accumulated would be too cumbersome to be included herewith, therefore, only one series made with raw sewage from Urbana, and one series with the same sewage after passing through the septic tank, have been included. (See Tables 2 and 3.) The consumption after ten days' incubation for all of the series has also been included. (See Table 4.)

TABLE 2.—OXYGEN DEMAND OF URBANA SEWAGE IN VARIOUS DILUTIONS WITH DISTILLED WATER INCUBATED FOR TEN DAYS AT 20°C.

Time.	Dissolved oxygen.		Per cent loss.	Oxygen added per liter.	Oxygen absorbed per liter.	K.
	Initial.	Loss.				
[Hours.]	*[Parts per million.]*			*[Parts per million.]*		
			THREE PER CENT SEWAGE.			
0	8.62	...	..	287	...	.....
1	4.70	3.92	45		130	.00366
2	3.72	4.90	57		163	.00253
3	2.66	5.96	69		199	.00236
4	1.70	6.92	81		231	.00246
5	1.12	7.50	87		250	.00246
6	.83	7.79	90		259	.00235
7	.50	8.12	94		271	.00245
8	.24	8.38	97		279	.00320
9	.20	8.42	98		281	.00252
10	.14	8.48	98		283	.00248
				Average	....	.00265
			ONE PER CENT SEWAGE.			
0	8.84	...	..	884	...	.....
1	6.90	1.94	22		194	.00448
2	6.50	2.34	26		234	.00278
3	6.24	2.60	29		260	.00210
4	5.92	2.92	33		292	.00181
5	5.50	3.34	38		334	.00171
6	5.22	3.62	41		362	.00158
7	5.00	3.84	43		384	.00147
8	4.60	4.24	48		424	.00147
9	4.10	4.74	54		474	.00154
10	3.80	5.04	57		504	.00158
				Average	....	.00205
			ONE-HALF PER CENT SEWAGE.			
0	8.40	...	..	1680	...	.....
1	7.60	.80	9		160	.00362
2	7.42	.98	12		196	.00234
3	7.16	1.24	15		248	.00192
4	6.60	1.80	21		360	.00218
5	6.24	2.16	26		432	.00215
6	6.05	2.35	28		470	.00198
7	5.84	2.56	30		512	.00188
8	5.73	2.67	32		534	.00173
9	5.61	2.79	33		558	.00162
10	5.62	2.88	34		576	.00152
				Average	....	.00208

TABLE 3.—OXYGEN DEMAND OF EFFLUENT FROM URBANA SEPTIC TANK IN VARIOUS DILUTIONS WITH DISTILLED WATER INCUBATED FOR TEN DAYS AT 20°C.

Time.	Dissolved oxygen.		Per cent loss.	Oxygen added per liter.	Oxygen absorbed per liter.	K.
	Initial.	Loss.				
[*Hours.*]	[*Parts per million.*]			[*Parts per million.*]		
			THREE PER CENT SEWAGE.			
0	8.24	...	..	275	...	.....
1	6.50	1.74	21		58	.00143
2	4.84	3.40	41		113	.00160
3	3.40	4.84	59		161	.00178
4	3.26	4.98	61		166	.00140
5	2.56	5.68	69		189	.00141
6	2.24	6.00	73.		200	.00139
7	1.62	6.62	80		221	.00147
8	1.30	6.94	84		231	.00145
9	1.32	6.92	84		...	.....
10	1.30	6.94	84		231	.....
				Average.		.00149
			ONE PER CENT SEWAGE.			
0	8.36	...	..	836	...	.....
1	7.60	.76	9		76	.00172
2	6.80	1.56	19		156	.00186
3	6.46	1.90	23		190	.00155
4	5.86	2.50	30		250	.00160
5	5.52	2.84	34		284	.00150
6	5.20	3.16	38		316	.00148
7	4.82	3.54	42		354	.00142
8	4.40	3.96	47		396	.00145
9	4.00	4.36	52		436	.00147
10	4.08	...	..		....	....
				Average.		.00155

CONCLUSIONS

Most of the results indicate that the oxygen consumption is nearly complete in ten days. The variability in the amount of oxygen absorbed per liter of sewage in different dilutions is excessive. The amount of oxygen absorbed depends entirely upon the amount added, and is always higher in higher dilutions. The values of K seem to be more concordant, although they are generally higher in higher dilutions.

The excessive consumption of oxygen in higher dilutions may be caused by the actual loss of oxygen gas, or may be caused by the more vigorous oxidation. Whatever may be the cause, the fact remains that the method did not give consistent results in varying dilutions. If the same dilution could always be used, the results would be of some comparative value. The biological oxygen consumption of any sewage as determined by this method, however, could not be balanced against the)oxygen in a stream, since almost any value could be obtained for the sewage, depending upon the dilution used.

TABLE 4.—OXYGEN DEMAND OF SEWAGES AND SEPTIC TANK EFFLUENT INCUBATED FOR TEN DAYS AT 20°C.

Per cent dilution.	SERIES I.				SERIES II.				SERIES III.				SERIES IV.			
	Oxygen Demand.			K	Oxygen Demand.			K	Oxygen Demand.			K	Oxygen Demand.			K
	Oxygen added. [P.p.m.]	Oxygen absorbed. [P.p.m.]	Per cent absorbed.		Oxygen added. [P.p.m.]	Oxygen absorbed. [P.p.m.]	Per cent absorbed.		Oxygen added. [P.p.m.]	Oxygen absorbed. [P.p.m.]	Per cent absorbed.		Oxygen added. [P.p.m.]	Oxygen absorbed. [P.p.m.]	Per cent absorbed.	
URBANA SEWAGE.																
.50	...	...	...	.....	...	...	...	.....	...	...	...	.....	1680	576	34	.00208
1.00	...	...	...	.....	780	388	50	.00144	856	468	55	.00143	884	504	57	.00205
2.00	429	314	73	.00151	372	260	70	.00114	430	288	67	.00122	...	...	...	.....
3.00	282	226	81	.00135	...	...	...	.....	...	...	...	.....	287	283	98	.00265
4.00	...	...	...	.....	...	...	...	.....	211	211	100	.00179	...	...	...	.....
5.00	162	162	100	.00145	148	148	100	.00210	...	...	...	.....	...	...	...	.....
EFFLUENT FROM URBANA SEPTIC TANK.																
1.00	...	...	...	.....	808	376	47	.00136	854	354	41	.00118	836	428	52	.00155
2.00	409	306	79	.00144	...	...	...	.....	...	...	...	.....	...	...	...	.....
3.00	276	239	85	.00142	263	163	62	.00091	276	225	81	.00110	275	231	84	.00149
CHAMPAIGN SEWAGE.																
.25	...	...	...	.....	...	...	...	.....	3488	1248	36	.00398				
.50	1512	864	57	.00357	1580	1100	70	.00585	1688	696	41	.00251				
1.00	728	594	82	.00284	780	780	100	.00993	826	710	86	.00318				
2.00	...	...	...	.....	390	390	100	.01469	...	...	...	.....				
3.00	231	231	100	.00357	...	...	...	.....	...	...	...	.....				

Phelps' coefficient is more or less constant after three or four days' incubation (see Tables 2 and 3), but after 24 hours it is usually very much higher than it is after longer incubation. This is probably caused by either the direct oxidation of gases ,which are not oxidized according to the monomolecular law, or to loss of oxygen. All of the tests indicated that at least three days' incubation is necessary. Phelps' coefficient obviates the necessity of making a long series of tests to show the ratio of short-time incubation to incubation extended for 10 or 20 days.

As a practical test, the English method of determining biological oxygen consumption is subject to very grave errors, and is only applicable under limited conditions. These conditions are that the same dilution must always be used if results are to be at all comparable, and that incubation must extend over at least three days, at 20°C. Oxygen demand for longer periods may then be calculated by Phelps' formula.

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PURIFICATION OF SEWAGE BY AERATION IN THE PRESENCE OF ACTIVATED SLUDGE[1]

By Edward Bartow and F. W. Mohlman.

In a paper[2] read before the Illinois Section of the American Water Works Association, November 11, 1914, it was stated that experiments on the purification of sewage by aeration in the presence of activated sludge were to be carried on in the laboratory of the Illinois State Water Survey at the University of Illinois. With the advice of Professor G. J. Fowler of the University of Manchester, the experiments followed the lines described by Ardern and Lockett.[3] A repetition of the work of Ardern and Lockett was avoided as far as possible, but it was necessary to repeat some of the experiments described by them in order to become familiar with the process, to obtain the necessary activated sludge and to study the reactions involved.

A study was made of the necessary mechanical devices, the physical, chemical, and biological conditions of the process, and the properties of the sludge.

Ardern and Lockett had abandoned experiments with continuous flow devices, so that it seemed best to confine the experiments to an intermittent system. The first experiments were made using bottles of three gallons capacity. Later, a tank 9 inches square and 5 feet deep was used. This tank has a plate-glass front and back to permit easy observance of the condition of the sewage and sludge. A porous plate was placed 4 inches above the bottom. An inlet for air and an outlet for any water which might pass through the plate were provided in the space below the plate. Compressed air furnished by the University power plant was used. All air was measured through an ordinary gas meter. The purified sewage was removed by means of a siphon. Experiments were carried out in the laboratory at room temperature with no special precautions to regulate the temperature.

The sewage used is from the city of Champaign, collected from the main sewer at the edge of the city, at least two miles from the outfall. When taken it is fresh. Average analyses indicate that it a fairly strong, domestic sewage containing no trade wastes.

[1] J. Ind. Eng. Chem., 7, 318-23 (1915) ;8, 15-20 (1916).

[2] Bartow, E., Observations on some European water-purification plants and sewage-disposal works: J. Am. W. W. Assoc., 2, 213-24 (1915); Illinois Univ. Bull., Water-Survey Series 12, 162-72 (1915).

[3] J. Soc. Chem. Ind., S3, 523-39, 1122-4 (1914).

AERATION OF SEWAGE WITHOUT SLUDGE

Air was blown into five separate portions of sewage until complete nitrification was accomplished. To show the progress of the reaction, tests for ammonia, nitrite, and nitrate nitrogen were made at intervals during each treatment. The time required for complete oxidation of ammonia nitrogen varied from 15 to 33 days. The shortest period was obtained with the tank, where the air was distributed through the porous plate. For all analyses, samples of the supernatant liquid were taken after one hour's settling without filtration. In each case, the ammonia nitrogen was almost quantitatively changed to nitrite nitrogen, then the nitrite nitrogen in turn was changed almost quantitatively to nitrate nitrogen. This change is illustrated in Table 1, A and B and Figures 1 and 2.

The oxidation of ammonia nitrogen in the tank was accomplished in 15 days with the use of 4830 cubic feet of air.

AERATION OF SEWAGE WITH SLUDGE

The supernatant liquid was siphoned off and a fresh portion of sewage added to the sludge. In this, the second treatment, the effect of a small amount of sludge was very nicely illustrated by the reduction of the time required for oxidation of ammonia nitrogen from 15 to 4 days, and the reduction in the amount of air used from 4830 to 1270 cubic feet: 34 parts per million of ammonia nitrogen in the raw sewage produced 23.8 parts per million of nitrate nitrogen in the supernatant liquid.

The supernatant liquid was again siphoned off, fresh sewage added, and aeration continued. In this, the third treatment, oxidation of ammonia nitrogen was complete in two days and but 720 cubic feet of air were used: 33 parts per million of ammonia nitrogen produced 22.3 parts per million of nitrate nitrogen. In the twelfth treatment the purification was complete in less than 8 hours with the use of less than 128 cubic feet of air and 36 parts per million of ammonia nitrogen produced 29.5 parts per million of nitrate nitrogen. In the thirty-first treatment with sludge and sewage in the proportion of 1:5, purification was complete in less than 5 hours: 35 cubic feet of air were used, equal to 0.20 cubic foot per square foot of surface area, per minute, or about 3 cubic feet per gallon of sewage.

Samples taken at the end of each hour of aeration during some of the treatments were tested for stability. A sample taken at the end of one hour's aeration in the thirty-first treatment did not decolorize methylene blue in twelve days. Since in one hour oxidation of am-

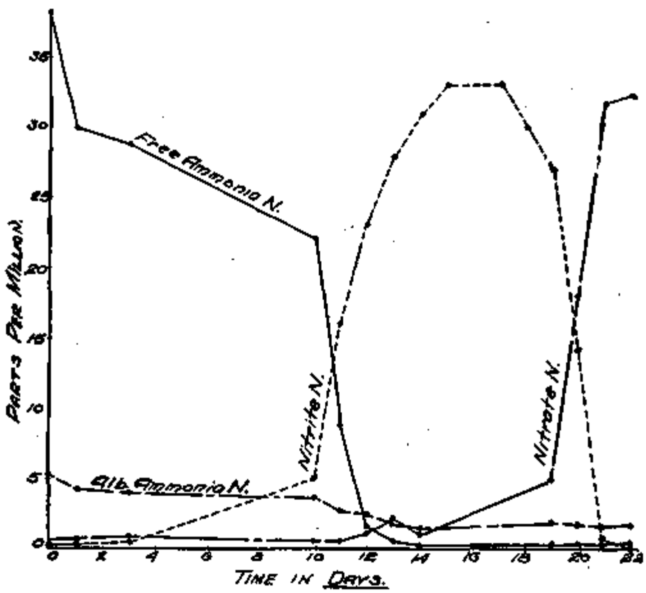

Figure 1.—Nitrification of sewage. No activated sludge present.

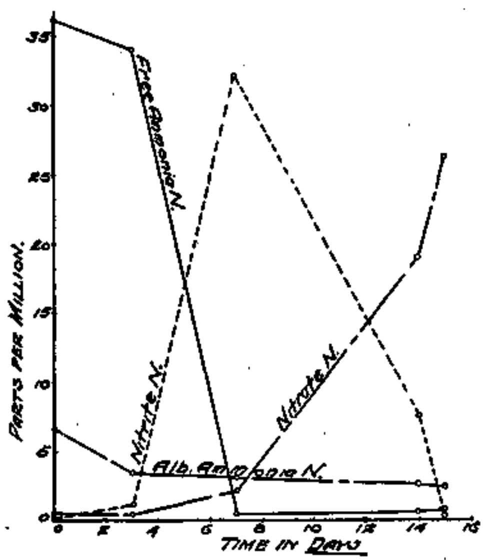

Figure 2.—Nitrification of sewage. No activated sludge present. Uniform distribution of air through porous plate.

monia nitrogen was not complete, it is, therefore, evidently unnecessary to obtain complete oxidation of ammonia nitrogen in order to obtain a stable effluent. Since it is impossible to separate the oxidized liquid entirely from the sludge it is probable that the stability is promoted by the oxidizing action of the nitrate in the residual liquid.

The progress of nitrification in the presence of activated sludge is apparent. The results are shown in Table 1 and in Figure 3. From

TABLE 1.—NITRIFICATION OF SEWAGE : WITH AND WITHOUT SLUDGE.

[Parts per million.]

Date.	Time Days.	Nitrogen.			
		Ammonia.	Albuminoid.	Nitrite.	Nitrate.
A—NO ACTIVATED SLUDGE PRESENT.					
Dec. 18, 1914	0	38.00	5.20	0.07	0.87
19	1	30.00	4.20	0.02	0.38
21	3	28.80	4.00	0.11	0.45
28	10	22.00	3.60	5.00	0.20
29	11	8.80	2.60	16.00	0.40
30	12	1.60	2.40	28.00	1.00
31	13	0.36	1.88	28.00	2.00
Jan. 1, 1915	14	0.16	1.48	31.00	1.00
2	15	....	...	33.00	...
4	17	....	...	83.00	...
5	18	....	...	80.00	...
6	19	0.28	1.92	27.00	5.00
7	20	0.44	1.84	14.00	18.00
8	21	0.28	1.68	.30	81.70
9	22	0.24	1.60	.05	81.95
B—NO ACTIVATED SLUDGE PRESENT: UNIFORM DISTRIBUTION OF AIR THROUGH POROUS PLATE.					
Jan. 4	0	36.00	6.60	0.01	0.71
7	3	34.00	3.40	1.20	0.60
11	7	0.40	3.00	82.00	2.00
18	14	0.60	2.60	7.50	18.50
19	15	0.80	2.20	0.10	25.90

C—ACTIVATED SLUDGE PRESENT (1 SLUDGE: 5 SEWAGE): UNIFORM DISTRIBUTION OF AIR THROUGH POROUS PLATE.

	Hours.	Ammonia nitrogen.	Nitrite Nitrogen.	Nitrate Nitrogen.
Feb. 24, 1915	0	27.00	0.05	0.59
	1	18.00	2.40	6.00
	2	8.20	2.80	10.80
	3	3.70	3.40	15.00
	4	0.20	2.60	18.60
	5	0.20	0.80	22.10

this and from other series of analyses it is indicated that there is no quantitative conversion of ammonia nitrogen to nitrite, followed by oxidation to nitrate, but that nitrate is formed simultaneously with nitrite.

The number of bacteria was determined during one treatment. Samples were taken after one hour's settling. The raw sewage showed a bacterial content of 750,000 per cubic centimeter. The supernatant liquid after aeration and settling one hour showed but 20,000.

Through the courtesy of Professor Frank Smith, Professor of Systematic Zoology at the University of Illinois, biological examinations were made of the sludge. Among the microscopic animals found were many *Vorticella* and *Rotifera,* but the predominant organism was an annelid worm, known as *Aeolosoma hemprichii.* This organism is about 2 to 5 millimeters long and quite slender. It abounds in various kinds of freshwater bodies where there is an abundance of decaying organic material, and thrives especially well where there is much fermentation and in waters contaminated with sewage, provided there is an abundance of oxygen. It belongs to a group of worms in which reproduction occurs very rapidly by asexual methods. A fission zone is formed near the middle of the body of the parent worm and develops the head of one daughter worm and the tail of the other.

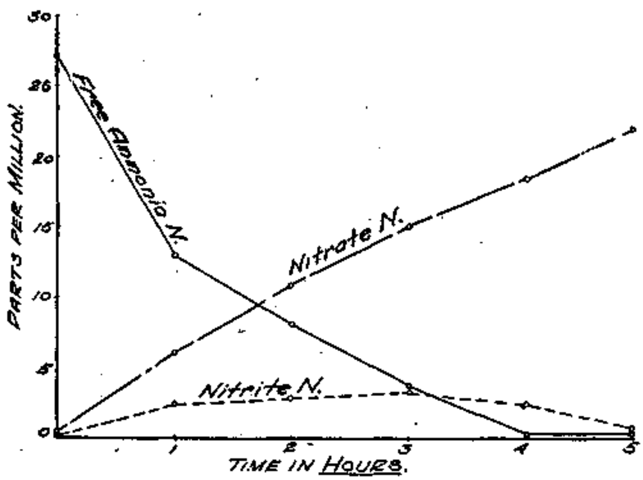

Figure 3.—Nitrification of sewage. Activated sludge present.
1 sludge: 5 sewage.

This requires not over two or three days and is repeated for an indefinite number of generations. It feeds greedily and almost continuously on any small organic particles that it can obtain and presumably destroys every day at least its own weight of organic matter. Because of the mode of reproduction, it takes but a short time to produce extensive colonies with great capacity for the destruction of organic material. It was later shown that these organisms were not essential to the process. (See a later article in this bulletin on the bacterial content of activated sludge.)

The sludge does not have an unpleasant odor but if kept for a long time in a moist condition without air, it will putrefy. Analyses of the sludge made by W. D. Hatfield and reported in the next paper, showed that the dried material contained 6.3 per cent nitrogen, 4.0 per cent fat, 1.44 per cent phosphorous (equivalent to 3.31 per cent P_2O_5) and 75 per cent volatile matter by loss on ignition.

The dried sludge would evidently have value as a fertilizer. In order to determine whether the theoretical value would correspond with the actual value, pot cultures of wheat were made. Portions of dried sludge were added to two pots, an equivalent amount of nitrogen from dried blood to a third, and nothing to a fourth. The cultures containing the dried sludge showed better growth than the culture containing an equivalent amount of nitrogen from dried blood and far better growth that the culture to which no additional nitrogen was added.

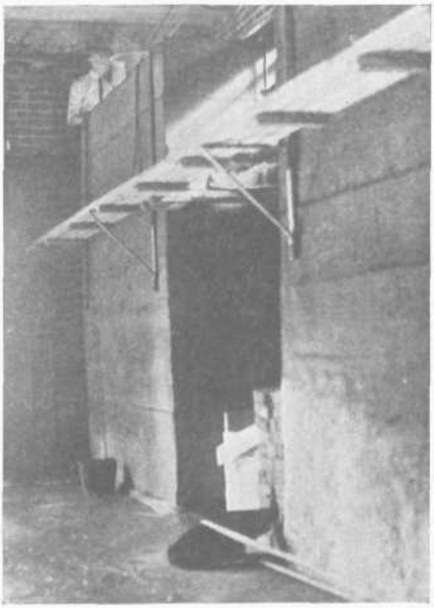

Figure 4.—Tanks for purification of sewage by aeration in presence of activated sludge.

The results of the first experiments were so promising that further experiments were made on a larger scale. Four reinforced-concrete tanks, operating on the fill and draw system, were designed and built to study in a comparative manner the amount of air required, the best method for distributing the air, the time required for purification, and the quantity and quality of activated sludge formed.

The tanks were placed in the basement of the University power plant (see Figure 4). The room was not affected by heat from the

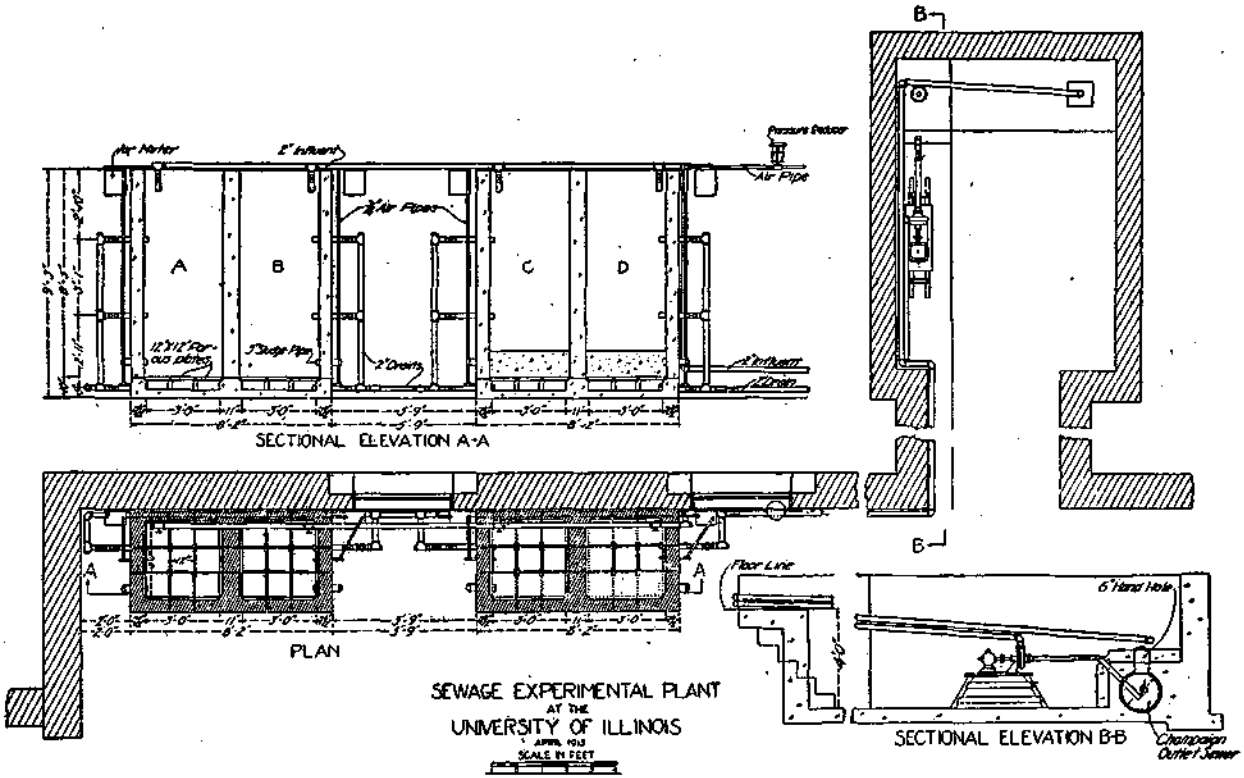

Figure 5.—Plan of concrete tanks for treatment of sewage by activated-sludge process.

boilers and conditions were similar to those which would be obtained by housing a plant. It was very easy to tap the main sewer of the city of Champaign which passes underneath the coal hopper (Figure 5) of the power plant. The sewage was pumped to the tanks by a centrifugal pump direct-connected to a motor.

Each tank was 3 feet 2 inches square, having an area of 10 square feet, and was 8 feet 5 inches in depth. In 2 tanks there were 9 plates, each 12 inches square, covering the entire floor. In the third tank there were 3 plates, covering one-third the area of the floor, forming the bottom of a central trough. The sides were built of concrete at an angle of 45°. In the fourth tank was a single plate in the center covering one-ninth the area with the bottom sloping to it at an angle of 45° from all sides. Below the plates were air spaces 4 inches deep. Pet cocks were provided to relieve the air pressure when draining the tanks and to prevent air bubbles from rising and stirring up the sludge. The air obtained from the University compressed-air plant at a pressure of 80 pounds was reduced by a pressure-reducing valve to 8 pounds and was further regulated by hand-operated valves before passing through meters to each tank. The pressure under which it entered the tank was sufficient only to overcome the pressure of the sewage, equivalent to about 8 inches of mercury, or a little less than 4 pounds per square inch.

Two outlets for the effluent were, respectively, 2 feet 6 inches and 5 feet 7 inches above the porous plates. A tank could be filled in 6 minutes and drained to the lower outlet in 8 minutes. Experience in operating the plant showed that a lower outlet connected to a floating outlet was preferable. A fixed outlet was objectionable because sludge was at times drawn out with the effluent. In fact, no accurate data were obtained concerning the quantity of sludge formed, because it was impossible to determine how much was lost with the effluent. In order to prevent this loss, a floating outlet made of 2-inch pipe connected together with loose joints was placed in tank C (see Figure 5). The effluent then flowed to the outlet through a screen of copper wire of about 16 mesh, which was fastened on both sides of an iron frame one foot square. With this arrangement no sludge was lost and accurate data concerning the amount of sludge formed from the sewage was obtained.

The true amount of sludge must be determined by weight on the dry basis for its volume and rate of settling vary with the amount of air applied. If an unusually large amount of air was applied, the sludge settled more slowly and occupied a greater volume even after prolonged settlement, than it did when less air had been applied. For quick tests settlement in cylinders or Imhoff cones was used.

If activated sludge is built up accompanied by complete oxidation of ammonia nitrogen in each portion of sewage added, it would require several weeks to put a plant in operation.

In order to obtain sludge more quickly the English investigators used sludge from sprinkling filters. At Milwaukee, Imhoff tank sludge was aerated until it became aerobic and similar to activated sludge. Since such sources of sludge would not be available in many places, especially at newly installed plants, it was shown by experiment to be possible to shorten the period of sludge formation.

Tanks A and B were filled with the same kind of sewage on May 5,1915. The sewage in tank A was aerated continuously. The sewage in tank B was aerated 23 hours and allowed to settle for one-half hour. Then the supernatant liquid was withdrawn, and the tank was refilled with fresh sewage. This cycle was repeated daily and determinations of the amount of sludge and of the degree of purification were made daily. At the end of 10 days, after one hour's settling in Imhoff cones, 1.0 per cent of the volume in A consisted of sludge while about 10 per cent of the volume in B was sludge. The effluents from A, which had been aerated 10 days, and from B, which had been aerated one day, were equally stable, while that from B was clearer.

Tank B was continued in operation, changing the sewage every 24 hours, until, after 15 days, oxidation of ammonia nitrogen was complete. Then the sewage was changed every 12 hours; oxidation of ammonia nitrogen was again complete after 8 days. Then the sewage was changed every 6 hours; many of the effluents with the 6-hour cycle were putrescible and it was necessary at intervals to aerate for longer periods. This comparison indicated, however, that sludge may be satisfactorily activated by changing the sewage before the oxidation of ammonia nitrogen is complete, and that the sewage might be changed at more frequent intervals.

Tank A was, therefore, cleaned and fresh sewage added every 12 hours. Stable effluents were obtained in 7 days; complete oxidation of ammonia nitrogen occurred in 18 days, after which the sewage was changed every 6 hours. The effluents obtained from the tanks during this 6-hour cycle were not all stable, yet the average improvement was so great that the conclusion was reached that activated sludge may be built up by changing sewage at frequent intervals without complete oxidation of ammonia nitrogen of each addition of fresh sewage. A considerable degree of purification is obtained from the beginning of the operation, and the time for building up adequate sludge for the process is cut down very decidedly. A later experiment with tank C showed that satisfactory activated sludge could be built up using a 6-hour cycle. .

The efficiency of tank C containing 3 square feet of Filtros plates, and tank D containing one square foot, was studied. These tanks were put in operation July 6 and the sewage was changed every 6 hours. There was a noticeable difference. C gave some stable effluents in 5 days; D did not give stable effluents in 18 days. The sludge from C was of good appearance, while that from D was not as flocculent and at times had a septic odor. During the comparative experiment an average of 1.12 cubic feet of air per gallon of sewage was used with C and of .90 cubic foot of air per gallon of sewage with D. The amount of air given D was always sufficient to keep the sludge mixed with the sewage. In fact, the sewage in D was agitated much more violently than that in C. It was concluded that one square foot of Filtros plate per 10 square feet of floor area is hardly sufficient. Of the four tanks, C with 3 square feet of Filtros plate per 10 square feet of floor area, gave the best results.

The quality of the effluents usually depended more on the strength of the raw sewage than upon any other variable. The tanks, when operating on a 6-hour cycle, were filled at 9 a. m., 3 p. m., 9. p. m. and 3 a. m. The strength of the raw sewage, estimated by ammonia nitrogen values, averagedlfor the 9 a. m. sewage between 20 and 25 parts per million, for the 3 a. m. sewage between 3 and 12 parts per million. Nearly all of the 3 a. m. sewages gave stable effluents, but the strong morning sewages quite frequently; gave putrescible effluents. Unless the sludge was in good condition, and well nitrified, a strong sewage could not always be purified in 4½ hours even by increasing the air to 2.0 cubic feet per gallon. In the normal working of the plant the sludge usually regained its "activity" if 2.0 cubic feet of air per gallon of sewage was applied for several periods after the strong sewage had been added. At times, however, with a succession of strong sewages, it was necessary to increase the time of aeration in order to obtain good effluents.

Ardern and Lockett noted in their first paper that if the aeration was stopped before the sewage was well nitrified, the activity of the sludge would be inhibited. When strong sewages are to be treated a definite cycle of operation can not be established without provision for longer aeration of the sewage or separate aeration of the sludge.

In the writers' experiments effluents were usually stable if 50 per cent of the ammonia nitrogen was removed, and 2 to 3 parts per million of nitrate nitrogen were present. The complete removal of ammonia nitrogen is neither necessary nor economical. The greatest economy in air consumption will be obtained when enough air is used to make the sewage non-putrescible and to keep the sludge activated. The operation of the plant during six months has suggested the advisability of studying more carefully other features of the process such as the amount of sludge formed, the building-up of nitrogen in the sludge, and the composition of the effluent gases.

THE VALUE OF ACTIVATED SLUDGE AS A FERTILIZER*

By W. D. Hatfield and Edward Bartow.

The suspended matter of sewage is removed either by settling or by the precipitation processes used in sewage purification. The disposal of the sludge thus formed is an important part of sewage purification. Present modes of sludge disposal are wasteful, from an economic point of view since the sludge contains valuable fertilizing constituents which are usually lost. Many economists have calculated the appalling waste of nitrogen and phosphorus in terms of dollars and cents, in terms of the number of acres that could be manured by it, and in terms of the bushels of grain which could be grown by its application to the soil. Nevertheless, we find it very little used since it has not proved practicable to use the values indicated by its chemical composition. Present methods of sludge disposal[1] are not only wasteful but are also expensive and insanitary.

(1). Sea disposal is the cheapest method for cities on the shores of the oceans or large bodies of water, but there is always the danger that the tide will bring the sludge back. Also it may contaminate fish and spread disease. Calculations[7] show that the cost of disposal is from $0.75 to $3.00 a dry ton.

(2). Filter pressing is only a preliminary process since it simply reduces the volume and thus makes the sludge easier to handle. It must still be disposed of. The cost[7] of filter pressing is said to be from $0.75 to $1.00 a dry ton.

(3) Centrifugal drying is a new method which is used in a few places. It costs[7] from $0.85 to $3.00 a dry ton. Like filter pressing, however, it is only a preliminary treatment.

(4). Heat drying is accomplished by heating the pressed cake on iron plates which are heated with steam from the plant. In some places hot air is forced through the sludge and the dried sludge fanned by it out of the machine.[11] The cost of heat drying is from $1.75 to $3.00 a dry ton.

(5). Disposal on land by dumping, trenching, and lagooning requires large tracts of land, and is impracticable unless large amounts of waste land are available. There is also the insanitary aspect as

*Abstract of thesis submitted in partial fulfillment of the requirements for the degree of Master of Science by William Durrell Hatfield, June, 1915. J. Ind. Eng. Chem. 8, 17-25 (1916).

odors invariably accompany this means of sludge disposal.

(6). Air drying requires large tracts of land since the sludge should not be spread more than three inches deep. Temperature and rainfall are quite important factors in this method.

(7). Destructive distillation is an expensive method and the gas obtained has a low calorific value.

(8). Grossman's method of distillation with superheated steam produces a very marketable sludge which is sterile and free from grease. There are no available data concerning the net cost.

(9). "Wet carbonization is a new method, which gives a fat-free and sterile sludge, but no data are available with regard to its expense.

Naturally the question of utilization of sewage sludge as a fertilizer has received attention. A careful study was made by the British Royal Commission on Sewage Disposal.[4] They concluded that while sludge undoubtedly has value as a fertilizer, this is small, however, in comparison with the gross mass of the sludge, and consequently the value is dependent on the cost of transportation to places where it can be used.

H. Maclean Wilson[12] of Wakefield, England, states that many farmers and market gardeners near the large cities use sludge and can show that it has a marked effect on their crops, whether of hay, grain, roots, rhubarb, or vegetables. He also claims that foreign agriculturists are buying large quantities of England's sludge in spite of the cost of transportation. Northern France, Argentine, and the United States make the largest purchases. He concludes "if sludge is found so valuable in these countries it should be well worth trying at home where the price would be much lower."

Probably less than one per cent of England's sewage sludge is used as a fertilizer. The British Royal Commission on Sewage Disposal[4] claims that the nitrogen and phosphorus are not available, because of the large proportion of grease present in sludge. The commission claimed that grease forms an impervious covering, keeping water, air, and microorganisms from the nitrogen and phosphorus. However, more recent investigators have shown that this is not entirely correct. The physical character of the applied sludge is a very important factor and apparently is not mentioned in connection with the sludge used in the early investigations of the commission.

Several British municipalities[12] with unusually rich sewage are able to sell all or part of their sludge and a few make it marketable by adding lime or other constituents. One of the three disposal plants at Glasgow, a chemical-precipitation plant, dries and grinds its sludge and sells it under the name of Globe Fertilizer at $2.40 a ton in bulk or $3.40 a ton in bags. Bedford has a sewage containing wastes from woolen mills, but after the grease is extracted the powdered sludge is quite marketable. At Oldham grease is removed by Grossman's process of steam distillation. The resulting sludge mixed with sodium nitrate or kainite makes an excellent fertilizer. Kingston on Thames sells a chemically precipitated sludge under the name of "Native Guano." Hebden Bridge sludge is sold in granular form. Huddersfield uses the wet-carbonizing method and sells the resulting sludge in a powdered form. In all but one of the above cases the sludge is powdered, and in a few the grease is removed. In the vast majority of cases, however, sludge is only filter pressed and contains from 60 to 70 per cent of moisture. In this condition it is not easily applicable to the ground, and the farmers will not carry it away. Such sludge, moreover, is very likely to contain the seeds of many troublesome weeds.

The chemical analysis of sludge indicates that it should be of value as a fertilizer. Naylor[10] states, after quoting analysis of commercial fertilizers, manures, and sewage sludges, that dried sludge should have a value of $7.50 to $10.00 a ton, but that the removal of grease is absolutely necessary before sewage sludge will be accepted as a fertilizer worthy of the consideration of the agriculturists.

Watson[11] mentions with approval the process at Dublin, Ireland, where "brewers yeast" is introduced into the sludge to permit rapid fermentation and separation of water. The separated water is drawn off and the remaining mass dried by hot air at 450°F., powdered, and blown out of the machine.

H. W. Clark[5] says that in order to reclaim the valuable material from sludge it must be dried, degreased, and powdered. The removal of grease by any known method is a costly procedure. The sludge has a value, however, and as the processes of treatment are improved, sewage sludge will become of increasingly greater agricultural importance.

H. Bach and L. C. Frank[2] discuss the composition of fresh and decomposed sludge and conclude that the physical quality or charater of sludge is equally as important as the content of nitrogen. They show that in fresh sludge the grease and fibrous material cause the earth to become impervious to rain and probably does more harm than good as a fertilizer. On the other hand, decomposed sludge contains less fat and is not so fibrous. In addition, the fat is very finely divided and uniformly distributed throughout the mass of sludge, and since the sludge itself is porous, this finely divided fat is not an appreciable hindrance to percolation. The decomposed sludge dries quickly and remains porous when dry. Hence, when it is used as a fertilizer the porosity of the ground is not affected, and moisture and air can easily come in contact with the nitrogenous material.

Lipman and Burgess[9] have devised a new and very interesting method for the determination of the available nitrogen in sludge and fertilizers. The new method was proposed because arbitrary chemical methods of determining "available nitrogen" seemed to have but little relation to actual conditions in the field. They determined the change of the nitrogen in sludge and; fertilizers to nitrate by the nitrifying bacteria of soils. Three different soils were inoculated with nine different sludges and six different fertilizers, the mixtures were incubated for a definite period, and the per cent of nitrogen changed to nitrate was determined. They have shown that the nitrogen in sewage sludge and low-grade tankage is more easily nitrified than that of dried blood, high-grade tankage, fish guano, cotton-seed meal, and goat manure. The three soils differ greatly in the rate of nitrification of dried blood, high-grade tankage, fish guano, cotton-seed meal ,and goat manure, in some cases no nitrification at all taking place. The change of the nitrogen to the nitrate form in sludge and low-grade tankage was more uniform. They conclude that, according to the ease of nitrification, sludge and low-grade tankage are of greater value than any of the other materials named.

FORMATION OF THE VARIOUS KINDS OF SLUDGES

In plain sedimentation the sewage passes through a specially constructed tank at a velocity which allows a part of the suspended organic matter to settle. At the Lawrence station 33 per cent of the total suspended matter is settled, including 30 to 50 per cent of the fats.

In septic tanks the sludge which settles is allowed to undergo anaerobic decomposition whereby it is converted into a nonodorous and stable product which can be more easily disposed of than the fresh* sedimentation sludge. The decomposition causes a relative increase in the mineral content and a decrease in the per cent of organic matter, fats, nitrogen, and phosphorus in the sludge. Bach and Frank[2] claim that this sludge is superior to fresh sedimentation sludge as a fertilizer chiefly because of its physical character.

In chemical precipitation certain chemicals which will produce a flocculent precipitate are added to the sewage. The precipitate envelops much of the suspended organic matter and carries it down as sludge. This sludge is usually filter pressed and disposed of in the cheapest way possible. In a few cases it is sold as a fertilizer.

"Activated sludge" is formed by blowing air through sewage[3] allowing the suspended matter to settle and removing the supernatant liquid. Fresh sewage is added and the mixture again aerated and the process repeated until sufficient sludge has accumulated to reduce the time of purification or complete nitrification to from 4 to 6 hours. This decrease in time is caused by the presence of "activated sludge" which is formed. The presence of organic matter and an excess of air produce optimum conditions for a flora of aerobic organisms and microorganisms. These organisms, the oxidizing property of the air, and the physical properties of the sludge, must help to carry down the suspended matter and bacteria, and to prevent anaerobic decomposition of the soluble matter. Since this sludge is developed under strictly aerobic conditions it does not possess any unpleasant odor and consequently is in no way obnoxious to handle. However, if allowed to stand more than 24 to 48 hours it will begin to putrefy.

PHYSICAL PROPERTIES OF ACTIVATED SLUDGE

Activated sludge as it settles from the purified sewage when the air current is stopped, is a brown, odorless, homogeneous, flocculent, and finely divided mass. The sludge obtained at Urbana was quite different from the Urbana septic-tank sludge, which was coarse, black, and foul smelling.

Activated sludge very much resembled plain brown mud. When dried on a steam bath the sludge was easily ground in a mortar to a fine powder. The sludge in this form had a strong organic nitrogenous odor much resembling that of commercial fertilizers. In the powdered form, the sludge is very porous and is not greasy. Septic-tank sludge, on the other hand, when dried by this procedure was not easily pulverized, but was sticky and adhered to the mortar and pestle. The specific gravity of the two sludges was nearly the same; that of the activated sludge was 1.03 and that of the septic-tank sludge, 1.02. Since activated sludge can be dried, and easily pulverized, it should be a marketable fertilizer. Examinations from time to time of different specimens of activated sludge showed that its physical properties do not vary.

COMPOSITION OF ACTIVATED SLUDGE AND ITS FERTILIZER VALUE

That activated sludge has manurial value is shown by its chemical composition, by its reaction with various soils, and by its effect on the growth of plants. Specimens of sludge obtained at the experimental plant have varied in nitrogen content from 3.5 to 6.4 per cent. The lower values were obtained during periods of high water. Street wash entered the sanitary sewers and since no grit chamber was provided to remove the grit, the nitrogen value of the sludge was greatly lowered. The tests of the fertilizer value have been made on the richer specimens which were first obtained.

Through the courtesy of Mr. Paul Rudnick, chief chemist, Armour & Co., Chicago, the availability, according to alkaline permanganate method as used by the New England States, was shown to be below 50 per cent (44.7 per cent), and the sludge would be classed as an inferior ammoniate, but the availability according to the neutral permanganate method which has been adopted by the southeastern States was shown to be above 85 per cent (89 per cent), and would therefore be classed as satisfactory.

Tests have been made by Professor C. B. Lipman, according to the method described by Lipman and Burgess,[9] in which a fertilizer and a soil are incubated for a month. The amount of nitrogen changed into nitrate is then determined. This amount is an index of the availability of the nitrogen with respect to the soil used. The results obtained were reported by Professor Lipman, as follows:

"The activated sludge used contained 6.2 per cent total nitrogen and no nitrate. The hundred grains of soil in every case contained nitrate as follows:

Anaheim soil, 1.0 mg. N. Davis soil, 0.3 mg. N. Oakley soil, 0.1 mg. N.

The amounts of nitrate produced in one month's incubation from the soil's own nitrogen and from the nitrogen of the sludge mixed with the soil in the ratio of one part of sludge per hundred of soil is as follows:

Soil.	Milligrams nitrate produced.	
	Without sludge.	With sludge.
Anaheim	6.0	10.0
Davis	4.2	14.0
Oakley	2.2	4.0

The Davis soil is the best nitrifying soil of the three, especially for high-grade organic material. Anaheim is next, and the Oakley by far the poorest. Indeed, the last named does not nitrify the nitrogen of dried blood at all in a period of a month in the incubator.

These figures indicate that the general tendency is to make available the nitrogen of sludge in type soils at about the same rate that nitrogen is transformed into nitrate in such organic nitrogenous fertilizers as fish guano. While it seems to hold a medium position, it nevertheless resembles very much more closely in its general characteristics, se far as available nitrogen is concerned, the so-called high-grade organic nitrogenous fertilizers, dried blood and high-grade tankage, etc., rather than the low-grade nitrogenous fertilizers, steamed bone meal, cotton-seed meal, garbage tankage, etc."

Although the chemical tests and the nitrification tests with soils indicate that the activated sludge has a high fertilizer value, the final test must be its effect on plant growth. Pot[3] cultures, using wheat, were started in March, 1915, under the general direction of Professor

C. G. Hopkins and with the assistance of Mr. J. C. Anderson. The contents of the pots in which the wheat was planted were as follows, in grams:

Pot No.	White Sand.	Dolo-mite.	Bone meal.	Potassium sulfate.	Activated sludge.	Extracted sludge.	Dried blood.
1	19,820	60	6	3	0	0	0.0
2	19,820	60	6	3	0	0	8.61
3	19,820	60	6	3	20	0	0.0
4	19,820	60	6	3	0	20	0.0

Each pot contained an equivalent of 5 tons per acre of dolomite, one-half ton per acre of bone meal, and 500 pounds per acre of potassium sulfate.

Pot 1, the check pot, contained only the 60 milligrams of nitrogen which were added in the bone meal. This small amount was without significance since the same amount was added to the other pots. Pot 2 contained an equivalent of 120 pounds of nitrogen per acre added in the form of dried blood. Pots 3 and 4 contained an equivalent of

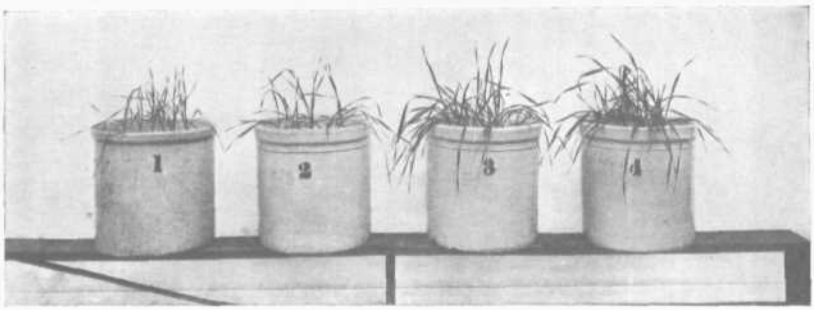

Figure 1.—Pot culture of wheat twenty-three days after planting.

Each pot contains pure white sand to which the same amount of plant foods except nitrogen has been added. No. 3 contains 20 g. dried activated sludge. No. 4 contains the same amount extracted with ligroin. No. 2 contains an equivalent of nitrogen from dried blood and No. 1 contains no nitrogen.

120 pounds of nitrogen in the form of dried activated sludge (one ton of sludge per acre). The sludge used analyzed as follows in percentages:

Total nitrogen	Phosphorus (P_2O_5)	Ether soluble. 3 hrs. extraction.	16 hrs. extraction.
6.3	2.69	4.00	11.8

Thirty wheat seeds were planted, 2 seeds in each of 15 holes, in each pot. In 4 days the; plants were up in each pot and in 10 days were 5 inches high. At the end of 18 days the plants were thinned to 15 of the best in each pot, in most cases leaving one plant to each hole. In 20 days from date of planting there was a marked showing in favor of the plants in pots 3 and 4. In 23 days the plants in pots 3 and 4 (see Figure 1) were growing far ahead of those in 1 and 2.

The plants in pot 2 fertilized with the same amount of nitrogen grew much more slowly than those in 3 and 4. The reason for the poor showing of the plants in pot 2 is not known.

In 30 days a slight brown mold appeared on the larger plants, which may have been due to the dark damp weather. Powdered sulfur was used to fight it.

During the fifth and sixth weeks the plants in the pots fertilized with the sludge, which had grown fully three times as large in height and in the amount of foliage as those in the pot fertilized with dried blood, began to yellow. About half of the foliage died, leaving two

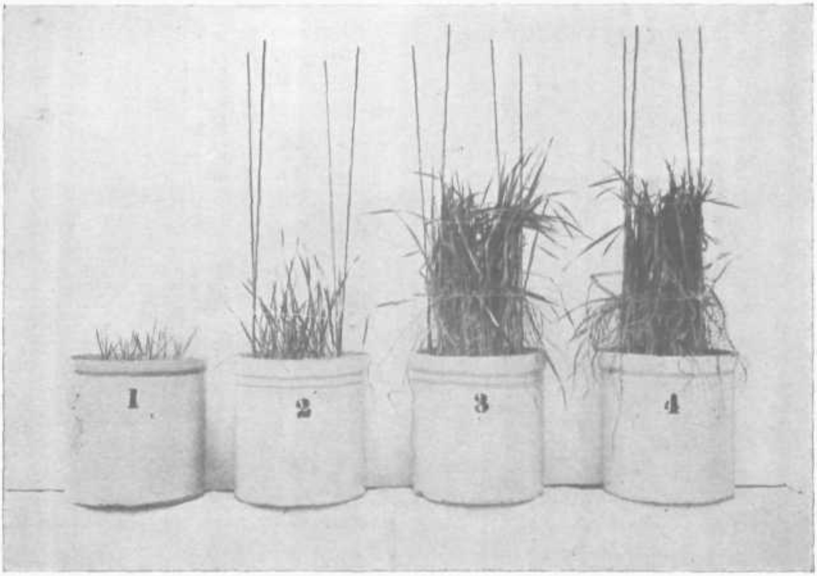

Figure 2.—Pot cultures of wheat sixty-three days after planting.

Each pot contains pure white sand to which the same amount of plant foods, except nitrogen has been added. No. 3 contains 20 *g*. dried activated sludge. No. 4 contains the same amount extracted with ligroin. No. 2 contains an equivalent of nitrogen from dried blood and No. 1 contains no nitrogen.

healthy stalks to each plant. The plants possibly grew so fast at first that all the foliage which had started could not develop. The remaining stalks immediately grew stronger and of a deeper blue-green color. After 9 weeks the plants were strong and healthy (see Figure 2).

In 14 weeks the plants in pots 3 and 4 began to head and in 15 weeks there were about 20 good heads in each. The plants in pot 1 were very weak, while those in 2 were just beginning to develop heads.

When it was first noticed that the plants fertilized with sludge were growing much better than those fertilized with dried blood, in order to confirm the results, a second series of pot cultures was started. In this series the sludge was compared with dried blood, nitrate of soda, ammonium sulfate and gluten meal. This series contained 14 pots: 2 check pots, 6 containing nitrogen equivalent equal to an application of 20 grams of sludge, and 6 with nitrogen equivalent to 30 grams of sludge. The plants in this series grew faster than those in the first because of better weather. They showed exactly the same characteristics that the plants in the other series showed. The plants fertilized with sludge were the best. The results confirmed those

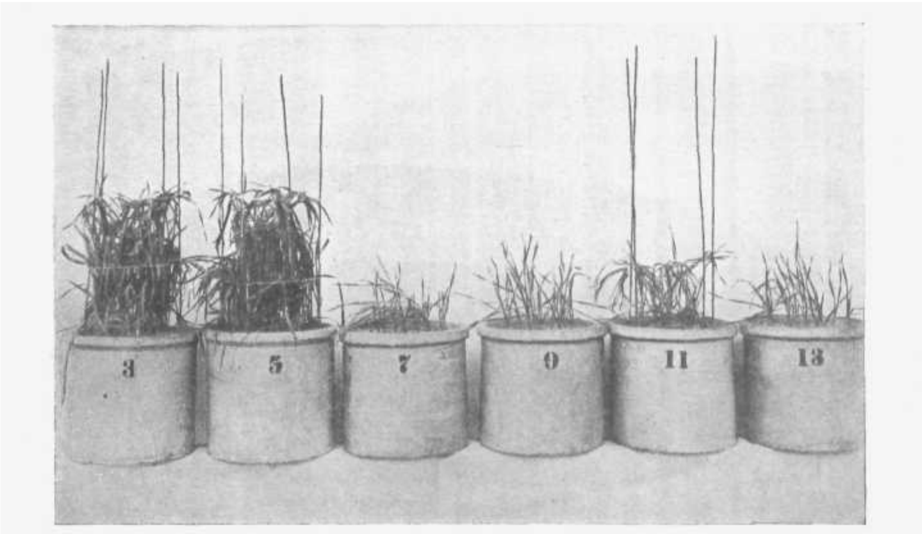

Figure 3.—Pot cultures of wheat (Series 2), thirty-five days after planting.

Each pot contains pure white sand to which the same amount of plant foods except nitrogen has been added. No. 8 contains 20 g. dried activated sludge. No. 5 contains 20 g. of dried activated sludge from which ether-soluble matter has been removed. No. 7 contains the nitrogen equivalent from sodium nitrate. No. 9 contains the nitrogen equivalent from ammonium sulfate. No. 11 contains the nitrogen equivalent from gluten meal. No. 18 contains the nitrogen equivalent from dried blood.

obtained in the first series. At the end of 5 weeks striking differences were noticeable (see Figure 3). The pots containg the equivalent of 30 grams of sludge gave no better results than those with an equivalent of 20 grams.

When the wheat matured it was carefully harvested and calculations made to determine the yield per acre.

The surprisingly rapid growth of the wheat fertilized by the sludge must be due for the most part to nitrogen present in a very available form. It may be due in part to the phosphorus (2.69 per cent) which is present in the sludge. At the time of making the pot

TABLE 1.—AMOUNTS OF WHEAT AND STRAW OBTAINED IN THE FIRST SERIES OF POT CULTURES.

	Yield.				Yield of straw.		
Pot No.	No. heads.	No. seeds.	Grams seeds.	Bu. per A. (calculated)	Av. stalk. Length. (in.).	Straw. Grams.	Tons per A. (calculated).
1	14	85	2.38	6.2	19.4	2.25	0.18
2	15	189	5.29	13.6	23.0	8.25	0.68
3	22	491	13.748	35.9	35.4	26.75	2.23
4	23	518	14.504	37.7	36.1	26.21	2.18

cultures phosphorus was not considered since it was present in such a small quantity. The growth may be due in part to the organic matter present in the sludge since the sand used contains no organic matter. The cause of the molding of the leaves has not yet been determined. It was quite noticeable that the mold appeared chiefly on the leaves of rapidly growing plants. In the first series it attacked only plants fertilized with sludge. In the second series it also attacked the plants fertilized with gluten meal. The rapidly growing leaves are naturally more tender than those which grow slowly and consequently are more easily attacked by mold spores. The mold evidently does not come from the sludge because it is certain that the extracted sludge would be sterile, and plants fertilized with it showed the same mold.

The sludge causes such a rapid growth of wheat that it should be valuable to truck gardeners for rushing spring crops. To test its value to the market gardener, three plots each 2 feet by 3 feet were laid out in a field. One plot was not fertilized, one was fertilized with an equivalent of 126 pounds of nitrogen or one ton of sludge per acre, and the third with an equivalent of extracted sludge. On April 24, 1915, two rows of radishes and lettuce were planted in each of the three plots. The plants in the plot where the extracted sludge was used came up first, a little ahead of those in the plot where the unextracted sludge was used. At the end of two weeks the lettuce and radishes of the treated plots appeared to be twice the size of those in the untreated plot. At the end of 4 weeks the plants were thinned. The roots of the radishes from the treated plots were already red and quite rounded near the tops while those from the untreated plots had not yet started to swell and had not become red. The lettuce plants from the treated plots were nearly twice as large as those from the untreated plots.

On June 1, 38 days after planting, the six best plants of lettuce and radishes were taken from each plot and are shown in Figure 4. The differences in size are very marked.

TABLE 2.—COMPARISON OF THE LETTUCE AND RADISHES FROM UNFERTILIZED AND FERTILIZED PLOTS.

Plot.	Treatment.	Wt. of lettuce.	Wt. of radishes.
1	None	4.5 g.	23.4 g.
2	Sludge	6.3 g.	63.0 g.
3	Extracted sludge	6.8 g.	68.0 g.

The increase in weight, caused by the sludge, is 40 per cent in the lettuce, and 150 per cent in the radishes. The radishes from the sludge plots, when cut open and eaten, were found to be very crisp and solid, and to have a good flavor.

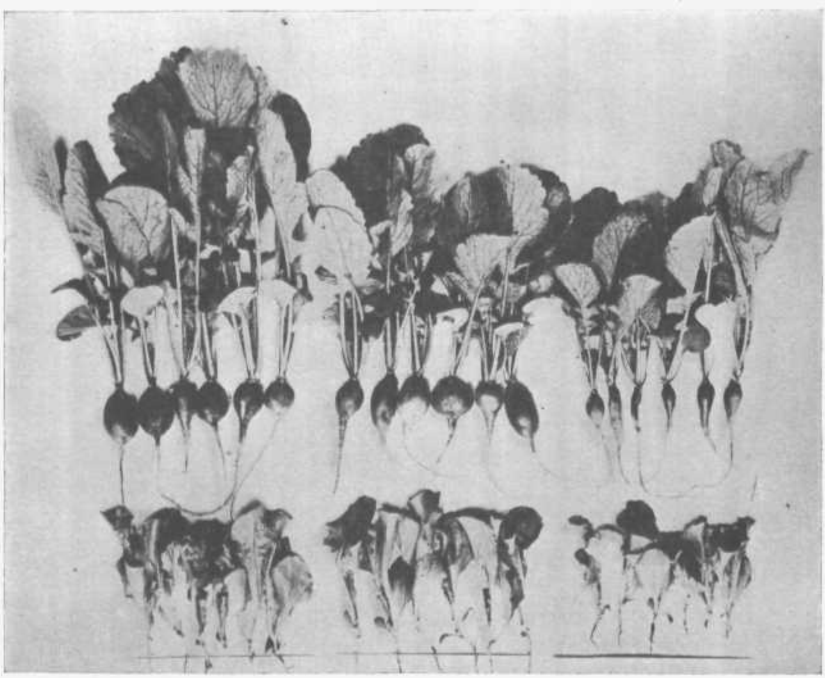

Figure 4.—Gardening experiments thirty-eight days after planting.

Radishes. From left to right, six radishes fertilized with extracted sludge, six radishes fertilized with sludge, six radishes unfertilized. Lettuce. Six heads fertilized with extracted sludge, six heads fertilized with sludge, six heads unfertilized.

These pot cultures and gardening experiments show that the nitrogen in activated sludge is in a very available form and that activated sludge is valuable as a fertilizer.

It is impossible to calculate the exact value of activated sludge since a market must first be established. However, calculations based on comparison with dried blood show that it should be worth about $20 a ton. In England, Oldham sludge containing 1.5 per cent nitrogen and Kingston on Thames sludge containing 2.67 per cent nitrogen are sold at $12.60 and $15.60 per ton, respectively. Thus is seems reasonable to believe that activated sludge with a content of nitrogen of 4 to 6 per cent would be worth $20 to $30 per ton.

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BACTERIOLOGICAL STUDY OF SEWAGE PURIFICATION BY AERATION*

By Robbing Russel and Edward Bartow.

In recent years the tendency has been to recognize the importance of the role played by biological agencies in the disposal of sewage and to utilize such agencies scientifically. Until Pasteur in 1863 proved that fermentation and putrefaction did not take place in the absence of living organisms, no advance toward the scientific explanation of sewage disposal could be made.

Sir Edward Frankland[8] in 1868 claimed that a nonputrescible effluent could be obtained by intermittent filtration of sewage through sand, but he attributed the results to mechanical removal of suspended matter and chemical oxidation of dissolved organic matter, and, accordingly, failed to recognize the true agencies.

Dupre[20] was one of the first investigators to comprehend the real agencies which accomplish the purification. In 1884 in a report to the Local Government Board he stated that "the consumption of dissolved oxygen in natural water is due to the presence of growing organisms", and in 1887 further stated that "the agents to which the ultimate destruction of sewage is due are living organisms and, therefore, our treatment should be such as to avoid killing these organisms or even hampering them in their action."

About this time Emich,[9] after studying the changes brought about in sewage by aeration and by treatment with antiseptics, concluded that the oxidation of organic matter was caused by minute organisms.

The first practical application of the utilization of biological agencies for the disposal of sewage was made in Prance in 1882 when the Mouras Automatic Scavenger was devised. It consisted of a closed vault in which anaerobic decomposition occurred, but since it did not give a stable effluent it was soon abandoned.

At almost exactly the same time E. S. Philbrick,[16] of Boston, obtained patents for a series of closed tanks similar to the Mouras Automatic Scavenger but which were followed by aerating filters.

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The process was a success experimentally but the cost and failure to comprehend the true agents of purification brought about the commercial failure of the enterprise.

The sewage-farm method of disposal was used almost exclusively in England from 1875 to 1882. The system was later abandoned to a large extent because of its inefficiency, cost, and the fact that it often created a nuisance.

The Royal Commission in 1882 introduced chemical precipitation of the suspended solids in sewage, with an attempted sterilization of the effluents. Dibdin[20] opposed this scheme, stating "as the very essence of sewage purification is the ultimate destruction or resolution into other combinations of the undesirable matters, it is evident that an antiseptic process is the very reverse of the desired object".

With Frankland's data as a foundation the Massachusetts State Board of Health[18] undertook experiments to remove the bacteria by straining or with chemicals. Studies of intermittent filters and purification by aerobic organisms were next undertaken. The conclusions drawn were that "to destroy completely and stabilize organic matter it is only necessary to provide optimum ecological conditions for aerobic bacterial life". The work of the Massachusetts State Board of Health was epoch-making but was not the complete solution of the problem. How to treat bacterially the sewage of large cities where land and sand are not plentiful, how to dispose of suspended matter, and how to treat sewage containing large quantities of trade wastes were questions still to be answered.

The Main Drainage Committee[20] of England in 1891, by substituting coke breeze for the coarse sand used by the Massachusetts State Board of Health, increased the amount of sewage which could be treated on a given area. In practice, however, it was found necessary not only to screen the sewage but also to treat it anaerobically in the so-called "bacteria tanks" before applying it to the filters. In order to decrease the cost and to prevent the variable and often unsatisfactory results obtained, further experiments were made. These followed the line of increasing the supply of air in the filter, accordingly creating more favorable conditions for aerobic action.

In 1894, Waring[20] at Newport, Rhode Island, treated sewage by forced aeration. The untreated sewage was run onto beds of broken stone and when the beds became clogged the sludge was drawn off and aerated. The removal of suspended matter and bacteria was considered to be caused by mechanical sedimentation.

In Cleveland,[20] in 1898, double filtration through slag and coke with aeration under light pressure was investigated. A reduction in bacteria of 99 per cent was obtained.

Following the use of intermittent filters, contact and sprinkling filters have been evolved. These are constructed of a much coarser medium and consequently the rate of flow may be increased and the liability of clogging is diminished. At the present time the most widely used method of sewage disposal is treatment in sedimentation tanks followed by application to contact or sprinkling filters.

According to Fowler[10] "The scientific solution of the sewage-disposal problems will not be attained until the following results can be guaranteed for any given case: (1) An effluent which will not deteriorate the stream into which it flows, (2) No nuisance in the course of sludge disposal, (3) No nuisance from smell or from flies in connection with the filter beds, (4) An expenditure strictly proportionate to the sanitary and esthetic results achieved."

To cut down the cost of treatment and to dispose of the sludge without nuisance are the two main factors urging further work. The cost of construction and maintenance of settling basins, screens, tanks, and filters is heavy, and a large volume of valueless and more or less putrescible sludge must be disposed of.

Clark and Gage[6] in 1913 aerated sewage in a bottle in the presence of green algal growths for 24 hours and obtained considerable nitrification. They later found that the period of aeration could be shortened by aerating in a tank containing slabs of slate placed about one inch apart and covered with a brown growth of solid matter from the sewage, which served to coagulate the colloids of the sewage. They were able to produce a well clarified, non-nitrified effluent which could be filtered at several times the normal rate.

Fowler and Mumford[12] in their work with M7, a peculiar organism which precipitates iron as $Fe(OH)_3$ from solutions of iron salts, obtained after 6 hours' aeration a clear and nonputrescible effluent.

Dr. Fowler having visited the Massachusetts Experiment Station in November, 1912, suggested a series of similar experiments to Ardern and Lockett[1] out of which the activated-sludge process of sewage treatment has developed. Their experiments together with those at the University of Illinois[2] are described elsewhere in this bulletin.

The experimental work described in this paper was undertaken primarily to find out (1) whether a consistent reduction in the number of bacteria is obtained in the activated-sludge process, and (2) what bacteria or other organisms cause the purification accomplished.

REDUOTION IN THE NUMBER OF BACTERIA

The reduction in the number of bacteria was determined by comparing the number in the raw sewage with the number in the effluent from the tank used in the second series of experiments described elsewhere in this bulletin.

The sample from the tank was drawn directly into a wide-mouthed 2-liter bottle. The mixture of sewage and sludge was allowed to settle for one hour, after which 10 cubic centimeters of the supernatant liquid were withdrawn for analysis, care being taken to insert the tip of the pipette to the same depth each time. Thirty-five samples were taken at intervals of a few days for nearly 4 months. At the end of 4 hours' aeration the average reduction in the number of bacteria growing on agar at 37.5°C. was 95 per cent or from 750,000 per cubic centimeter in the raw sewage to 40,000 per cubic centimeter in the effluent. The average reduction in the number of bacteria growing on gelatin at 20°C. was 95 percent or from 4,000,000 to 200,000 per cubic centimeter. At Milwaukee[15] there was found a bacterial reduction of 97 per cent of the bacteria growing on gelatin at 20°C. after 4 hours' aeration with activated sludge.

The reduction may be caused by mechanical removal of bacteria by the rapidly settling sludge, which is similar in appearance to a flocculent precipitate of ferrous-ferric hydroxide. Some of the bacteria may also be destroyed by organisms of higher order present in the sludge, inasmuch as bacteria form no inconsiderable part of their food.

Reduction of B. coli. During a period of about one month 7 series of samples were tested in standard lactose broth containing one per cent azolitmin solution and a similar series on standard litmus-lactose agar. There was a reduction in the number of bacteria growing in these media of from 90 to 99 per cent. It would seem from a comparison of the number of bacteria growing on agar at 37.5°C. with the acid gas formers that 80 to 95 per cent of them are acid gas formers. From these experiments which showed a consistent reduction in the number of bacteria we may expect a similar reduction in pathogenic varieties. The effluent is not bacteria-free but is so much improved in quality that it should be easily taken care of by dilution or sterilization.

ORGANISMS PRESENT IN ACTIVATED SLUDGE

An extensive examination of the organisms in the sludge was carried out. Special attention was paid to those forms constantly appearing in the sludge.

The nitrification is entirely caused by living organisms, as has already been stated by Ardern and Lockett.[1] Their results were confirmed by mixing 50 cubic centimeters of activated sludge with an equal volume of N/250 ferrous sulfate. After 24 hours no living organisms could be found by examination with the microscope. Eaw sewage, which had been sterilized in flowing steam for periods of 30 minutes on each of 3 successive days, was added to the mixture in the proportion of 4 to 1 and aerated for 24 hours. There was no nitrification after 24 hours although ammonia nitrogen decreased slightly. Believing that this experiment had shown that the organic life in the tank was responsible for the changes taking place a more detailed study of this organic life was undertaken.

The most noticeable of the nonbacterial flora found in the sludge was a relatively large worm 1-5 millimeters in length. This worm is an annelid of the class oligochaetae, known as aeolosoma hemprichii. Its food consists of bacteria, diatoms, unicellular-algae, and the mesophyl tissue of decaying leaves.

Cultures of this worm were grown in a one-tenth per cent wheat extract in a bottle so arranged that air could be blown through the solution. A number of the worms were separated as much as possible from other substances by withdrawing about 200 of them with a pipette from the culture in wheat broth. They were filtered, washed, rapidly with sterile distilled water, and inoculated immediately into ammonia broth to which sufficient sterile sludge had been added to bring the specific gravity of the mixture up to that of the tank sludge. The mixture was then aerated in the apparatus described by Beesley.[3] This consists of a wide-mouth 2-liter flask fitted with a 3-hole rubber stopper. Through one hole passes a glass tube reaching nearly to the bottom and having a long piece of sterile rubber tubing perforated in many places attached to its lower extremity. Another tube extends just through the stopper. A 3-way stopcock passes through the third hole with one limb extending to the bottom of the flask. Another limb is bent at right angles to the first tube, and on the third is a bulb of 10-cubic centimeters capacity. The outside extremities of the tubes were plugged with cotton and the entire apparatus was sterilized. The worm culture prepared as mentioned above was aerated in this apparatus for one week. The air was purified by passing through a series of wash bottles containing cotton wool, sterile water, and chemically pure sulfuric acid. Daily examinations, both microscopic and chemical, were made. (See Table 1.)

TABLE 1.—AERATION OF WORM CULTURE IN AMMONIA BROTH.

Day	1	2	3	4	5	6	7
Nitrite nitrogen *(Parts per million)*	0	0	.1	.1	.1	.2	.4
Worms	+	+	+	+	+	—	—

The worms had disappeared on the sixth day. A small amount of nitrite developed in the broth from which nitrifying bacteria were isolated. In all probability the culture of worms was not pure and the nitrification was due to the presence of bacteria. These experiments with the worms were not continued owing to the difficulty of obtaining pure cultures. About the same time James Crabtree under the direction of Dr. Fowler[12] completed his work on the function of the nonbacterial population of contact beds and gave the following conclusions.

"1. In normal beds, protozoa, etc., satisfy their hunger on the fresh bacteria brought into the bed by the sewage, thus allowing the normal population to carry on its work of purification undisturbed.

2. The change in the bacterial population can never become marked, however, because the fresh sewage, rich in all manner of forms, keeps the population nearly normal.

3. It is extremely improbable that the animal population influences the soluble constituents in the sewage directly."

Vorticella and rotifera constitute the major portion of the nonbacterial population other than the worms. No algae were observed and other forms appeared only sporadically. No experiments were attempted with these forms since later experiments with bacteria indicated that the role of the nonbacterial flora in nitrification is negligible. The absence of algae is contrary to the suggestion of Clark and Gage,[6] that the stabilization obtained in their experimental plant was caused by algal growths.

BACTERIA IN ACTIVATED SLUDGE

The function of bacteria in sewage-purification processes has been under consideration for over 25 years. Only recently have clear, connected ideas been advanced. Pasteur first suggested that oxidation from ammonia to nitric acid was caused by microorganisms and two French chemists, Schlosing and Müntz actually proved this to be the case. In 1889 Warrington made an excellent and exhaustive study of conditions under which nitrification occurs, but he was never successful in isolating the specific organism causing this action. Almost simultaneously Winogradski,[21] in Russia, and Percy Frankland,[13] in England, succeeded in isolating the specific organism which forms nitrite from ammonia. They employed gelatinous silica as the medium for cultivation. The organism which forms nitrate from nitrite was more difficult to isolate, but Winogradski[21] succeeded in identifying it in 1891. The direct application of this discovery to the explanation of the action of contact and other bacterial beds has been worked out by Boullanger and Massol[4] of the Pasteur Institute at Lille, by Schulze-Schuizenstein in Germany, and by Dr. Harriette Chick[11] of the Lister Institute, England. These investigators agree that the nitrifying organisms found in ordinary sewage filters are the same as those occurring in the soil. Dr. Chick determined that nitrification takes place in two distinct stages, first nitrite then nitrate being formed. Dr. Fowler and Percy Gaunt[11] showed that the character of the surface of the filtering medrum had a noticeable effect on the rate of nitrification. Better results were obtained with porous irregular material such as broken clinker than with a hard material such as quartz. It seems surprising that such good results have been obtained by the activated-sludge process without any supporting medium. In order to study these conditions the organisms taking part in the reaction were isolated.

Four hundred cubic centimeters of sterile ammonia broth and 10 cubic centimeters of activated sludge were placed in a flask and aerated until active nitrification was obtained. Four hundred cubic centimeters of nitrite broth and 10 cubic centimeters of activated sludge were treated in the same way in another flask. When strong reactions for nitrate were obtained 10 cubic centimeters from each flask were inoculated into other flasks containing the same broths and the process repeated in accordance with the well-known accumulation method of Beijerinck. Thus almost pure cultures of the nitrifiers were obtained. These were planted on silica-jelly[5] plates which were incubated at 37°C. Growth occurred in about 12 days. From these colonies fresh silica jelly and synthetic agar plates were poured for both the nitrite- and nitrate-forming bacteria. The culture which formed nitrite was also inoculated on gypsum blocks partly covered by ammonia broth. Samples of each or these were incubated at 37°C. and 20°C. In nine days slight growth of the nitrite-forming organism on the synthetic agar at 37°C. was found. Two days later the nitrate-forming organism appeared. A much slower and more scanty growth of both was secured on silica jelly. Of all the gypsum blocks incubated only one gave growth. The failure was due to too great concentration of the magnesium in the media. Morphological study showed that the nitrite-forming bacterium was a fairly large, short, rod-shaped organism, without doubt nitrosomonas, the typical nitrite-forming organism of soil. The nitrate-forming organism was a very small bacterium only slightly longer than broad, conforming in every respect to the common nitrobacter of the soil. According to Harding's[14] application of Koch's postulates in order to identify an organism as the causative form in a process, the form should first be isolated, then reinoculated into fresh material, where it should produce the same effect as was originally observed. The organism isolated from this new culture should be identical with the original organism. This procedure was followed as closely as possible in studying the nitrite- and nitrate-forming bacteria isolated.

Fresh sewage was sterilized in flowing steam for 30-minute periods on two successive days. To one aerating flask containing this sterilized sewage a strong inoculum of nitrosomonas was added from the synthetic agar culture. Nitrobacter was added to a second; a mixture of both forms was added to a third; 2 cubic centimeters of activated sludge were added to a fourth; and, as a check, no bacteria were added to a fifth. Washed air at room temperature was passed continuously through all the flasks in series. At the end of 24 hours the flask containing nitrosomonas showed between .1 and .2 part per million more of nitrite than was shown in the fifth flask. The second flask containing nitrobacter showed no nitrate and no increase in nitrite. The third flask containing the mixture of nitrosomonas and nitrobacter contained traces of nitrite and nitrate. The fourth flask inoculated with activated sludge contained 12 parts per million of nitrate and no nitrite or ammonia. From each of the above flasks the representative organisms were again obtained. It seemed surprising that the sewage was not nitrified by the pure cultures of the nitrifying organisms. Sewage, however, contains only partially broken down proteins, which the nitrifying bacteria can not attack directly. It is known also that the nitrifiers will not function if protein exists in too great concentration which probably explains why the pure cultures of nitrifying organisms did not attack the sterile sewage. The small amount of nitrite formed comes probably from the urea and ammonia present, both of which can be attacked and nitrified by nitrosomonas. It is evident that bacteria in the activated sludge other than the nitrifiers have important functions in connection with the purification. A number of bacteria were isolated after incubation on agar at 30°C. for 48 hours. Those appearing most constantly were chosen and studied in accordance with the directions of the Society of American Bacteriologists. The group numbers of the thirteen varieties are shown in the following table.

TABLE 2.—GROUP NUMBERS OF THIRTEEN VARIETIES OF NONNITRIFIERS ISOLATED FROM ACTIVATED SLUDGE.

Variety.	Group number.	Variety.	Group number.	Variety.	Group number.
1	111.2223022	6	111.2222012	10	111.2222818
2	111.2222082	7	222.4444614	11	212.2224432
3	111.2222033	8	111.2223012	12	221.2223582
4	111.2222084	9	111.222–022	13	212.222–432
5	111.2222022				

Four were nonspore formers, 2 were facultative anaerobes, almost all attacked sugars forming no gas and very little aeid. Nearly all hydrolized starch and attacked casein in milk tubes. With four exceptions these bacteria belong to the B. subtilis group of aerobic spore-forming bacteria which attack protein without putrefaction. These bacteria evidently predominate in the process as long as aerobic conditions exist. Having obtained pure cultures of a representative flora the nitrification of sterile sewage by pure cultures of nitrifiers in the presence of organic matter was repeated. There was added, however, a mixture of the nonnitrifying forms which had previously been isolated. After aeration for 6 hours the ammonia was completely oxidized and 18 parts per million of nitrate and a trace of nitrite were formed. A flask containing no bacteria showed no nitrification. A flask containing the nitrite-forming organisms and the bacterial mixture showed almost complete oxidation of the ammonia to nitrite with no nitrate. Another flask containing only the mixture of nonnitrifying organisms showed traces of nitrite and no nitrate, but gave the same clarification as was obtained in the other flasks.

CONCLUSIONS

These investigations have shown the following bacteriological features of the activated-sludge process of sewage purification.

(1) There is a large and consistent reduction of the total number of bacteria in the sewage.

(2) The actual stabilization process is due to a typical aerobic bacterial flora which gains almost complete ascendency. The other inhabitants are largely incidental.

(3) The actual nitrification is accomplished by two typical known nitrifiers, nitrosomonas and nitrobacter.

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HYDROGEN SULFIDE IN THE WELL WATERS OF CHICAGO AND VICINTY*

By H. J. Weiland and Edward Bartow.

During the summer of 1914, under the direction of the Illinois State Geological Survey and the Illinois State Water Survey, a study was made of the deep wells in Chicago and vicinity. The character and quantity of water which could be obtained from the strata pierced by these deep wells were determined. Data were collected concerning (1) the geology of the region; (2) the casings of the wells; (3) the rates and duration of pumpage; and (4) the static level of the water in the wells. . Mr. C. B. Anderson has prepared a detailed report of these investigations, which will be published in a bulletin of the State Geological Survey. The amounts of hydrogen sulfide in the waters have been determined, and the results of the analyses of waters from adjacent parts of the State have been compared in an attempt to show the relation of the geological formations to the amounts of hydrogen sulfide found.

The geological formations pierced in the Chicago district by deep wells are: glacial drift, Niagara limestone, Maquoketa shale, Galena-Trenton limestone, St. Peter sandstone, Prairie du Chien limestone, and the Cambrian group of ("Postdam") sandstones, limestones, and shales. Since the content of hydrogen sulfide depends upon the composition of the water-bearing strata, a brief description of each formation is given.

Glacial drift. The surface deposits in the vicinity of Chicago consist of glacial drift, and alluvial and lacustrine deposits. The drift consists of blue clay and hardpan with numerous boulders and covers most of that area to a depth of 10 to 80 feet. The metallic minerals which are met with in this vicinity occur chiefly in the drift.

Niagara limestone. The Niagara group consists of several limestones, varying in compactness and color. In its upper portion it furnishes an oblique irregular bedding, which is porous. The lower two-thirds is composed of horizontal beds of compact bluish-gray

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rock in which are numerous fossils. In the lower 30 to 40 feet there are nodular layers of white chert. Iron pyrite occurs in the Niagara limestone. This stratum bears a small amount of water. The average well in Chicago, a 5-inch hole 350 feet deep, will furnish continually 25 gallons per minute. The capacity may vary considerably, because of the large number of crevices in the Niagara limestone.

Maquoketa shale. The shale varies in thickness from 40 to 240 feet, and the average is about 200 feet. It is extremely compact and in many places contains pyrite, gypsum, and other accidental minerals. The upper 120-150 feet is light green or grayish-green in color and is not at all, or but slightly, calcareous above, but which becomes so farther down. A little below the middle of the shale the color turns to gray. Because of its compactness, it bears no water and serves as a partition to prevent water from passing downward or upward.

Galena-Trenton limestone. The Galena-Trenton limestone is shown by well drillings to be a light-gray, finely grained dolomite or limestone, having some fragments of chert and a small amount of rounded quartz grains. In some portions of the State the upper part of this formation (Galena) bears water, but the lower part (Trenton) has not been known to bear water. According to Udden[1] "The water-bearing rock which is limited to the upper 300 feet is a magnesian limestone of porous texture. Its flow is frequently as strong as the St. Peter water and its head about the same. This water is often found charged with hydrogen sulfide, however, and this circumstance renders it disagreeable to the taste and limits its use as a potable water". The above condition was not found in the Chicago region where this stratum furnishes no. water. There was no positive evidence of hydrogen sulfide from this stratum.

St. Peter sandstone. The St. Peter sandstone is probably the uppermost water-bearing stratum of any importance in the Chicago district. It varies in thickness. 'In some well borings there is no record of piercing it at all, in others it has a thickness of over 250 feet, while the average is about 100 feet. The sand composing the St. Peter sandstone was probably deposited upon a very uneven surface. The stratum is remarkably pure white or light cream-colored silicious sand. The sand grains are well-rounded and show considerable sorting and abrasion before they were deposited. The St. Peter sandstone outcrops in Grant, Green, Jefferson, and Eock counties of southern Wisconsin.

[1]Udden, J. A., Geological classification of the waters of Illinois: Illinois Univ. Bull., State Water Survey Series *i*, 15 (1908).

Prairie du Chien limestone. The Prairie du Chien limestone is usually separated from the St. Peter sandstone by strata of vari-colored shales having a maximum thickness of 70 feet. These shales are very soft and in the Chicago district wells must be cased through them to prevent caving. The Prairie du Chien formation is a light-colored magnesian limestone with chert and occasional intercalation of sandy and shaly material.[1] It does not exceed 200 feet in thickness. It contains water in some regions (Ottawa and vicinity) but in Chicago at the present time it is not depended upon as a source of water.

Cambrian group. This group is often spoken of as the "Potsdam" standstones, because of the character of the first heavy sandstone of the series. Around Chicago it is reached at a depth of from 1,350 to 1,400 feet. It is usually a light brown sandstone for the first 100 feet, cream colored for the next 100 feet, then it is a sandy and shaly dolomitic limestone for 200 feet, and finally ends in layers of brown, red, buff, or white sandstone, alternating with beds of dolomite and shale. The "Potsdam" is the oldest stratum penetrated by deep wells in Chicago. It furnishes the chief source of the artesian water pumped in the city. The absorbing area[2] for the "Potsdam" is in the central part of Wisconsin, embracing the counties of Eau Claire, Dunn, Barrow, Monroe, Vernon, Richland, Sank, Columbia, Adams, Waushara, Jackson, and Trempealeau.

"Coal Measures" or Pennsylvania series. The "Coal Measures" do not appear in the Chicago district; but to the west and south overlie the Niagara and are the first rock pierced by wells in that part of the State.[3] The "Coal Measures" occur principally in the southern two-thirds of the State and consist largely of shales with alternating sandstones and limestones and contain seams of coal. Most waters from these strata contain various mineral salts in considerable quantities and some contain hydrogen sulfide.

DETERMINATION OF HYDROGEN SULFIDE

Method of analysis.[4] Place 500 cubic centimeters of the water in a liter bottle graduated at 10-cubic centimeter intervals in the vicinity of the 500-cubic centimeter mark. Add 10 cubic centimeters of

[1]Udden, J. A., Geological classification of the waters of Illinois: Illinois Univ. Bull. State Water Survey Series 4, 11-12 (1908).

[2]From Map Plate, CXI, U. S. Geol. Survey, 1895-96.

[3]Udden, J. A., Geological classification of the waters of Illinois: Illinois Univ. Bull. State Water Survey Series 4, 17 (1908).

[4]Standard methods for the examination of water and sewage, Am. Pub. Health Assoc, New York, 2nd ed., 69 (1912).

N/100 iodine solution and one gram of potassium iodide. Allow the reaction to reach equilibrium which requires about 2 or 3 minutes. Determine the excess of iodine by titrating with N/100 sodium thiosulfate until a straw color is obtained, adding about one cubic centimeter of starch solution and continuing the titration until the blue color developed has disappeared. Multiply the difference in the number of cubic centimeters of iodine and sodium thiosulfate used by the factor 0.34 to obtain the amount of hydrogen sulfide in parts per million.

The content of "hydrogen sulfide. The results of the analyses (see Tables 1 and 2) were compared with reference to (1) the geological strata from which the water is drawn, (2) the ratio of the

TABLE 1.—HYDROGEN SULFIDE IN THE WATER FROM NIAGARA LIMESTONE IN THE CHICAGO AREA.

Owner of well.	Depth.	Length and condition of casing.	Yield.	Pumpage.	Method of pumping.	Place of collection.	Content of hydrogen sulfide.
	Feet.	*Feet.*	*Gals. per min.*	*Gals. per min.*			*[Parts per million.]*
Wisconsin Steel Co.	405	100 good	20	20	Deep-well pump	Well	1.75
L. Wolff	400	70 old	15	15	do.	Well	0.84
Wolff, Sayre & Heller	400	70	10–15	10–15	do.	Well	.895
Rialto Elevator Co.	401	45	17.5	15	Air lift	Well	.236
Irondale Elevator Co.	502	70 good	6–7	6–7	Deep-well pump	Well	.738
J. Rosenbaum Grain Co.	350	70 good	18	18	do.	Well	.440
S. Chicago Elevator Co.	347	95 good	34	25	do.	Well	.539
S. Chicago Elevator Co.	367	95 good	31	31	do.	Well	.71
Star & Crescent Milling Co.	340	185 good	15	15	do.	Well	.476
Winamac Apartments	400	70 good	20	20	do.	Well	.885
Windemere Hotel	350	70 good	25	25	do.	Well	3.14
Lehigh Valley Coal Sales Co.	365	69 good	20	20	do.	Well	.680
Hetzel	160	70	15–20	15–20	do.	....	.59
Miller & Hart	300	78	12	12	Air lift	Well	2.10
John Mohr & Sons	350	75 good	85	85	Deep-well pump	Well	.64
Morse Chocolate Co.	350	70 new	20–25	20–25	do.	Well	.652
Morse Chocolate Co.	600	70 new	30	30	do.	Well	1.38
Murray & Nickels	286	70 new	30	30	do.	Well	.578
National Biscuit Co.	300	70	10–12	10–12	do.	Well	1.537
Norris & Co. Elevators	348	88 good	30	30	do.	Well	.556
Hotel del Prado	250	...	18	18	do.	Well	2.84
Drexel Cafe	450	...	20	20	do.	Well	1.55
Drexel Arms Hotel	450	70 good	8	8	do.	Well	2.02
Casper & Durand	235	70 poor	15	15	do.	Well	4.72
B. A. Eckhardt Milling Co.	156	70	30	30	do.	Well	.364
Farley Candy Co.	336	70	6	6	do.	Well	1.44
John V. Farwell	250	70	6	6	do.	Well	.94
Grand Crossing Tank Co.	300	...	25	25	do.	Well	.87
Hoerbers Brewing Co.	350	...	36	36	do.	Well	2.24
Bissel Laundry	...	70 good	25	25	do.	Well	5.89
Broman Building	200	70 poor	15	15	do.	Well	.577
W. H. Bunge	300	...	10–12	10–12	do.	Hose	.540
Calumet Elevator Co.	363	75 good	20	20	do.	Well	.493
Crane & Co.	250	70	16–20	16–20	do.	Well	.73
Crane & Co.	415	70	18	18	do.	Well	2.03
Crane & Co.	290	70	16–20	16–20	do.	Well	1.75
Crane & Co.	235	70	100	100	do.	Well	.199
Diener & Co.	250	70	10	10	do.	Well	3.17

TABLE 2.—HYDROGEN SULFIDE IN THE WATER FROM WELLS TERMINATING IN ST. PETER OR THE "POTSDAM" SANDSTONES.

Owner of well.	Depth.	Length and condition of casing.	Yield.	Pumpage.	Method of pumping.	Point of collection.	Content of hydrogen sulfide.
	Feet.	*Feet.*	*Gals. per min.*	*Gals. per min.*			*[Parts per million.]*
Bartholomae & Roesing	1654	85 poor	125	50	Air lift	Well	.175
Booth Coal Storage Co.	926	79 poor	35	35	Air lift	Well	.550
Arnold Packing Co.	1660	....	120	80	Deep-well pump	Well	.315
Cook Brewing Co.	1800	280 good	245	35	do.	Well	.314
Liquid Carbonic Co.	1650	517 good	175	175	do.	Well	.166
Fulton Market	1350	90 good	...	40	do.	Well	.070
Oscar Mayer	1628	70 good	100	100	do.	Well	.660
Omaha Packing Co.	1300	500	225	200	Air lift	Well	.214
River Forest	1000	54	159	109	do.	Tap	.702
River Forest	1000	54	216	150	do.	Tap	1.36
Schoenhofer Brewery Co.	1600	75	...	81	do	Tap	.148
Schoenhofer Brewery Co.	2187	75	300	160	do.	Tap	.155
Seipps Brewery Co.	1200	70	100	100	do.	Well	.170
Stock Yards Well 1	2180	70	...	80	do.	Tap	.408
Stock Yards Well 2	2180	70	...	80	do.	Tap	.589
Sulzberger & Sons (East well)	1691	a	600	600	do.	Tap	.262
Sulzberger & Sons (West well)	1620	70	634	634	do.	Tap	.258
Summit (City supply)	1547	70	325	175	Deep-well pump	Well	.192
Hammond & Co. (Well 2)	1592	70	275	100	Air lift	Tap	.284
Hammond & Co. (Well 3)	1592	70	275	100	do.	Tap	.284
Manhattan Brewery Co.	1643	b	250	80	do.	Well	.407
Maywood (City supply)	1605	c	725	725	Deep-well pump	Tap	.217
Mechanical Rubber Co.	1260	70	75	75	Air lift	Tap	.244
Miller & Hart	1641	174 good	225	225	do.	Tap	.248
Morris & Co. (Section J)	1331	70	275	275	do.	Tap	.318
Morris & Co. (Oleo house)	2800	70	250	250	do.	Tap	.262
Morris & Co. (Hog house)	2300	70	300	300	do.	Tap	.361
Morris & Co. (Glue house)	1622	577	400	300	do.	Tap	.416
Mullen's Brewery Co.	1632	39	...	69	do.	Tap	.456
Armour & Co.	1585	70 good	1250	1250	do.	Well	.423
Argo (Well 1)	1685	70 good	300	300	Deep-well pump	Well	.28
Argo (Well 2)	1507	d	200	200	Air lift	Weir box	.157
Argo (Well 3)	1590	62 good	520	520	do.	Well	.175
Argo (Well 6)	1654	e	300	300	Deep-well pump	Well	.098
Argo (Well 7)	1870	86	200	200	Air lift	Weir box	.21
Chicago Packing Co.	1615	86 good	700	400	do.	Well	.509
Consumers Ice Co.	1967	70	303	303	do.	Tap	.136
Darling & Co.	....	70	200	200	do.	Tap	.255
Darling & Co.	1683	70	200	100	do.	Tap	.368
Hammond & Co. (Well 1)	1600	70	200	100	do.	Tap	.357
Western Electric Co.	1600	....	500	500	Deep-well pump	Tap	.083
Western Packing Co.	1650	f	350	225	do.	Well	.660
Wisconsin Steel Co.	1706	70 good	150	150	do.	Well	.388
Acme Malting Co.	1350	....	125	125	do.	Well	.96
American Malting Co.	1350	70 good	107	107	Air lift	Well	.171
Independent Packing Co.	1605	70 good	150	75–90	do.	Well	.808
Lomax Bottling Co.	1625	113 good	175	75	Deep-well pump	Well	1.86
John Jelky	1640	70 good	225	75–100	Air lift	Well	4.35
Adler & Obendorfer	1600	70	125	125	do.	Well	.379
Armour & Co.	1600	g	1900	1250	do.	Well	.883

[a] 0–64, 280–534, 691–1014. [b] 0–211, 211–600. [c] 0–58, 375–575.
[d] 0–79, 256–481. [e] 0–67, 330–489. [f] 0–70, 350–550. [g] 0–70, 285–585.

pumpage to the maximum yield of the well, and (3) the method of pumping the well whether by deep-well pump or by air-lift equipment.

EFFECT OF GEOLOGICAL STRUCTURE ON CONTENT OF HYDROGEN SULFIDE

The majority of the waters examined for hydrogen sulfide were obtained from wells in or about Chicago. A few were taken from wells in other parts of northern Illinois. There is an average of about 76 feet of glacial drift above the Niagara limestone which is the source of all nonartesian wells in rock in Chicago. The wells in this rock range in yield from 6 gallons to about 30 gallons per minute. Most wells in Chicago yield on an average about 25 gallons of water per minute. Hydrogen sulfide is found in all Niagara-limestone water in Chicago although the amount varies in different localities. In South Chicago several wells grouped closely together yield only a small amount of hydrogen sulfide. The maximum content of 5.9 parts per million of hydrogen sulfide was found in a well at West Thirty-ninth Street, near Cottage Grove Avenue. Large amounts were also found in wells along Lake Michigan from Fifty-first to Fifty-ninth Streets.

Data seem to indicate that hydrogen sulfide in water of Chicago comes entirely from the Niagara limestone. Of two wells of the Wisconsin Steel Co., one 405 feet deep and terminating in the Niagara limestone, contains 1.76 parts per million of hydrogen sulfide, and the other, situated about 12 feet distant, 1,706 feet deep, and terminating in the "Potsdam" series of sandstones, contains only 0.394 part per million of hydrogen sulfide. The deep well received not only the lower water from the "Potsdam" series and the Prairie du Chien limestones, but also the water from overlying strata. The shallow well yielded 20 gallons per minute and the deep well 150 gallons per minute. At least 20 gallons per minute or about 14 per cent of Niagara water is contributed to the deep well. This 14 per cent contains 1.76 parts per million of hydrogen sulfide. When diluted 14 to 100, the deep-well water should contain .25 part per million of hydrogen sulfide, a value which approximates the determined content.

Most of the deep-well waters have very little hydrogen sulfide, the amount ranging from .098 to about .5 part per million. Practically no hydrogen sulfide is present in water from deep wells, if that from the Niagara is shut out by casing. A 1,650-foot well at

Thirty-first and Kenzie Streets, which is cased below the Niagara and excludes its water, gave an average low value of 0.168 part per million of hydrogen sulfide.

Waters from other places in the northern half of the State have amounts of hydrogen sulfide varying from what is found in wells of the same depth in Chicago. The water in a 1,360-foot well at Odell contained 7.1 parts per. million of hydrogen sulfide. Water from a well of this depth in Chicago would have contained only the hydrogen sulfide from the Niagara limestone or approximately .3-.4 part per million. This is caused by the different geological strata. The well at Odell in the first 270 feet penetrates the "Coal Measures", which are rich in iron pyrites and organic matter, and from which most of the hydrogen sulfide must come since the formations below that depth are the same as those in Chicago. The water from the "Coal Measures" is supposedly shut out by a 1,259-foot casing and it is popularly believed that the hydrogen sulfide comes from the St. Peter sandstone at the lowest level. This supposition is doubtful, however, for St. Peter sandstone in Chicago contains no hydrogen sulfide. Also an analysis of water from a 292-foot well at Odell shows practically the same characteristic as the 1,360-foot well. Water from upper strata is probably entering the well and furnishes the hydrogen sulfide. Other wells in the vicinity of Odell drawing water from the "Coal Measures" contain considerable hydrogen sulfide.

At Streator in La Salle County, two wells 640 feet and 660 feet have the very high hydrogen-sulfide content of 14.5 and 15.0 parts per million, respectively. These wells are obtaining the hydrogen sulfide from the "Coal Measures" for Niagara limestone is not penetrated.

At Joliet in Will County, a flowing well 300 feet deep and terminating in the shale, contains 16 parts per million of hydrogen sulfide. The geological succession at Joliet is similar to that in Chicago. Most of the water from this well comes from the Niagara limestone which is the probable source of the hydrogen sulfide since pyrite is apparently very abundant. This is a flowing well and there is no chance for an accumulation of hydrogen sulfide as in some wells in Chicago where an abnormal amount of hydrogen sulfide is given off just after pumping is started.

At Custer Park in "Will County, water from a 166-foot well contains 49 parts per million of hydrogen sulfide, which is the highest amount found in any water examined. The water is very alkaline, containing 661.6 parts per million of sodium carbonate, which is sufficient to hold the hydrogen sulfide in combination for a long time. A silver dime placed in the water for one minute was completely covered with the black silver sulfide. The hydrogen sulfide from this well is probably from the "Coal Measures" since the log of a near-by well indicates that it terminates in a bed of coal.

At Pairbury in Livingston County, the water from a 2,000-foot well contains 12.5 parts per million of hydrogen sulfide. A 1,285-foot well near-by penetrates 21 feet of coal between the depths of 82 and 270 feet. Below this, the same strata appear as in the Chicago district but the mineral analysis indicates that a high percentage of the water is drawn from the upper strata.

At Buckley in Iroquois County, the water from a 172-foot flowing well contains 4.7 parts per million of hydrogen sulfide. The outcrop as shown on the geological map of Illinois is Cincinnatian shales overlying the Niagara limestone.

At Everett in Lake County, a 212-foot well with a 90-foot casing yields a water containing 13.3 parts per million of hydrogen sulfide. This water comes from the Niagara limestone. Professor T. E. Savage found grains of pyrites in the drillings from a near-by well which might account for the abnormal amount of hydrogen sulfide.

From the waters examined it is evident that in the vicinity around Chicago, the Niagara limestone is the principal source of hydrogen sulfide; but to the south and west the "Coal Measures" furnish even greater amounts.

EFFECTS OF PUMPAGE ON THE CONTENT OF HYDROGEN SULFIDE

The amount of hydrogen sulfide in the water varies directly with the amount of water pumped, unless all the water is drawn from one stratum. Waters entering the well from all water-bearing strata not shut out by casings vary according to the different chemical constituents of the rocks through which they flow. The suction pipe of a well rarely reaches below 600 feet in the district investigated. If the well is pumped only at the rate of flow from the Niagara, it will contain only a small amount of St. Peter or "Potsdam" water. While this seems contrary to the laws of homogeneous solutions it is not surprising, because the vertical distance between the sources of the waters is great. A well between 1,600 and 2,000 feet deep, when pumped at a rate of 20 to 30 gallons per minute, will yield the typical non artesian well water of the district. As the rate of pumping is increased the character of the water more and more approaches that of the deep-well water.

The hydrogen sulfide found in water from a well known to pierce the "Potsdam" series casts a doubt on the validity of the statement that all hydrogen sulfide appearing in wells in Chicago comes from the Niagara limestone, but hydrogen sulfide is present in a deep artesian well because water from the upper strata is being pumped. Several apparently deep artesian wells are given as examples of wells from which shallow-well water is being pumped. (See Table 3.) Numbers 1-4 are deep wells furnishing a

TABLE 3.—HYDROGEN-SULFIDE CONTENT OF DEEP ARTESIAN WELLS FROM WHICH SHALLOW WELL WATER IS BEING PUMPED.

Number.	Owner.	Depth.	Content of hydrogen sulfide.
		Feet.	*[Parts per million.]*
1	Lomax Bottling Co.	1625	1.86
2	Booth Cold Storage Co.	926	.570
3	Acme Malting Co.	1350	4.96
4	Felkys.	1640	.431
5	Calumet Elevator Co.	863	1.85
6	Mechanical Rubber Co.	1260	.244

shallow-well water. Number 5 is an average shallow or nonartesian well and has a similar composition. Number 6 is an average deep artesian well pumping at full capacity and the water has a very different composition.

The quality of the water from the well is a function of the ratio of the pumpage to the maximum yield of the well. If the water comes from but one formation its quality should not vary with the rate of pumping. Such a condition exists in a well deriving its supply from only Niagara limestone, and in a properly cased deep well teminating in "Potsdam" sandstone.

EFFECT OF METHOD OF PUMPING ON THE CONTENT OF HYDROGEN SULFIDE

The amount of hydrogen sulfide in a water varies with the method of pumping. The water is usually pumped by means of an air lift or a deep-well pump. When air-lift equipment is used the air continually passing through the water carries off the hydrogen sulfide as a gas or oxidizes it to free sulfur.

$$2H_2S + O_2 = 2H_2O + S_2.$$

The air lift is particularly effective in removing hydrogen sulfide and the amount removed increases as the submergence of the air nozzle decreases. Removal in such cases is almost complete unless the well originally had a very high content of hydrogen sulfide. When the deep-well pump is used no air gets into the pump and the hydrogen sulfide is not removed.

A comparison of the amounts of hydrogen sulfide in the waters from several wells which are affected by no other variable except the method of pumping shows a noticeable variation in the content of hydrogen sulfide. (See Table 4.)

TABLE 4.—CONTENT OF HYDROGEN SULFIDE IN WELLS PUMPED BY DEEP-WELL PUMPS AND BY AIR-LIFT EQUIPMENT.

Owner of well.	Depth.	Method of pumping.	Content of hydrogen sulfide.
	Feet.		[*Parts per million.*]
Morris & Co.	1331	Air lift	.318
Argo (Well 2)	1507	Air lift	.157
Schoenhofer Brewery	1600	Air lift	.167
Hammond & Co. (Well 1)	1600	Air lift	.357
Oscar Mayer	1628	Deep-well pump	.662
Western Packing Co.	1650	Deep-well pump	.671
Wisconsin Steel Co.	1706	Deep-well pump	.394

CONCLUSIONS

The quantity of hydrogen sulfide in well water in Chicago and vicinity depends upon three factors:

(1). The strata from which the water is drawn. In Chicago the hydrogen sulfide comes from Niagara limestone but to the west and south the hydrogen sulfide comes principally from the "Coal Measures."

(2). The ratio of the rate of pumping to the maximum yield of the wells. The limits of hydrogen sulfide are the amounts in the waters entering the well from the different water-bearing formations.

(3). The method of pumping. In pumping with air-lift equipment aeration removes a large part of the hydrogen sulfide.

REPORTS OF ASSOCIATIONS AND COMMISSIONS

References to articles regarding water, water supplies, sewage disposal and other subjects of interest to waterworks men, published during 1915, by the organizations that are interested in water supplies and sewage disposal are given in the following lists. An attempt has been made to make the list complete but there are poscibly some articles which may have been overlooked.

ILLINOIS STATE BOARD OF HEALTH

The State Board of Health began the publication of Illinois Health News. In volume I are two articles.

Hansen, Paul. (1) Sewerage and sewage disposal for small communities. p. 55; (2) Sewage treatment in small communities where a sewerage system is not available. p. 179.

STATE LABORATORY OF NATURAL HISTORY

Publications in 1915.

Malloch, J. E. The chironomidae, or midges, of Illinois, with particular reference to the species occurring in Illinois River. Bulletin X, 275-541, 24 plates.

ILLINOIS ACADEMY OF SCIENCE

Transactions for 1914 contain one article concerning water supplies.

Lewis, W. L. Water supply of Evanston. p. 96.

Transactions for 1915 contain five articles on water supplies.

Bartow, Edward. Examination of drinking water on railway trains. p. 71.

Bennett, A. N., The arsenic content of filter alum used by Illinois water-purification plants. p. 75.

Corson, H. P., Manganese in Illinois water supplies. p. 82.

Hinds, M. E., The longevity of Bacillus coli and Bacillus typhosus in water. p. 78.

Mohlman, P. W., A comparison of methods for determining dissolved oxygen in water and sewage. p. 88.

ILLINOIS SOCIETY OF ENGINEERS

The official publication in 1915, the Thirteenth Annual Report, contains four articles concerning water supplies.

Report of the committee on sewerage and sewage disposal.

Anderson-DeWolf. Artesian waters in Chicago and surrounding territory.

Graham, D. A. The selection of deep-well pumping machinery.

Hansen-Hilscher. Public water supplies in Illinois.

RIVERS AND LAKES COMMISSION

Publications in 1915.

The annual report (19 pages) tells of the action in numerous complaints made to the Commission and describes surveys of (1) Lima Lake and Hunt drainage districts, (2) Pecatonica River, (3) La Moine River, (4) Illinois Valley lakes, (5) Elgin encroachments, (6) Lake Michigan shore, and (7) Chicago River.

A report of survey and proposed improvement of Fox River (106 pages) is a special publication.

Report on Illinois River by Alvord, J. W. and Burdiek, C. B. (139 pages). This report of a study of Illinois River below LaSalle shows that floods similar to that of 1904 may be expected every 50 years. If all districts are to be protected a greater available flood cross section must be provided or the flood rates must be reduced by storage. The interests affected most are agriculture and fishing. Proper height of levees, means of storage and promotion of fisheries are discussed. Recommendations are made.

WESTERN SOCIETY OF ENGINEERS

The official publication is a monthly journal. Volume 20 was issued in 1915.

A paper entitled: Investigation of the International Joint Commission upon boundary waters was given by E. B. Phelps, pages 721-36.

INTERNATIONAL JOINT COMMISSION

The hearing and arguments held before the Commission for 1915.

The matter of applications of the St. Croix Water Power Co. and the Spragues Falls Manufacturing Co., Ltd., for the approval of the obstruction, diversion, and use of the waters of St. Croix River (192 pages).

Levels of the Lake of the Woods and its tributary waters and their regulation and control (504 pages).

Measurement and apportionment of the waters of St. Mary and Milk rivers and their tributaries in the United States and Canada (304 pages).

Remedies for the pollution of boundary waters between the United States and Canada (330 pages).

UNITED STATES PUBLIC HEALTH SERVICE

Public Health Eeports is issued weekly. Volume 30 contains several articles on water.

Frank, Leslie C. Sewage disinfection for vessels and railway coaches. (p. 9). The description of a device utilizing steam which automatically disinfects sewage.

Carter, H. E. Impounded waters. (pp. 15-47). Survey at Blewett Falls, North Carolina, to determine relation to prevalence of malaria.

Le Prince, J. A. A. Impounded waters. (pp.473-481). A study to determine the extent to which they affect the production of anophelines, and of the particular conditions which increase or decrease their propagation.

Whittaker, H. A. Hypochlorite treatment of water supplies. Portable plant and field equipment for its administration. (pp. 608-617.)

Legal liability of water companies. (p. 2613).

Manheimer, W. A. Essentials of swimming-pool sanitation. (pp. 2796-2811).

Pollution of streams by municipal sewage (p. 3267.).

State control of sewerage systems—The Maryland act giving the State Board of Health supervision over sewerage systems. (p. 3201)

Garbage reduction plant is not a nuisance is the decision of the State Supreme Court of Ohio. (p. 3473).

Whittaker, H. A. A water-borne dysentery epidemic caused by using water from an auxiliary fire hydrant. (pp. 3473-3476).

Damages awarded against a city sewer district for injury caused by a sewage-disposal plant. (p. 3398.)

AMERICAN WATER WORKS ASSOCIATION

Volume 2 of the Journal (quarterly) was published in 1915. It contains many interesting articles.

Anderson, Carl B. Studies of artesian waters in Chicago and surrounding territory.

Babbitt, Harold E., Wash-water salvage at Champaign and Urbana.

Baker, M. N., Artesian wells.

Bartow, Edward, Arsenic content of filter alum.

Bartow, Edward, Examination of drinking water on railway trains.

Observations of some European water-purification and sewage-disposal plants.

Bennett, A. N., Arsenic content of filter alum.

Bennett, C. G., Illinois Utilities Commission and the waterworks companies.

Berry, *5*, P., Artesian wells.

Blauvelt, Albert, City fire limits.

Booth, William M., Water analyses and the nitrogen content of water.

Brush, William M., Maintenance of the water supply distribution system of New York City.

Bulkeley, Oscar, Artesian wells.

Burgess, Philip, Mechanical analysis of sands.

Caird, James M., Air bound filters.

Carpenter, Horace, The choice of alloys for waterworks design.

Dallyn, F. A., Some features of the Ontario statutes and their administration affecting water supplies and sewerage systems.

DeBerard, W. W., Kinks in the control of hypochlorite at Denver.

De Wolf, P. W., Studies of artesian wells in Chicago and surrounding territory.

Pritze, L. A., River sand as a filter medium.

Prost, W. H., Some considerations in estimating the sanitary quality of water supplies.

Pulton, D. P., The Yonkers water supply and its future development.

Gaub, John, Method of washing slow-sand filters.

Gelston, W. R., The new filtration plant at Quincy, Illinois.

Graham, D. A., The application of the theories of public regulation to the management of utilities.

Green, P. E., The water supply of Longview, Texas.

Haddon, S. C., The practical value of publicity to the waterworks man.

Heilman, Ralph E., Some economic aspects of waterworks valuation.

Highland, Scotland G., Plumbing code and control of plumbers.

Hodgkins, Henry C, Franchises of public utilities as they were and as they are.

Hoover, Charles P., The manufacture of sulfate of alumina at the Columbus water-softening and -purification works.

Jennings, C. A., Bubbly Creek filter plant adopts liquid chlorine treatment.

Kay, Edgar B., Impounded waters of Alabama.

Kilpatrick, John *D.*, Artesian wells and methods of pumping.

Klein, Jacob, How to determine the size of tap and meter.

Larson, C. M., State regulation of municipally owned plants.

Longely, Francis F., Present status of disinfection of water supplies.

Massa, E. F., Cooled drinking water.

Monfort, W, F., A special water standard. Dry feed of chemicals in water purification.

Parkin, E. E., Experience with artesian-well water at Elgin, Illinois.

Pearse, Langdon, The rapid filter plant at Evanston, Illinois.

Powell, S. T., The effect of algae on bicarbonates in shallow reservoirs.

Pownall, W. A., Treatment of water for locomotive use.

Pratt, Edward A., Ancient and modern accounting for public utilities.

Eector, Frank L., The true object of water analyses.

Eeed, D. A. Assessing cost of extension in municipally owned plants.

Ruthrauff, Harry, Filtration plant, City of Decatur, Illinois.

Smith, Owen T., Experiences in rebuilding and reinforcing a waterworks system.

Tribus, Louia L., Water-supply treatment at Council Grove, Kansas.

Veatch, N. T., The design and operation of intermittently operated purification plants.

Wagner, Bernard M., The acquisition of private water plants by municipalities.

Wiles, C. W., Water from gravel wells.

Williams, C. B., The possibility of an improved water from deep wells in Illinois.

Wynne-Eoberts, R. O., Waste prevention by individual meters versus district meters.

AMERICAN PUBLIC HEALTH ASSOCIATION

The official publication is the American Journal of Public Health (monthly), Volume 5 issued in 1915, includes several articles of interest to waterworks men.

Bartow, E. Bureaus of water supplies. (p. 871).

Birge, E. G. The action of certain bacteria on the nitrogenous materials of sewage. (p. 1048.)

Freas, E. Apparatus for the accurate filling of dilution flasks. (p. 323.)

Lederer, A. Application of the "saltpeter method" for determining the strength of sewage. (p. 254.)

Lederer, A. "Relative stabilities" in polluted waters carrying colloids. (p. 740.)

Longely, F. F. Report of committee on water supplies of the sanitary engineering section. (p. 918.)

McLaughlin, A. J. The International Joint Commission of sewage pollution of boundary waters. (p. 555.)

Melia, T. W. An improvement in the composition of lactose bile. (p. 1148.)

Report of the committee on sewage works operation and analytical methods.

Silver, J. F. A study of methods of sewage disposal in industrial and rural communities. (p. 820.)

Whipple, G. C. Permanent sediment records for water and sewage. (p. 989.)

CHICAGO REAL ESTATE BOARD

A special report, prepared by George A. Soper of New York, John D. Watson of Birmingham, England, and Arthur J. Martin of London, England, gives their findings concerning water supply and sewage disposal for Chicago.

The water supply is not entirely free from pollution. The policy of using the rivers, and constructing canals, as open sewers, is not in accordance with good sanitary practice. Intercepting sewers, screens, and settling basins will have to be employed extensively and it is probable that more efficient methods of purification will be required to a considerable extent. It is recommended that trade wastes be dealt with at private expense when they add unduly to the cost of treating the sewage. Sewage purification must be accompanied by filtration of the water supply. A definite general plan showing what will be needed during the next fifty years should bo prepared.

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