STATE WATER SURVEY

No. 62

UNIVERSITY OF ILLINOIS BULLETIN
ISSUED WEEKLY

VOL. 14 OCTOBER

CONTENTS

ILLUSTRATIONS

ORGANIZATION

EDMUND JANES JAMES, Ph.D., LL.D President

STAFF 1915

EDWARD BARTOW, Ph. D Director
PAUL HANSEN, B.S Engineer
SAMUEL WILSON PARR, M.S Consulting chemist
ARTHUR NEWELL TALBOT, C.E Consulting

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 submi

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 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.ee

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

Nature of work.	1912	1913	1914	1915	Total.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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,

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

	October	Total
[illegible]	[illegible]	[illegible]

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
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	577

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	113	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										

[illegible]

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 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

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 water0 11.001j4.154 Tw(co 0.000 0.000 rg56.400 447.30.05.) TjETBT ceded 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 actiT0o9Tc(,) Tj2.41

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 scientific knowledge, and the unification of the scientific interests in the State. All residents of the

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

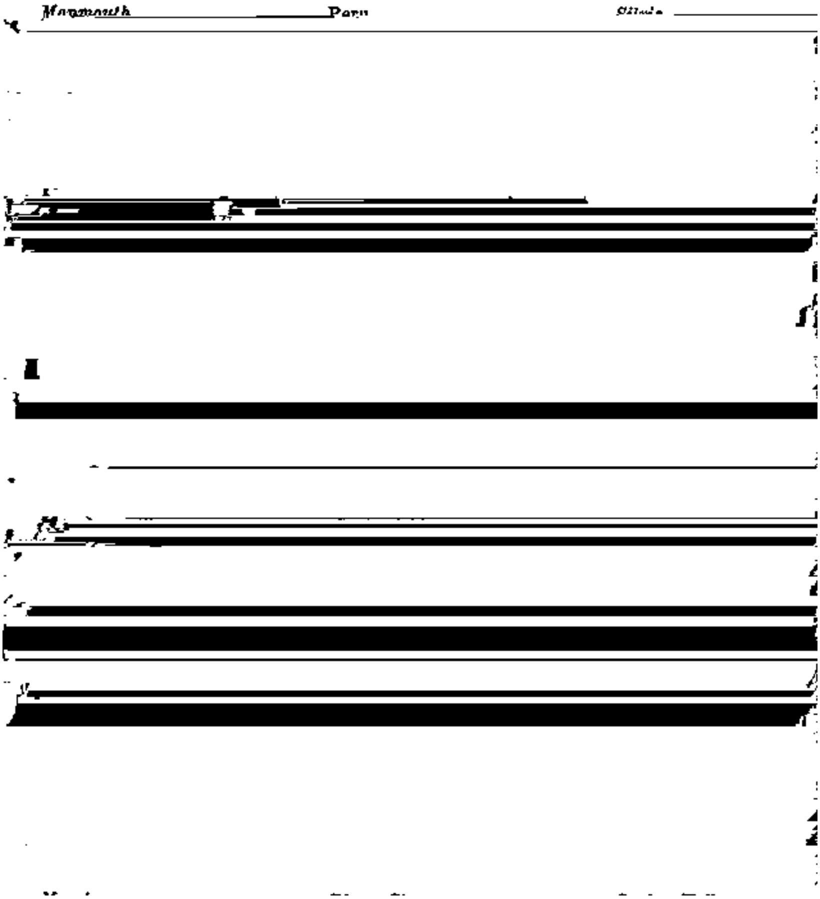
Carrollton
Cedar Point
Centralia
Cerro Gordo
Chadwick
Charleston
Chatsworth
Chenoa
Cherry

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

Geneva
Genoa
Gibson City
Gilman
Glencoe
Glen Ellyn
Grand Ridge
Granite City
Granville

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

Colony
Litchfield
Little York
Lockport
London Mills
Lostant
Lovington
Lyons
McHenry



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

1915 havs

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

Albion	*Bradley*	*Decatur*
[illegible]	[illegible]	[illegible]
Alton	Bunker Hill	Deland
Anna	*Cairo*	Depue

n

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 1 (Pollutc 4.13B838 Tw (hig)Tj0 Tc (0 Tc (.)Tj0.2p3653hig)Tjs10Tw

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.

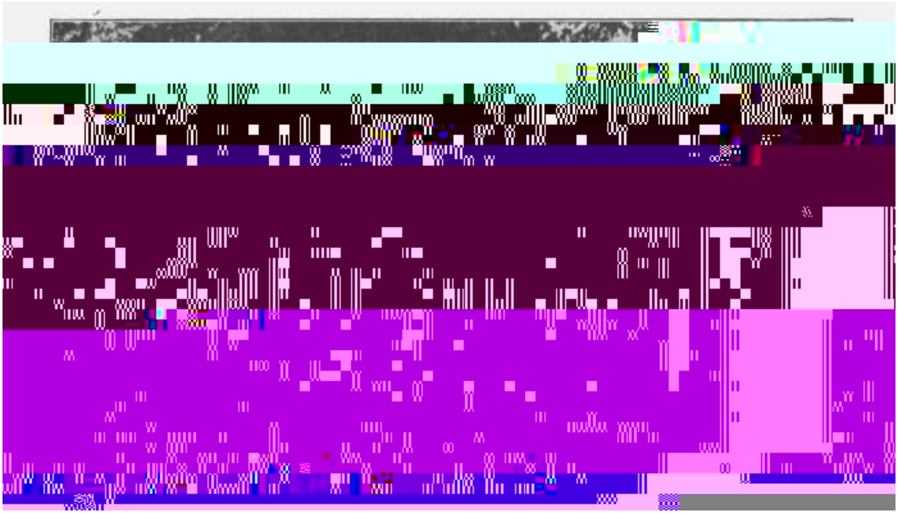
ALEXIS (829). Water supply.—Visited October 26. Alexis is located near the northern border of Warren County in the drainage basin of Middle Henderson Creek. The village does not have sewerage, but a drainage system of open-joint tile, which has been installed primarily for ground-water drainage, has 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 supplyl5sh1.800 Tw-0.134 Tc(fro)10.000 Tcc(l) Tjevide2.73

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 producedf 50 highe A 100,06.1 Tj2.934 .000 0.000 0.000 rg49.92

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

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 other, 10 feet

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 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 pum

The system in the south end has cost approximately $125,000, and that in the northh

The oil-refinery wastes produce an objectionable pollution that coats the water with oil and fringes the banks a miectionabl th 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 lastp 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

BUREAU (534). Water supply.—Visited September 2. Bureau is in the southeast corner of Bureau County in the valley of Illinois River about a m0about 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**, the small demand.

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 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
plex91.8997Twj2.0(.) TjET Tw0.008 Tc(cu) Tj0.5 Tc(b) Tw0.00323 Tc(-TH) Tj0.000 Tc() T
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 hol elevate 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**BT0 Tr0e

the

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 an 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 th

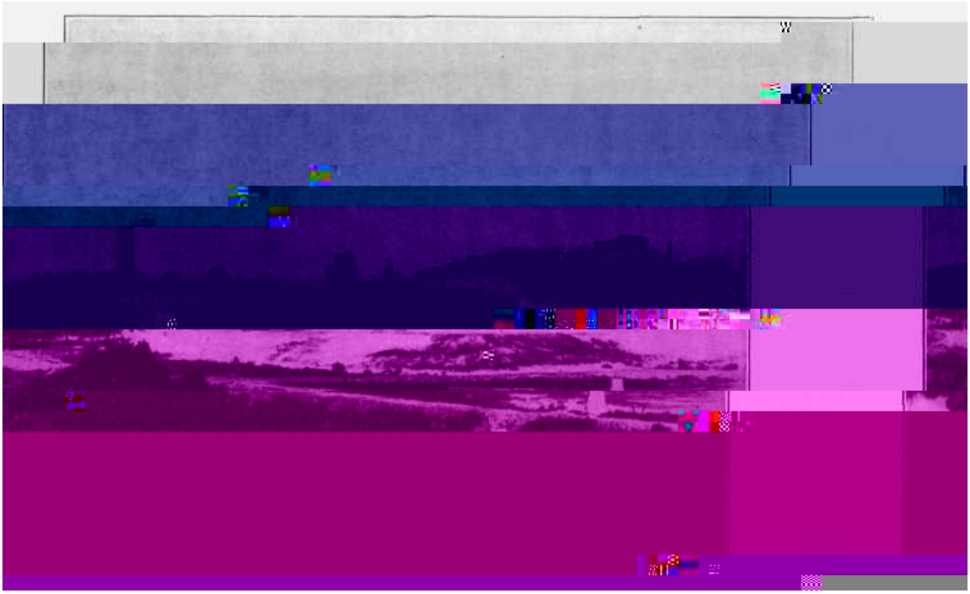
to warrant pumping. This well ia the same size and depth as the fourth well, and the supply is now obtained from these two wells. Both are equipped with 10-foot Cook screens and derive their supply from sand and gravel. The static level is about 60 feet below the surface. The water is pumped from the 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.)

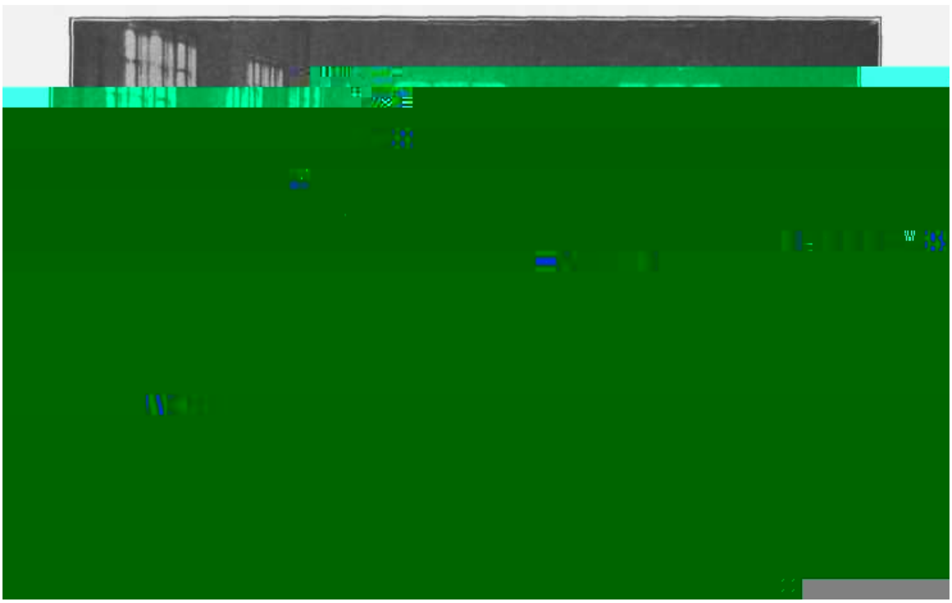
DECATUR (31,140). Water supply.—(Bull. **10**, 106; **11,** 53; **12**, 55.) Visited March 2-3 and 30. Decatur, the county seat of Macon County, is bordered on the south by Sangamon River. It is the location of many industrial establishments.

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 coagulating 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



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 flTc(t) Tj2.690 Tw0.013 Tf0 Ts-0.020 Tc(g60 Td0.000 Tw99.Td0.000 Tw99.Td0.000 T0.000

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



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 tabl

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.

and thus the check can swing open again when the extra pressure is released. The pumpage as recorded by a Venturi meter except that used for fires as the [illegible] 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 [illegible] has increased [illegible] per capita consumption has decreased.

[illegible] per million [illegible]

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. of

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.

Waterworksh water

charge 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 stor 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

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

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 dition 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

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 Rive installation sewerage.—Eureka 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 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

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 reservoir, and additioan

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 on 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 ground-water 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

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, TO 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 gallon triplex pump. Leaks in joints and valv.882 Tw0.088 TciR

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 rise(s) Tj395 TcTj1.922 T(rise)pi0.000 Tc(.) Tj1.790 Twn soda, a80 133.920 Td0.00

3w a pump northeasi0.000 Tc0 Tc(s).292 Tw0.218 Tc(brin) 1iplee Tji0.000 T.0000 Tzvail-0Ti0.000 Tc(n) Ti2.237

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 Tw-0.011 Tc(b) Tj0.0627yr dam, and on May 6 to attend a second hearing before 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 anddrr d Tw0.309.440 Td(y) Tj1T1. an spac

deep sp231 Tw0.304 Tc(1) Tj0.000 Tc(6) Tj216195 Tw-0.060 Tc(inche) Tj0.000 Tc(s) Tj17459 Tw0.014 Tc(i) Tj0.000

tpiope with gallon a

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

HAVANA TO HIGHLAND

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

ANALYSES OF WATER AT HINSDALE

[Parts per million.]

	Raw water	Settled water	Filtered water
DETERMINED QUANTITIES			
Total residue	644	417	270
[illegible]	[illegible]	[illegible]	[illegible]
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 recommende

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.

ing 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. well 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

swater

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 place927 Tw0.151 T elevation of the bottom of the deeper well is 7 feetle 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 minerald Tj1.069 Tw0.0t Tj1.08yielf47Tj2.525 Tw0.0806 Tc(04erin) 3j0.000 Tar 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 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(I) Tj3its.

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

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 stage Tc (l)Tj-e0.0ehTj-0.04

limited number of connections. The maximum consumption, which covered a 3-hour 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 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 [illegible]

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

.

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 thenwas insanitar

MORTON (1,004). Water supply.—Visited September 14. Morton is in the north-central part of Tazewell Count 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

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 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 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 43al.i413 Twd2(n) Tj2-0.000 Tc(0.104 Tc(2000.032 Tc(i) Tj0.000 Tc Tj1.924p 0

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 at

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 oneeic(school) Tj0.000 Tc

2 . 7 5 7 T w - 0 . 2 4 2 T c (w h e) T j 0 . (

Development of a surface supply does not seem feasible as the water of North Pork has a high content

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 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

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

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.004 T0tyn

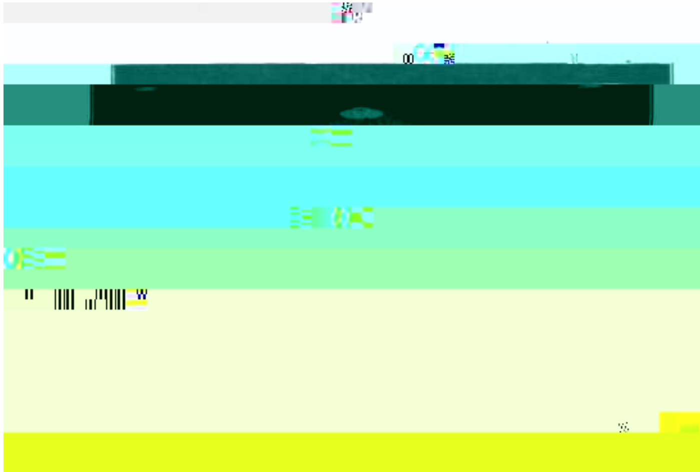


Figure 5.—Operating floor and filters, Rock Island.

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

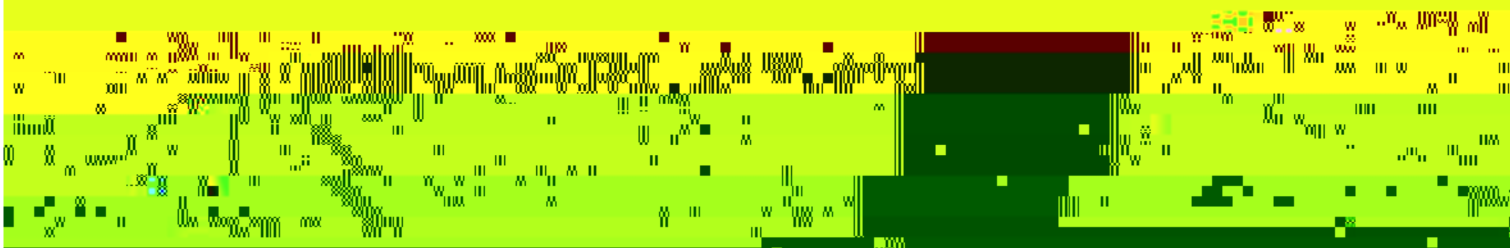


Figure 7.—Filtration plant, Rock Island.

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 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

on the discharge from the triplex pump is 66,000 gallons. More than three-fourths of the population use the y4d-l

The plans provide

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 equippeds drille the 2280 Tw0.049 Tc(basi) Tj0.030,3.-Tc(Tj1.726 Tw-0.334 Tc7(Develop

024 5ree e 000 0.Dte39(suppl) 0.000 Tc(.) Tj3.572 Tw-0.1422 554c(j0.000 Tc1. 523.680 Tc

Waterworks were installed about 1880, the original

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 coninch, 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 waterworks 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 northwest 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 above it diverts water into a feeder of Illinois-Mississippi Canal. Both cities are 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 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 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-rocky 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 beeey 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 capacit

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 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.

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 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 594 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 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

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,s thAmes-0.256 Tc(eveaz51Tw-0.0k2.0,0.158 5e Tw0.030 Tc(i) Tj0.0Tj0.000 TcTj1.627 neTw

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 ($(NH_4)_2S_2O_8$) 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 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 dfte, ife

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
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[1]Cram, Walter, Empfindliches Prüfungsmittel auf Mangan: Ann., 55. 219-20 (1845).
[2]Klut, H.,

[illegible]

[redacted]

[redacted]

[redacted]

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

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous	Standard	Determined	Theoretical	Excess of deter-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ers 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 and

Cubic centimeters of solution.		Milligrams of manganese.	
[illegible]	[illegible]	[illegible]	[illegible]

series 6 are as accurate as those with distilled water. Manganese can, therefore, be determined with a

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous	Standard	Determined	Theoretical	Excess of deter-

of that radicle. Chloride is present in many natura 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
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[1]Standard methods for the examination of water and sewage, Am. Pub. Health Assoc, New York, 2nd ed., 49-51 (1912).

Cubic centimeters of solution	Milligrams of manganese

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 sodigane.000 Tc5000 Tc(MANGANES22 Tw/F0 8.200 Tf0 Ts48400 0.

Solution of [illegible]	Theoretical	Determined content of manganese in presence of designated amounts of chloride

Cubic centimeters of solution.		Milligrams of manganese.		
Manganous	Standard	Determined	Theoretical	Excess of deter-

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	[illegible]	.08	.075	[illegible]

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.				

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.]

[illegible]

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 of4

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
[illegible]	[illegible]

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).

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 centimeter

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 Pete ST

Locality.	County.	Depth.	Manganese (Mn).	Iron (Fe).	Dissolved solids.
		Feet.			
Abingdon	Knox	1,850	0.00	0.0	1,323

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

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	243	.00	.2	[illegible]

TABLE 20.—CONTENT OF MANGANESE, IRON, AND DISSOLVED SOLIDS IN WATER FROM WELLS IN UNCONSOLIDATED DEPOSITS.

[Parts per million.]

Locality	County	Depth	Manganese	Iron	Dissolved
		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	20	1.50	.2	1,066

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	[illegible]	Illinois	[illegible]	[illegible]	[illegible]

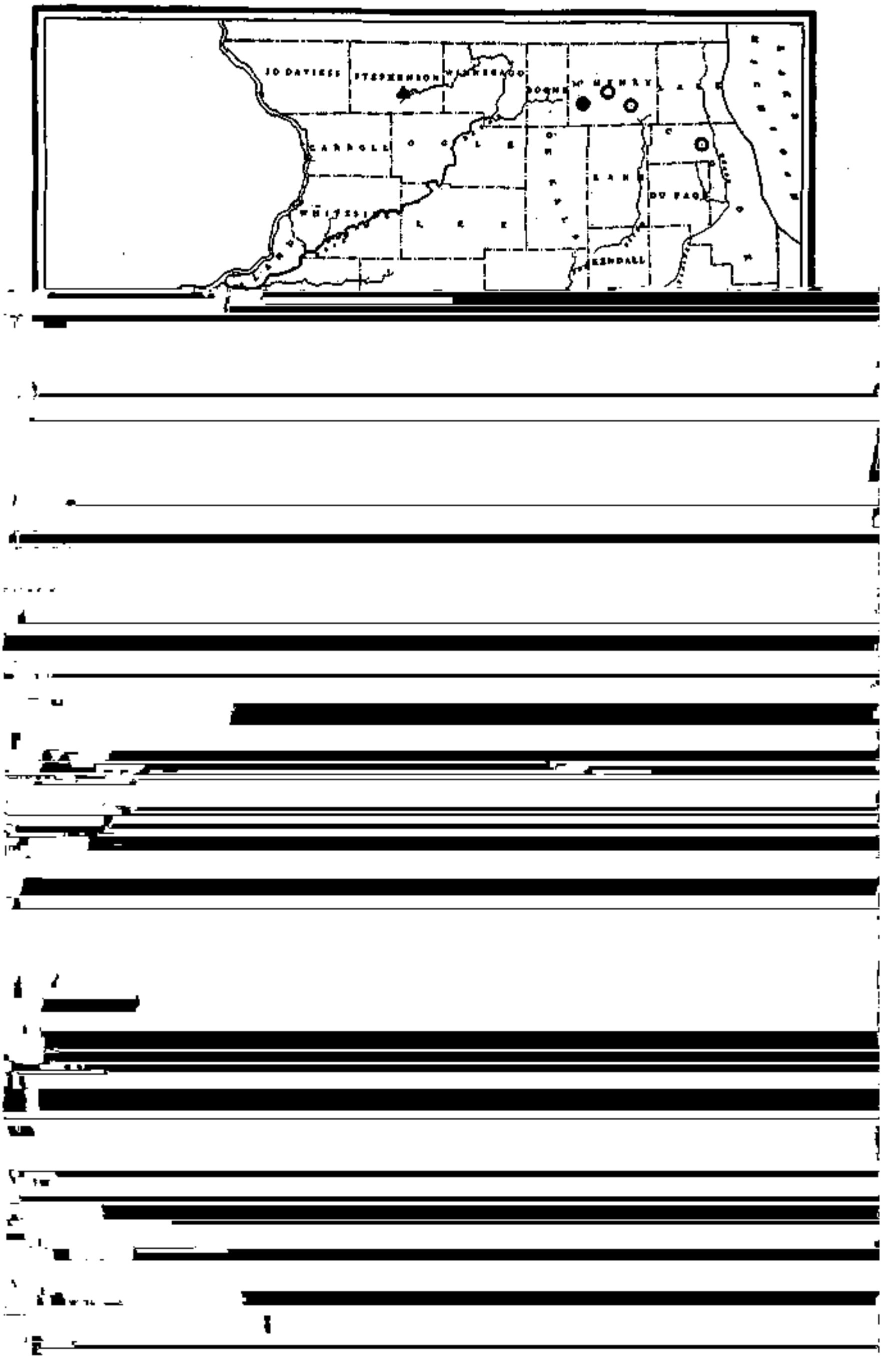


Figure 1.—Map of Illinois showing occurrence of manganese in water from wells in unconsolidated deposits,

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.

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	

COAL-MINE DRAINAGE

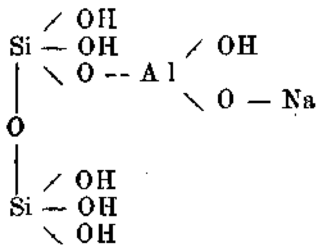
Coal-mine drainage usually contains iron and often large amounts of it, and such drainage is often acid because of hydrolysis of salts of iron and precipitation of iron hydroxide. The iron is derived from pyrite, marcasite, sulphide-bearing shales, and other compounds of sulphur, which are leached by water containing oxygen,

as shown by analyses of samples collected at Kangley, Lowell, and Oglesby. Samples taken at Streator above the dam at the waterworks contained no manganese or iron. This river below Streator is heavily polluted with mine drainage

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 thence through slow sand filters operating at a rate of 10,000,000 gallons per 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 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

$$2SiO_2 \cdot Al_2O_3 \cdot CaO + MnCl_2 = 2SiO_2 \cdot Al_2O_3 \cdot MnO + CaCl_2$$

(a) $2SiO_2 \cdot Al_2O_3 \cdot MnO_2 + CaMn_2O_8\ 2SiO_2 \cdot Al_2O_3 \cdot CaO + MnO \cdot Mn_2O_7.$

(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) $3(SiO_2 \cdot Al_2O_3 \cdot MnO) + 2H_2O + CaMn_2O_8 = \left\{ \begin{array}{l} 2SiO_2 \cdot Al_2O_3 \cdot CaO \\ 2SiO_2 \cdot Al_2O_3 \cdot H_2O \\ 2SiO_2 \cdot Al_2O_3 \cdot H_2O \end{array} \right\} + 3MnO \cdot Mn_2O_7.$

(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) $2(3MnO \cdot Mn_2O_7) + 9Mn(HCO_3)_2 = 15MnO \cdot 2Mn_2O_7 + 18CO_2 + 9H_2O$

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:

$$p\text{-}Na_2 + MnCl_2 = p\text{-}Mn + 2NaCl$$
$$p\text{-}Mn + 2KMnO_4 = p\text{-}K_2MnO:Mn_2O_7$$
$$p\text{-}K\ MnO\ Mn\ O = p\text{-}K\ 3MnO + 5O$$

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] itd

$$MnO_2 + MnSO_4 = Mn_2O_3 + SO_3$$

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

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,0 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 and

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
[illegible]	[illegible]

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.

$$K_2\ Permutit + \overset{++\,--}{MnSO_4} = Mn\ Permutit + \overset{+\,--}{K_2SO_4}$$

salt thus: $MnO_2 + MnSO_4 \Rightarrow Mn_2O_x + SO_3$. This is the basic reaction

[illegible]

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

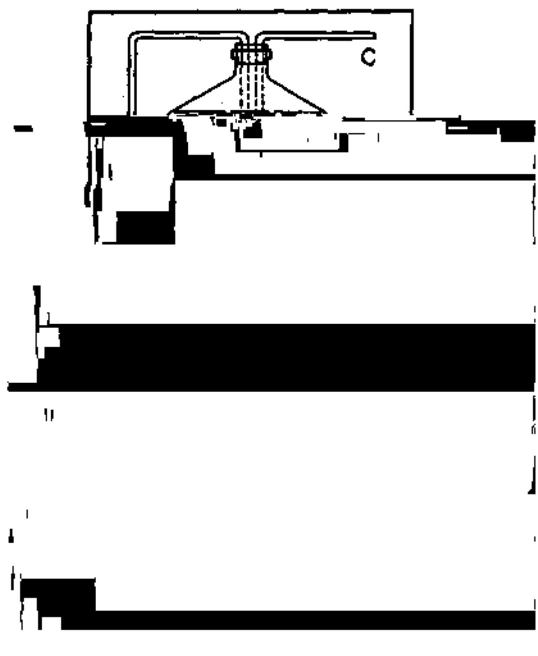


Figure 2.—Experimental sand filters for the removal of manganese.

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.

Bac

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 Tc(s) se

Determinations.	Unfiltered water.	Water filtered through—	
		Sand.	Sand coated with manganese dioxide.
AT START			
Manganese	4.8	4.4	.0
Iron	[illegible]	[illegible]	[illegible]

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

Determinations	Unfiltered water	Water filtered through—

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

Determinations.	Unfiltered water.	Water filtered through—	
		Sand.	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
[illegible]	[illegible]	[illegible]	[illegible]

by addition of the coagulant. Complete removal of

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	[illegible]	10.0	[illegible]

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

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
[illegible]	[illegible]	[illegible]

dissolved oxygen and very little carbon dioxide. Determinations showed 9.8 parts per million of dissolved oxygen, which is

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

Date.	Reservoir water.	Raw water.	Filtered water.	Date.	Reservoir water.	Raw water.	Filtered water.
1914 [illegible]	15	07	02	1915 Mar. 1	4	2	[illegible]

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.

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 rANGANESE

Raw water.	Water filtered through—	
	Sand.	Sand coated with

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.

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

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

E

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.
[illegible]	[illegible]	[illegible]

TABLE 41.—CONTENT OF MANGANESE OF RAW AND FILTERED WATER

A

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. 18	.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

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 S1.764 Tw-0.069 Tc(san) Tj0.000 Tc(d) S1.764 Tw-0.069 T

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

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. Thees 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 processe

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 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.f mentionin filtedd i0u52-0.076 Tpinvesti 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, $A1_2O_3,2H_2O$, 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, $A1_2(SO_4)_3,18H_2O$, with a small amount of a basic sulfate, so that there is an excess of $A1_2O_3$ over the amount required to combine with the SO_3 present. All specifications for this product call for at least 17% $A1_2O_3$. The following is a typical analysis. Total $A1_2O_3$, 17.5% ; Free $A1_2O_3$, 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% $A1_2O_3$. This is made by driving off sufficient water of crystallization to make the required percentage of $A1_2O_3$. To prepare this product approximately 60% of the water of crystallization would have to be driven off to raise the $A1_2O_3$ 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:

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 = 2Al(OH)_3 + 3CaSO_4 + 6CO_2$$

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

th aluminiumd

In some cases the samples came directly from the producer, and in others from the water-treatment plants. The specimens were caretains 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:

$$2AsH_3 + 12HgCl_2 + 3H_2O = 12HgCl + As_2O_3 + 12HCl$$

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

City.	Arsenic as As_2O_3		Gallons.[a]
	Parts per million.	Per cent.	
Cairo	1.6	0.00016	8213
Carlinville	[illegible]	[illegible]	[illegible]

mained 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.		Gallons.[a]
	Parts per million.	Per cent.	
1	0.5	0.00005	10280.0
2	1.2	0.00012	4283.0

[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.

Thed

ARSENIC CONTENT OF SULFAT

d9ayer, and.that 56 Tc(gator) Tj0.000 Tc(e) Tj0.789 TT

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 numbert,6rn con--

Location.	Depth.	Bacteria per cubic centimeter.	
		Agar	Gelatin

gators 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

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

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																	

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.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The results of analysis show a decided difference in composition between the water of the river and that from the wells. Pollution from this

centrated 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.

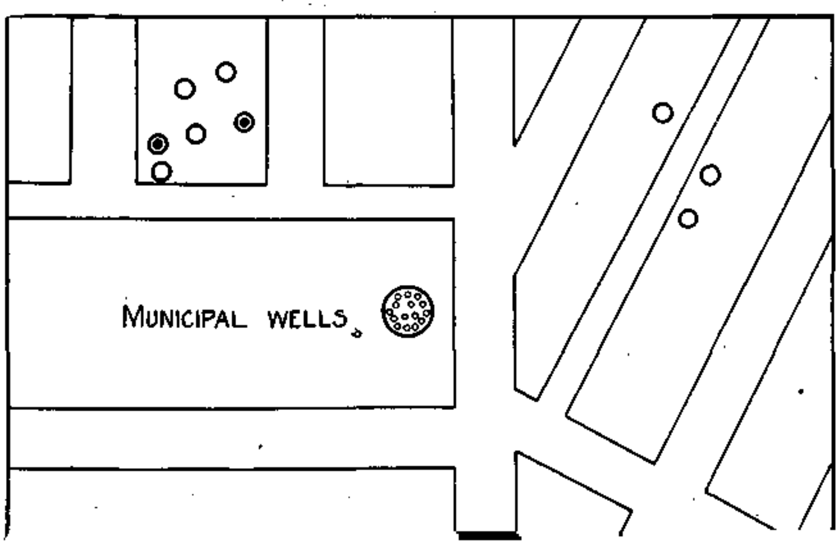


Figure 1.—Location of wells and privy vaults in which salt was placed.

Experimental study. It was thought best not to use

Date.	Chloride Parts per	Remarks	Date.	Chloride Parts per	Remarks

4. Breunig, Bakteriologische Untersuchung des Trinkwassers der Stadt Kiel im August und September, 1887. Kiel, (1888); quoted by Frankland, in Microorganisms in water, London (1894).

5. Chick, The distribution of Bacterium coli commune. Thompson Tates Lab. Report No. 3, p. 1.

6. Dole, R. B., Use of fluorescein in the study of underground waters: U. S. Geol. Survey Water-Supply Paper 160, 73-85 (1906).

7. Dyer, H. G., and Keith, S. C. Jr., Notes on normal intestinal bacilli of the horse and of certain other domesticated animals: Tech. Quart. 6, 256-7 (1893).

8. Eyre, J. W. H., On the distribution of Bacillus coli in nature: Lancet, 1, 648-9 (1904).

9. Flint, J. M., Notes on the distribution on Bacillus coli communis: J. Am. Med. Assoc, 26, 410-1 (1896).

10. Frankland, Percy, and Frankland, G. C, Microorganisms in water, 105-6, London (1894).

11. Horton, E. G., The colon bacillus in ground water: Public Health, 28, 419-21 (1902).

12. Johnson, G. A., Isolation of B. coli communis from the alimentary tract of fish and the significance thereof: J.

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 dealing9Tj-0.0cul Tce.914 Tw (numero

pen.c 19t0.057 Tc 2.35 Tc (l)3 Tc 0.92.24 Td(wit)Tj0 Tc c (*)TjTw (11)TTw 0.24 -12.24 T

form by the daily transfers (see Table 1). Miscellaneous samples of water were used at the same

$$K = \frac{1}{t} \log_e \left(\frac{N}{n} \right)$$

Hours.	Series 1.		Series 2.		Series 3	
	Count.	K.	Count.	K.	Count.	K.
0	1,168,000	...	10,240,000	...	2,180,000	

Hours.	Air.		Nitrogen.		Hydrogen.	
	Count.	K.	Count.	K.	Count.	K.
Series 1.						

Hours.	Series.					
	1	2	3	4	5	6
8°						
0-2	.283	.235	.092	(.556)*	.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	...	...

	20°					
0-2	.713	.143	(.088)	(.270)	.069	.087
2-6	.596	.084	.035	.019	.083	.059

[redacted]

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.E

Hours.	Count.	K.	Count.	K.	Count.	K.
	Series 5.					
	8°		20°		37°	
0	668,000		690,000		560,000	

[redacted]

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	8.106	3,800	2.562	520	3.500

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 is1

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	.158	.318	2.36	1.13	.47
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

n s5in 1(wit) Tm70.320 254.640 T3.422 Tw197 Tc(s5in) TiF0 7.150 Tf4.98d0.000 T

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 temperatpW0(t) Tj0.000 Tc(o) Tj1.80

Hours.	Air.		Nitrogen.		Hydrogen.	
	Count.	K.	Count.	K.	Count.	K.
			Series 1.			
0	3,000	...	29,000	...	20,000	...

TABLE 9.—RATIOS OF THE CONSTANTS FOR B. TYPHOSUS IN AIR, NITROGEN, AND HYDROGEN.

Series.	Air/Nitrogen.	Air/Hydrogen.	Nitrogen/Hydrogen.

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	1.306
6	1,825	.832	280	1.007	0	1.934
8	950	.665	230	.779	......	...
10	500	.596	150	.666	......	...
12	......	...	80	.689	......	...

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.

REFERENCES

1. Chick. Jour. of Hygiene, 10, 237, 1910.
2. Eijkman. Verslag. der kon. Akad. Wetenschappen, 21, 1, 510, 1912.
3. Hale and Melia. Am. Jour. Pub. Hygiene, XX, 622, 1910.
4. Houston.,, Th col determiney

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 butd 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 aboutrnerrer(r) Tj1.782

Date.	Discharge.	Date.	Discharge.
	Gallons per minute.		*Gallons per minute.*
1914			
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	[illegible]

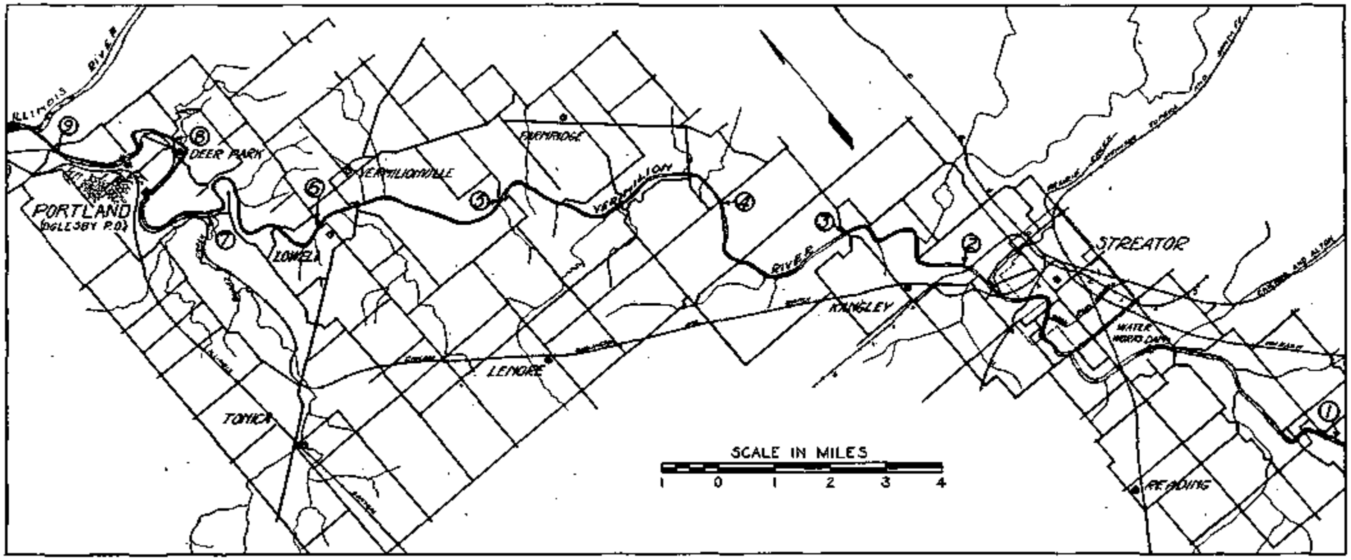


Figure 1.—Map showing sampling and stream-gaging stations on Vermilion River above and below Streator.

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

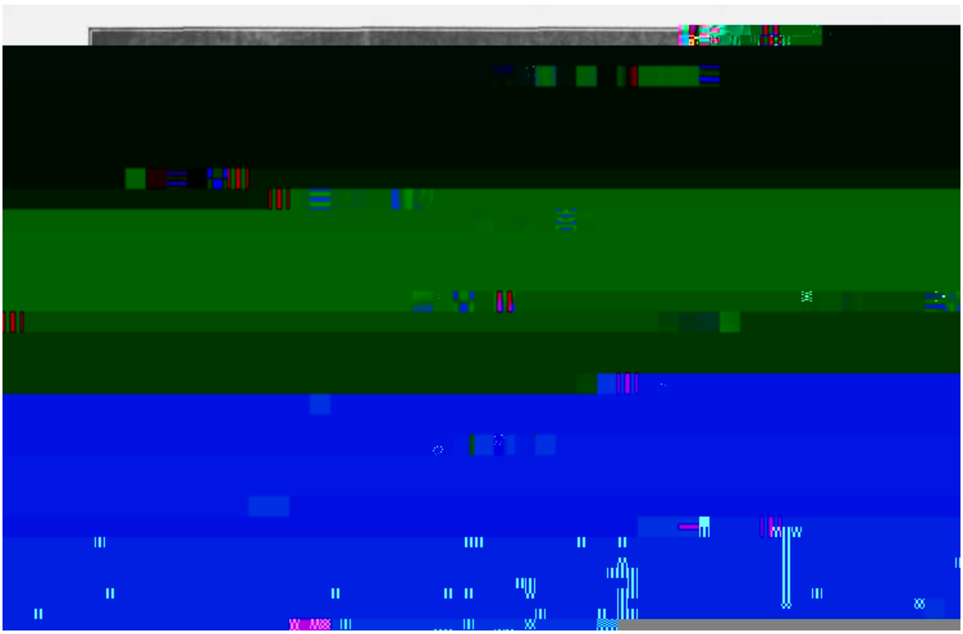
That portion of Vermilion River in question, with numbers to show the various points at which detailed observations were made and samples were collected, is shown in Figure 1.

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 Avasm

The gas plant owned by the Public0oee238543 Tw-1.400 TcServic(Th) Tj0.0



c0o0.548720 Tw132323 Tcubli

c0oee434720 Tw04.323 Tcublic0oee32.304 Tw06.347 Tcsituatownedc0oee285304 Tw10.026

th

Thomc0o0.076.232 Tw8.235 Tcdischarc0o0.86.512 Tw-0.369 Tcsecretwnec0o0.924720 Tw171727 Tco 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

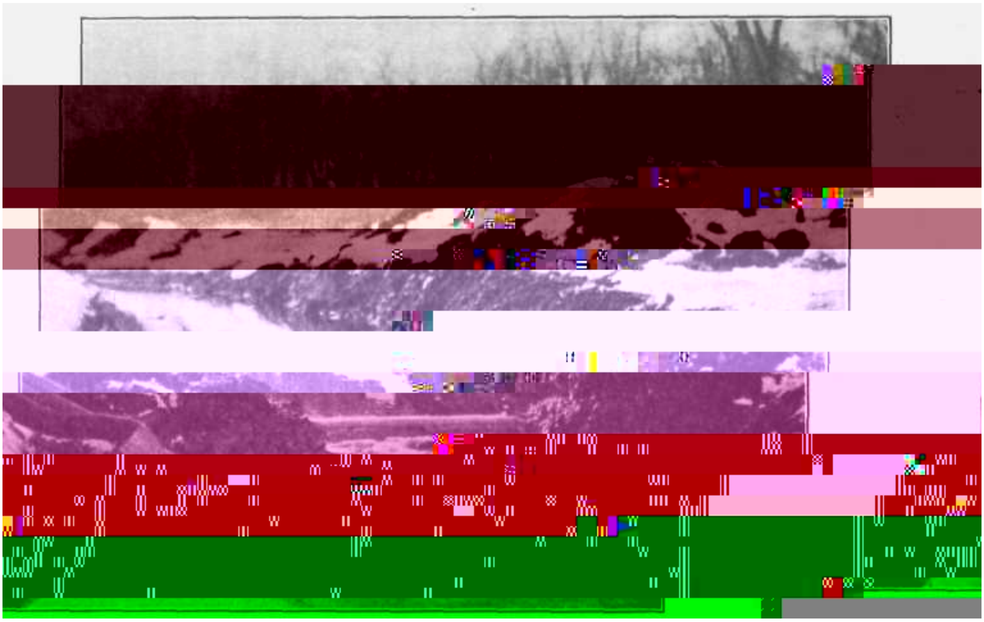


Figure 3.—Weir in Vermilion River at Station 1, above Streator.

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 thfe Tht Stat04.160 Td0.000 Tw99.000(d) Tj02.575 Tw-0.564 Tc(effect) Tj(r)5 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.

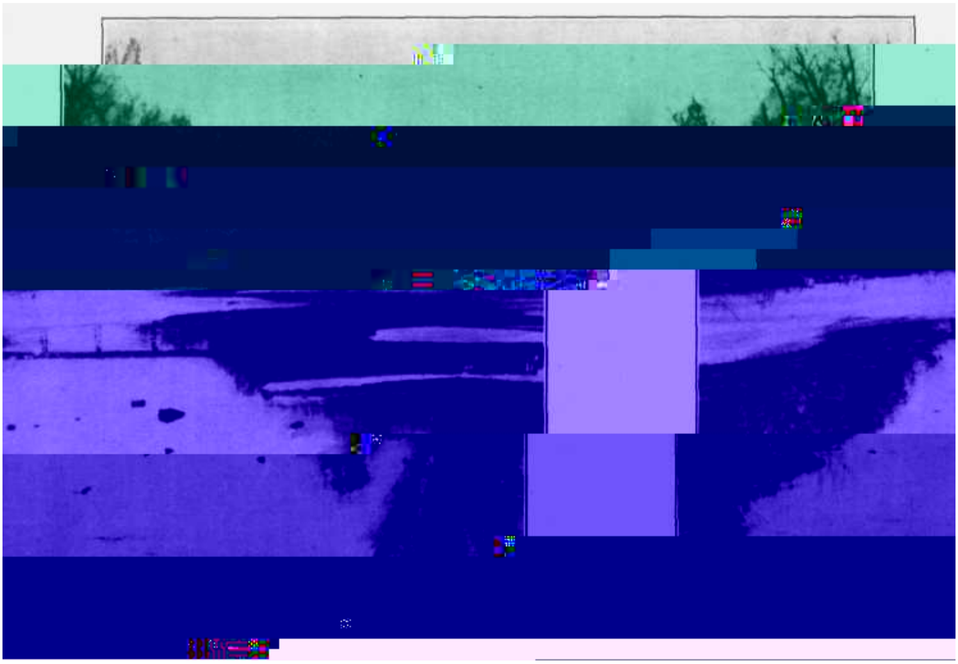
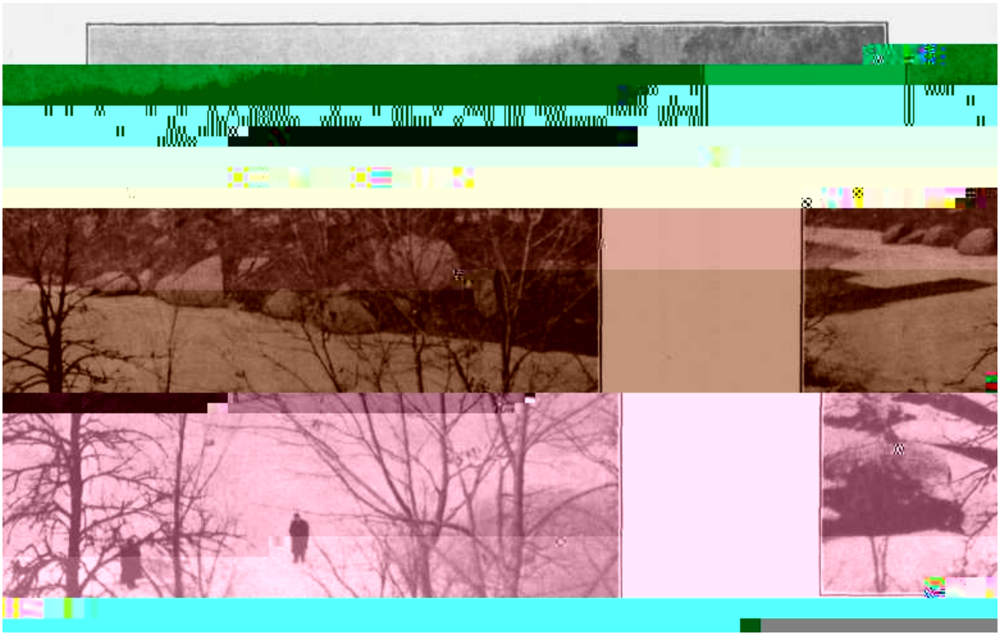


Figure 4.—Vermilion River at Station 2, below Streator.

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 o

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 mile



deposits may have existed beneath the ice. Thedeposits

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

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	....
[illegible]		[illegible]	

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 wer

TABLE 3.—ANALYSES OF WATER FROM VERMILION RIVER AND TRIBUTARIES, JANUARY 14-15, 1915.

[Parts per million.]

Station	Miles below	Turbidity.	Color	Residue on evaporation.			Chloride.	Oxygen consumed.
					Dissolved.	Suspended.		

[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

INVESTIGATION OF THE DESTRUCTION OF FISH IN SANGAMON RIVER BELOW SPRINGFIELD

By Paul Hansen and Ralph Hilscher.

At the request of the State

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 someegd

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.

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 ditow-0.323 1 certifie 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,lsplae0.000 Tc(s)

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 formulate

Bickel[3] experimenting with a

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

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 examine

TABLE 1.—ANALYSES OF WATERS FROM WHICH RAILWAY TRAINS ARE SUPPLIED, DECEMBER 30, 1914-MAY 17, 1915.

[Parts per million.]

Nitrogen.	Bacteria per cc.	B. coli in lactose broth.

[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

TABLE 1.—ANALYSES OF WATERS FROM WHICH RAILWAY TRAINS ARE SUPPLIED, DECEMBER 30, 1914-MAY 17, 1915 (continued).

[Parts per million.]

										Nitrogen.					Bacteria per cc.		B. coli in lactose broth.			
																			Five 10-cc. Portions.	
,.	road.	rce.	nership.	bidity.	or.	or.	idue.	oride.	ygen sumed.	monia.	uminoid.	rite.	rate.	alinity to hyl Orange.	Agar.	atin.	cc.	cc.	itive.	firmed.

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 [illegible]

TABLE 2.—CHEMICAL ANALYSES OF RAW AND TREATED WATERS FROM MUNICIPAL FILTER PLANTS IN ILLINOIS.

[Parts per million.]

	Turbidity	Color	Odor	Residue	Chloride	Oxygen	Ammonia	Albuminoid	Nitrite	Nitrate	Alkalinity

TABLE 3.—BACTERIAL EXAMINATION OF RAW AND TREATED WATERS FROM MUNICIPAL FILTER PLANTS IN ILLINOIS.

		Bacteria per cc.	Gas formation in lactose broth.	Confirmation of B. coli.

[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.

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- colonie

REFERENCES

1. Abel, Mass. State Board of Health, 488 (1900); 293 (1905).
2. Bartow, J. Am. W. W. Assoc, Vol. 2, No. 1, 74-82 (1915).

3.dd 1;

Tc(8) Tc(.) Ti0 Tj5.542 Dept.000 T7(Tc(.H38 Tj2.3206oar)

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

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

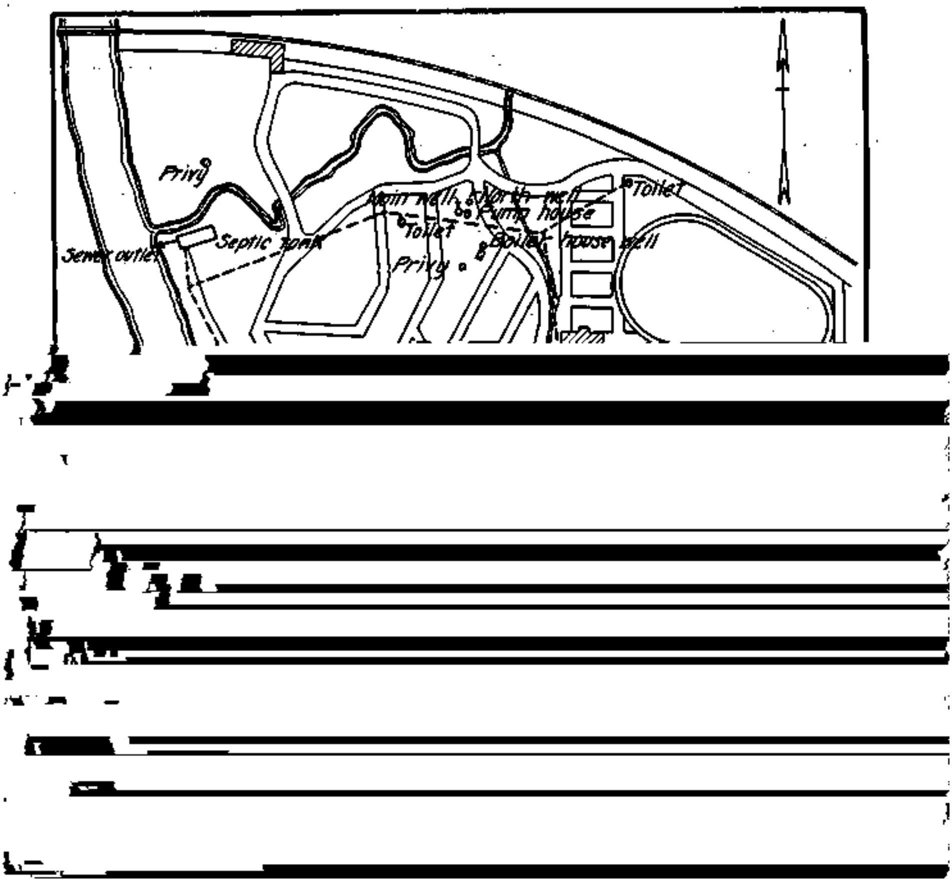


Figure 1.—Plat of Old Salem Chautauqua grounds, showing waterworks and sewer systems.

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

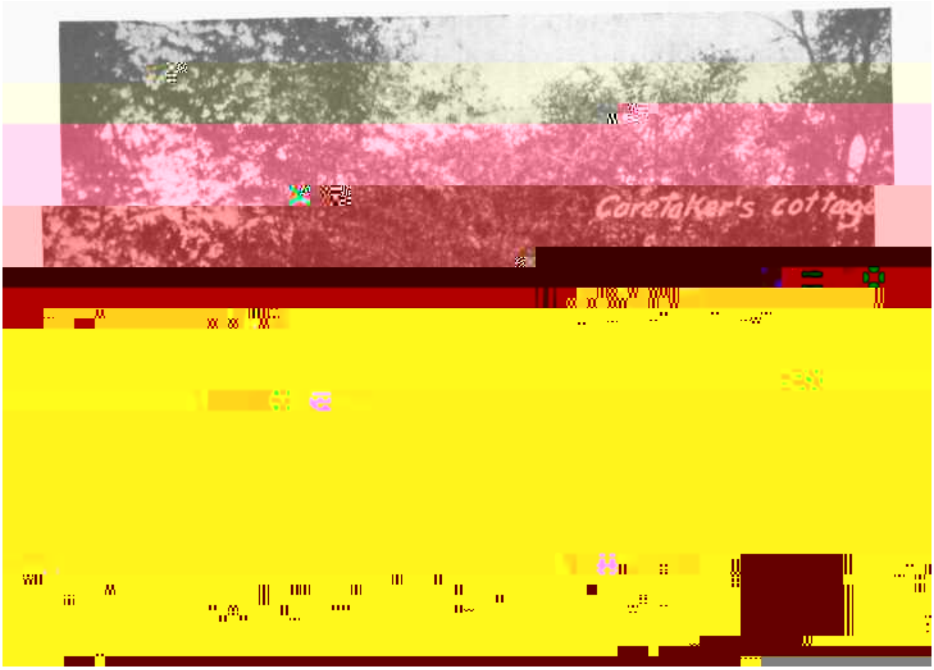


Figure 3.—Waterworks.

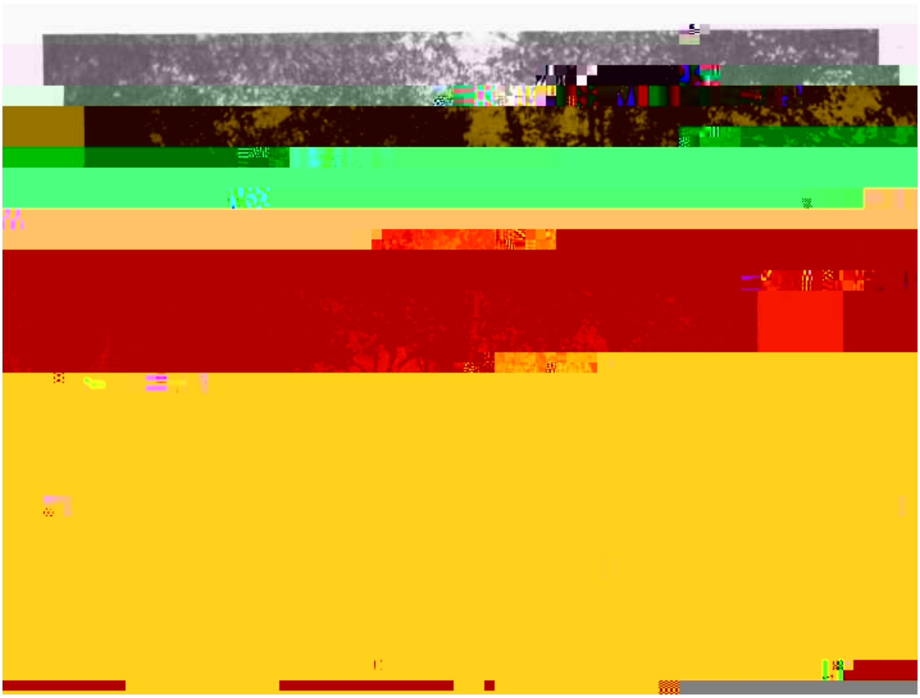
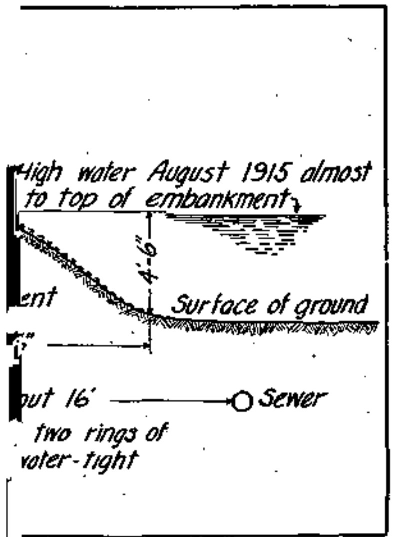


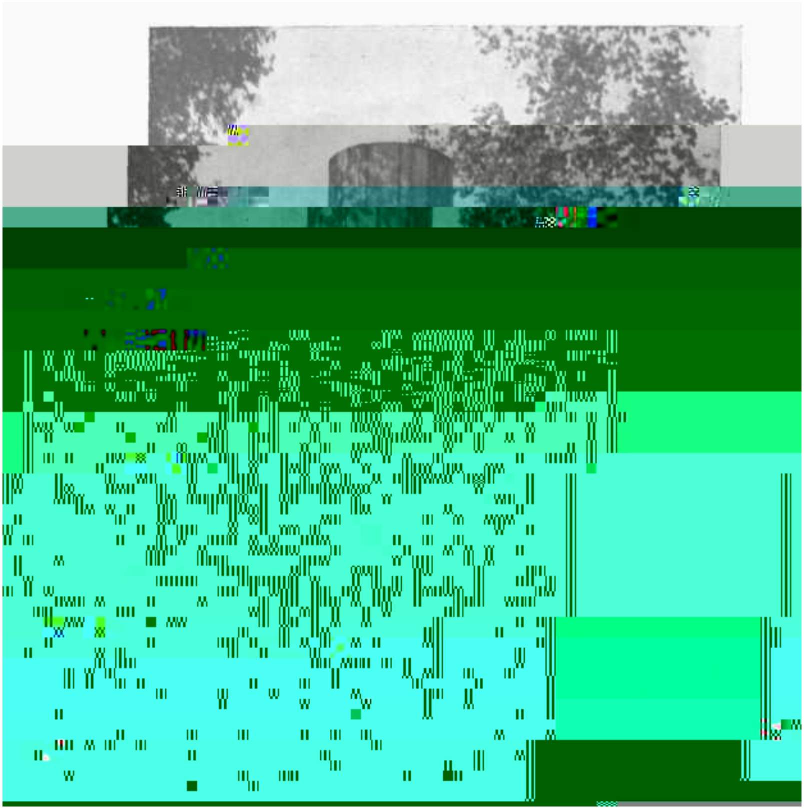
Figure 4.—Pump bouse, main well and north well.


High water August 1915 almost
to top of embankment
4'-6"
ent
Surface of ground
ut 16'
Sewer
two rings of
voter-tight

ell.

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



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

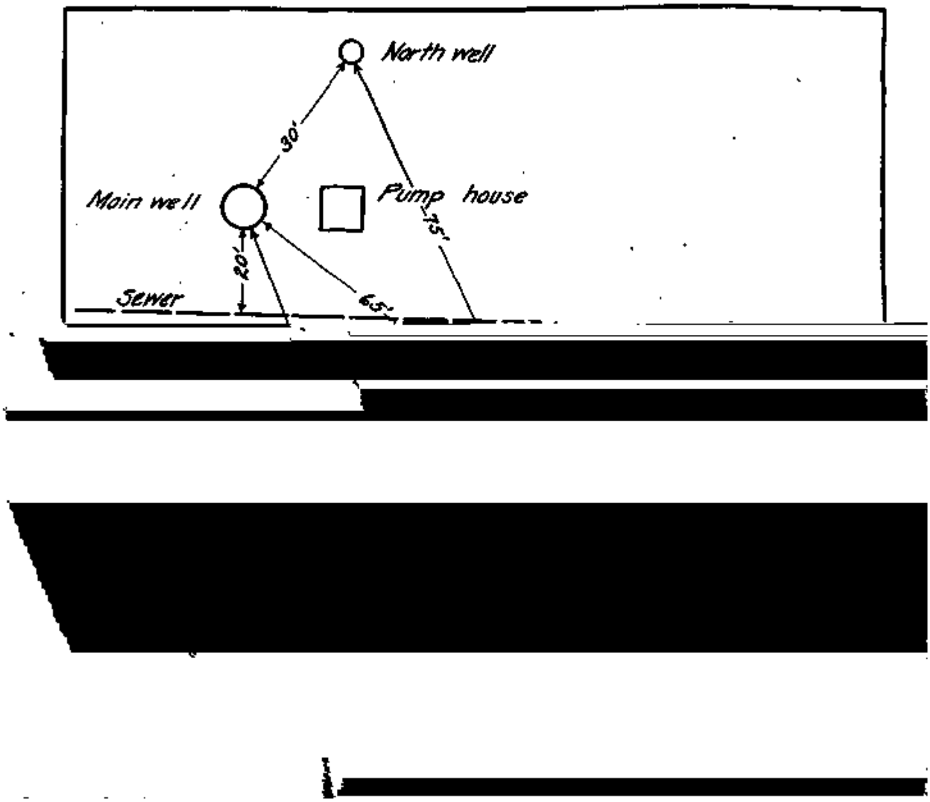


Figure 7.—Sketch showing general layout of waterworks.

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 shed 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.

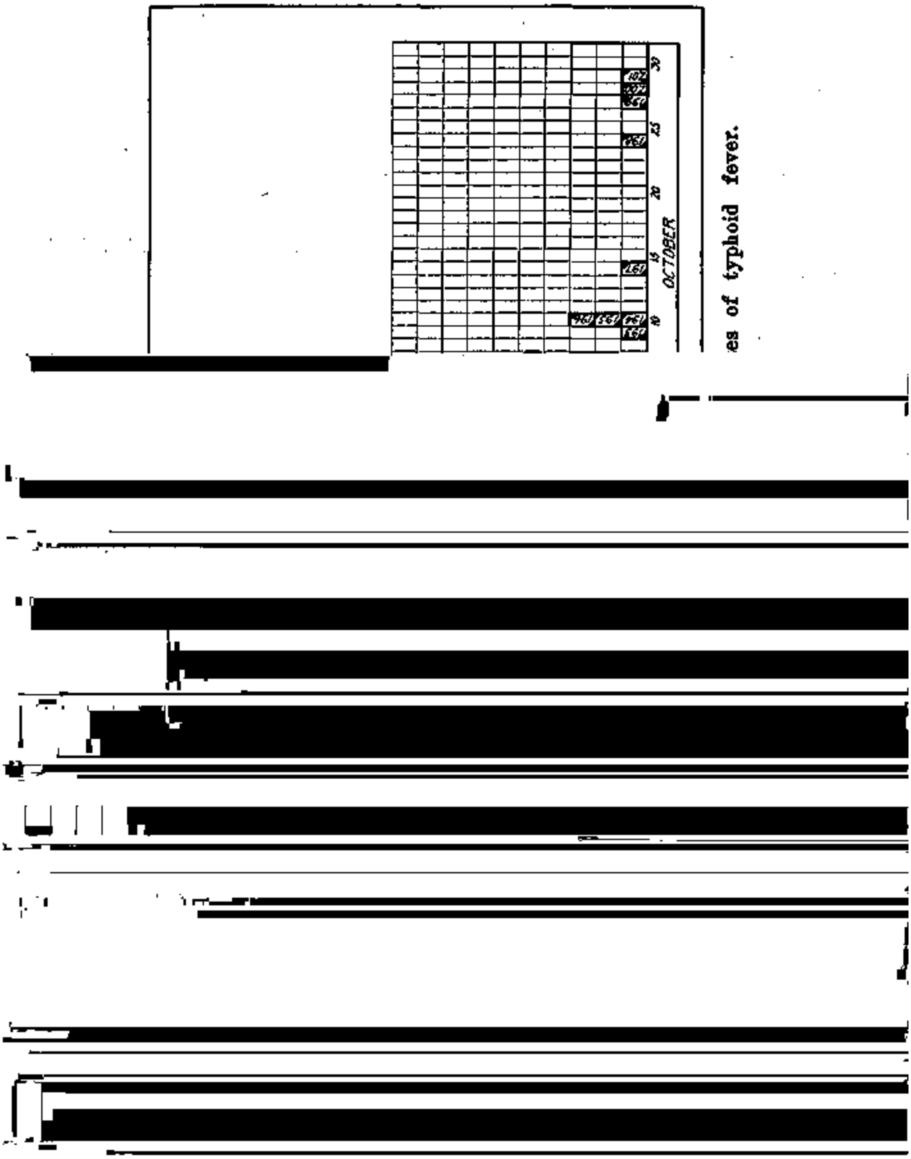
THE EPIDEMIC

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. 99.000 Tz/F1 19.000 Tcps0.3 Tw-0.thes

sur32i an71fata heav

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 which0.000 Tc(e) Tj2.345 Tw1

Notation has been made on the diagram of those cases which were of secondary origin, that is, incurred their infection from contact



es 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 coun-

TABLE 1.—DISTRIBUTION OF CASES

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		

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.

the cases have been distributed among all ages except SEXT0 Tj1.578 Tw-0.292 T

Age, Years—	Number of cases.	Per cent of total.
[illegible]	[illegible]	[illegible]

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 dayrcentages grounds e to on1.360 T

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. questions

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 i00 Tc(s) Tj1.886 Twc(sho).000 Tc(s) Tj1.369 Tw-0.093 Tc(Rivdone

2900r 0l000 sa0.000 rg48.720 158.400 Td0.000 Tw00 .000 Tz/F0 11.000 Tf0 Ts-0.093 Tc(sto

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-

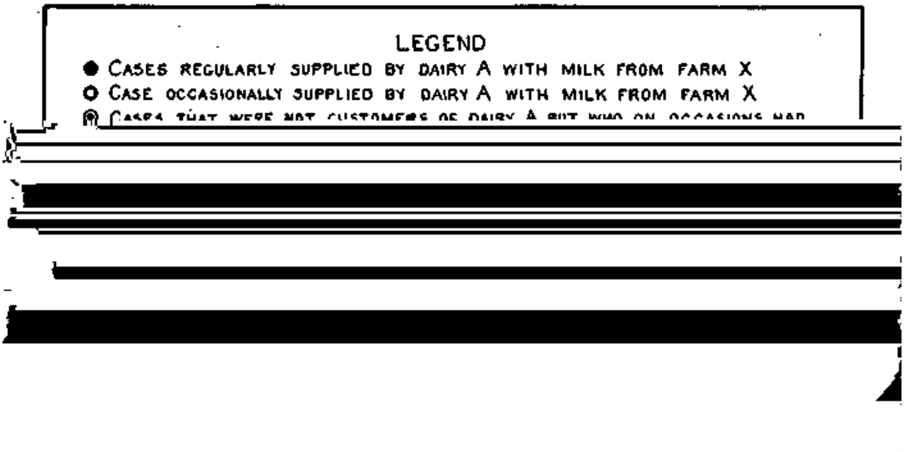
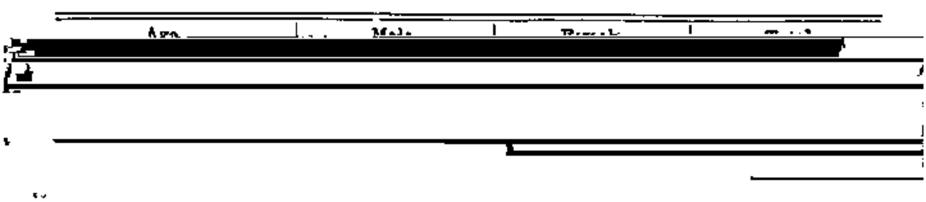


Figure 1.—Diagram showing chronological distribution of cases of typhoid fever at Park Ridge.

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 wer0 1228 Tw0.l000



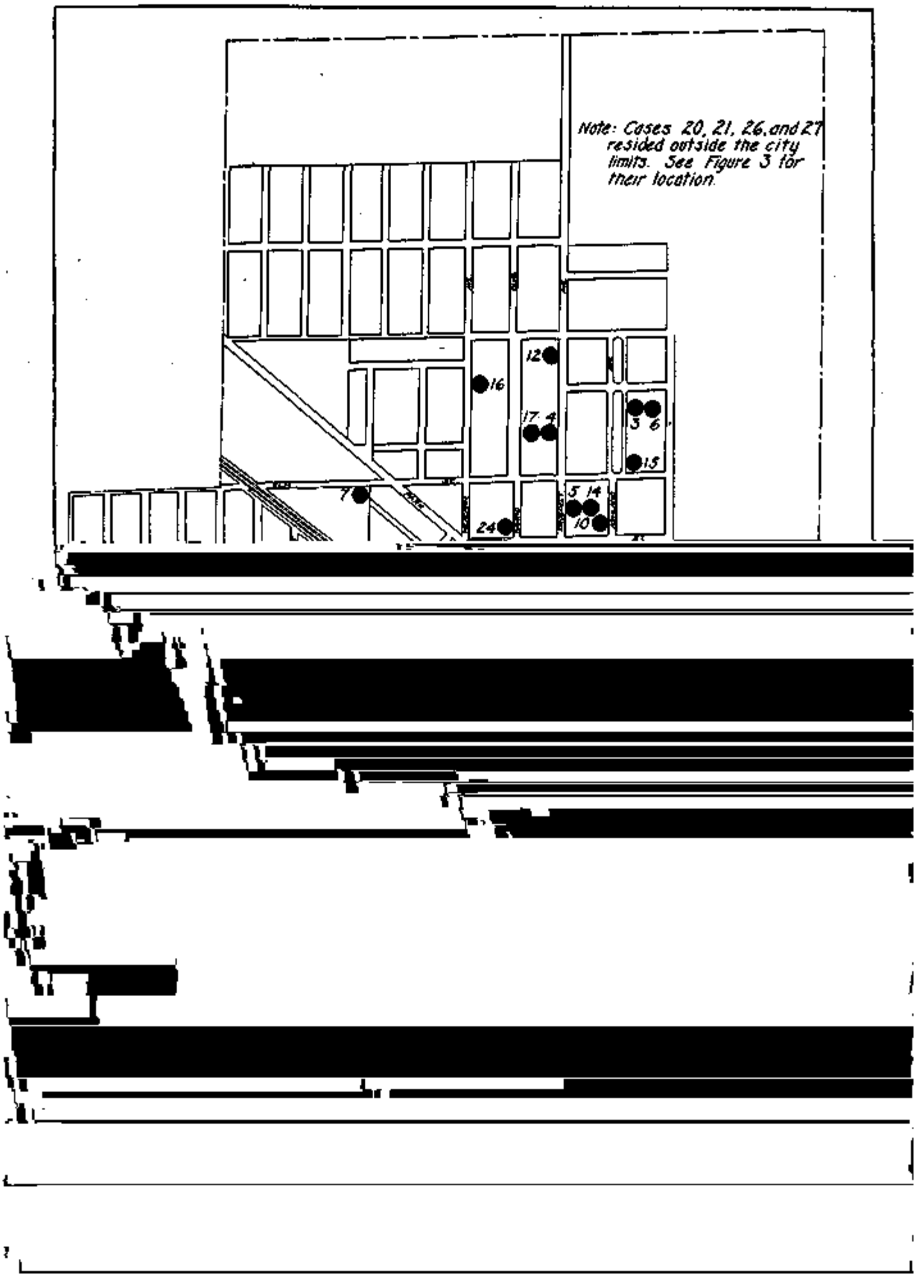


Figure 2.—Map of Park Ridge showing location of cases of typhoid fever.

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

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 SCHOO

(see Table 4 and Fig..l). 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

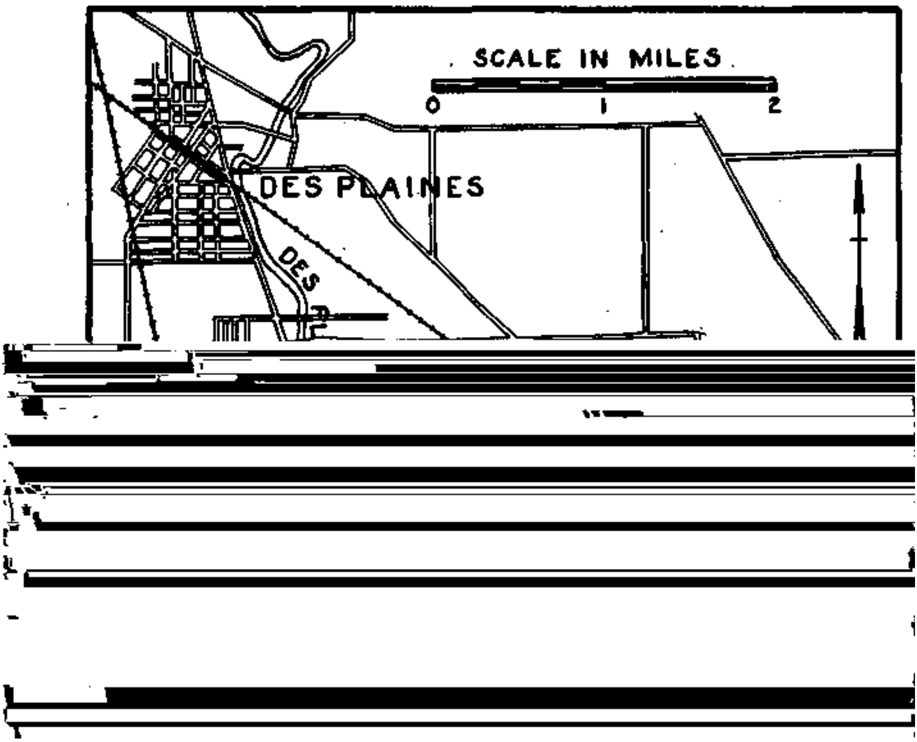
TABLE 4.—DISTRIBUTION OF CASES BY DAIRIES.

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 littases.

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 O, wer



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

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

itsiscdhemipcaolsesibelxeamfoirnaTthieocnoxydgeteenrmciinoantioinn,oanfd tfihnealgl yBeecaasu,se chemical
ptelassttwsatceorgn0o0f0, Tictjapaoarcatiec(ts)yTcj2h.a0r6a8c Ter0o.f1a06dTrci(nkkinhg)Tjw0a.t0e0r0. Tc(d) Tj21.91

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 propcohsleodritdhee5 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 consoisvteerd, oofg pwuarseldyt cdhemical 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 f00 Tc.6000 Tc(,g) Tjj1.581

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 presente

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 sodar thy

b o

THE USE OF BARIUM SALTS IN WATER TREATMENT*

By J. D. Snook and Edward Bartow.

Some municipal water supplies contain so much

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

TABLE 1.—TREATMENT OF WATER WITH VARYING AMOUNTS OF BARIUM HYDROXIDE.

[Parts per million.]

Sam-	Ba(OH)2.	Non car-	Mag-	Alkalinity.		[illegible]	[illegible]	[illegible]	Resi-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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.]

[illegible]	[illegible]	[illegible]	Non car-	[illegible]	Alkalinity.	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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

THE USE OF PERMUTIT IN WATER SOFTENING*

By J. F. Garrett and Edward Bartow.

Permutit is the name chosen to

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

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

$$2SiO_2.Al_2O_3.Na_2O + CaH_2(CO_3)_2 = 2SiO_2.Al_2O_3.CaO + 2NaHCO_3.$$

$$2SiO_2.Al_2O_3.(Ca,Mg)O + NaCl = 2SiO_2.Al_2O_3.Na_2O + (Ca,Mg)Cl_2.$$

plete 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
[illegible]	[illegible]	[illegible]

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

Residue on evaporation	672
Silica (SiO_2)	11.4
Chloride (Cl)	40.0
Sulfate (SO_4)	139.8
Potassium (K)	6.54

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

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	006	6	239.6	34
3	—216	221	12	10.1	5	228.9	33

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.

REFERENCES

1. Anders, H. G., Wochschr. Brau., 28, 78 (1910).
2. Basch, E. E., Chem. Ztg., 36, 769-70 (1912) through J. Ind. Eng. Chem., 4, 851 (1912).
3. Duggan, T. B., Eighth Internat. Cong. Applied Chem. 25, 125-9 (1912).
4. Do. Textile World Record, (Boston) March 1912.
5. Do. Textile World Record, (Boston) November, 1912.
6. Ford, W. E., Dana's Manual of Mineralogy (New York) 267 (1915).
7. Gans, E., Chem. Eev. Fett-. Harz-. Ind., 16, 300-2 (1909).
8. Do. Tiber die technische Bedeutung der Permutit (der künstlichen zeolithartigen Verbindungen). Chem. Ind. 32, 197-200 (1909).
9. Kinniard, E. N., Experiment with natural water-softening zeolite, Eng. Bee, 72, 794 (1915).
10. Wheaton, H. J., National Laundry Journal, March 15, 1912.
11. Do. National Laundry Journal, May 091 Tw0.161 Tc(Marc) T325NT

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 w i t

lowing relation should hold: $\frac{dO}{dt} = KOC$. **O is the amount of oxygen**

formula becomes: $\log \frac{O'}{O} = KCt$ **expressed in parts per million.**

efficient, $K = \frac{1}{Ct} \log \frac{O'}{O}$, remains fairly constant when the per cent 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

Time. [Hours.]	Dissolved oxygen. Initial. [Parts per million.]	Dissolved oxygen. Loss.	Per cent loss.	Loss per hour.	Oxygen demand. Loss/Dilution. [P. p. m.]	Oxygen demand. Loss per hr./Dilution. [P. p. m. per hour.]	K.
			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

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.				
THREE PER CENT SEWAGE.						
0	8.62	....	....	287	....	.....

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	.00143
7	4.82	3.54	42		354	.00142
8	4.40	3.96	47		396	.00145
9	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

Per	SERIES I.		SERIES II.		SERIES III.		SERIES IV.	
	Oxygen Demand.		Oxygen Demand.		Oxygen Demand.		Oxygen Demand.	

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.

REFERENCES

1. Adeney, W. E., Fifth Report, Royal Commission on Sewage Disposal. London, England. 11 (1908).
2 Do. Transactions, Royal Dublin Society, 6, 539 (1895).
3. Buswell, A. M., J. Ind. Eng. Chem., 6, 325 (1914).
4. Chick, H., Journal of Hygiene, 8, 92 (1908).
5. Clark, H. W., Report Mass. St. Bd. of H., Lawrence, Mass. 389 (1900).
6. Dupre, E. F., Report of Local Government Board, London, England. 14, 238 (1884).
7. Fowler, G. J., Sewage Works Analysis, Manchester, England. 82 (1902).
8. Frankland, Edward, First Report, Rivers Pollution Commission, London, England. 20 (1868).
9. Geradin, A., Compt. Rend., 40, 989 (1875).
10. Hoover, C.P., Eng. News., 65, 311. (1911).
11. Jackson, D. D.,'and Horton, W. A., J. Ind. Eng. Chem., 1, 328 (1909).
12. Lederer, A., Am. J. Pub. Health, 2, 99 (1912).
13. Müller, A. R., Arb. a. d. Kaiserl. Gesund., 38, 294 (1912).
14. Phelps, E. B., and Black, W. M., Report on the discharge of sewage into New York Harbor, New York. 65 (1911).
15. Do. Am. J. Pub. Health, 3, 527 (1913).
16. Pleiszner, W. E., Arb. a. d. Kaiserl. Gesund., 34, 230 (1910).
17. Spitta, Oscar, Archiv. fur Hyg., 38, 160 (1900).
18. Do. Archiv. fur Hyg., 38, 2Tc(11) Tj0.000w Tc(,) Tj3.207 Tw-07S (1900ol(

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,d is

super-

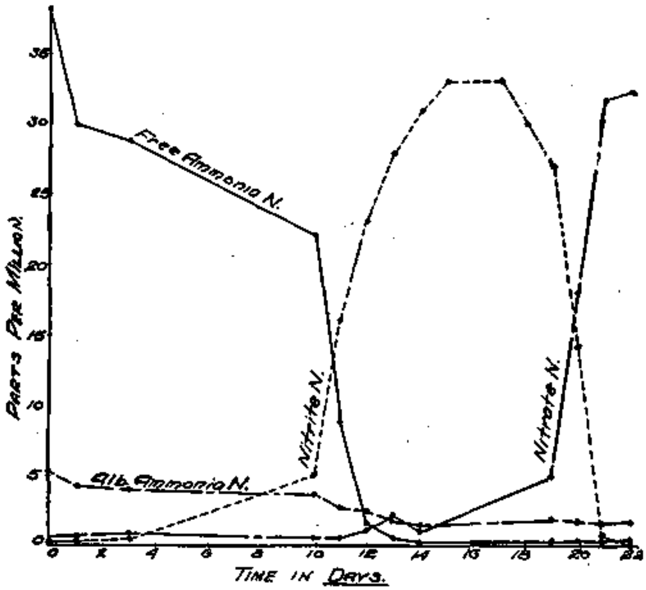


Figure 1.—Nitrification of sewage. No activated sludge present.

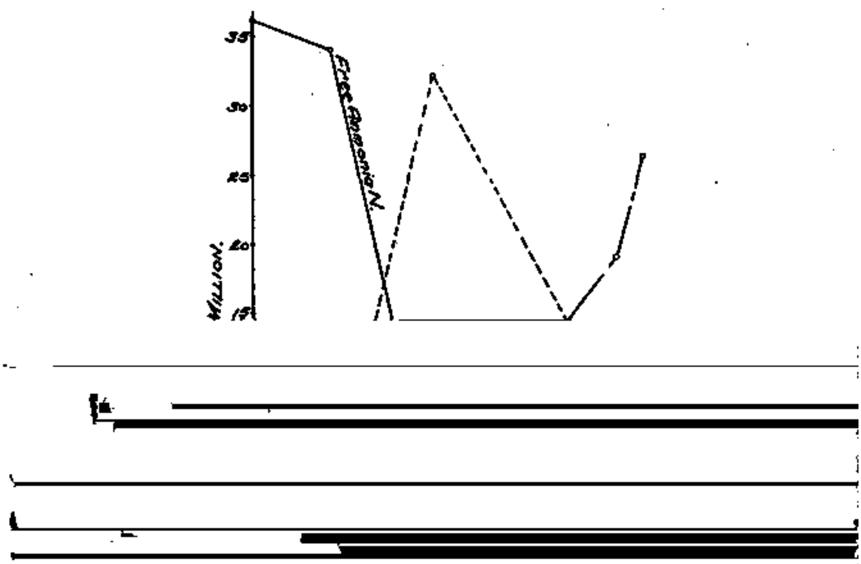


Figure 2.—Nitrification of sewage. No activated sludge present. Uniform distribution of air through porous plate.

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.

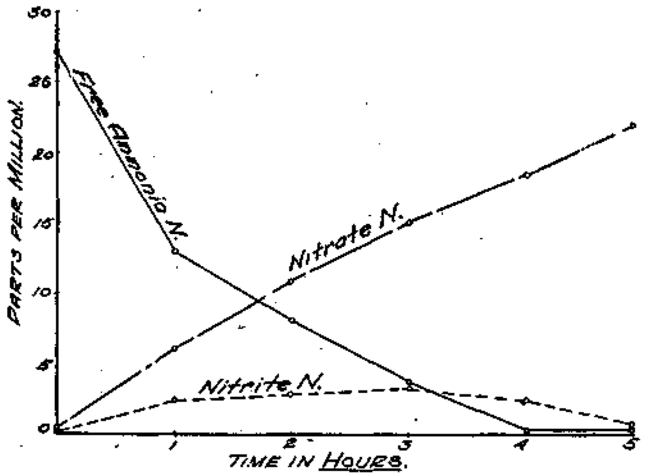
[Parts per million.]

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	23.00	1.00
B—NO ACTIVATED SLUDGE PRESENT: UNIFORM DISTRIBUTION OF AIR THROUGH POROUS PLATE.					

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 examina-



Free Ammonia N.
Nitrate N.
Nitrite N.
PARTS PER MILLION.
TIME IN HOURS.

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.

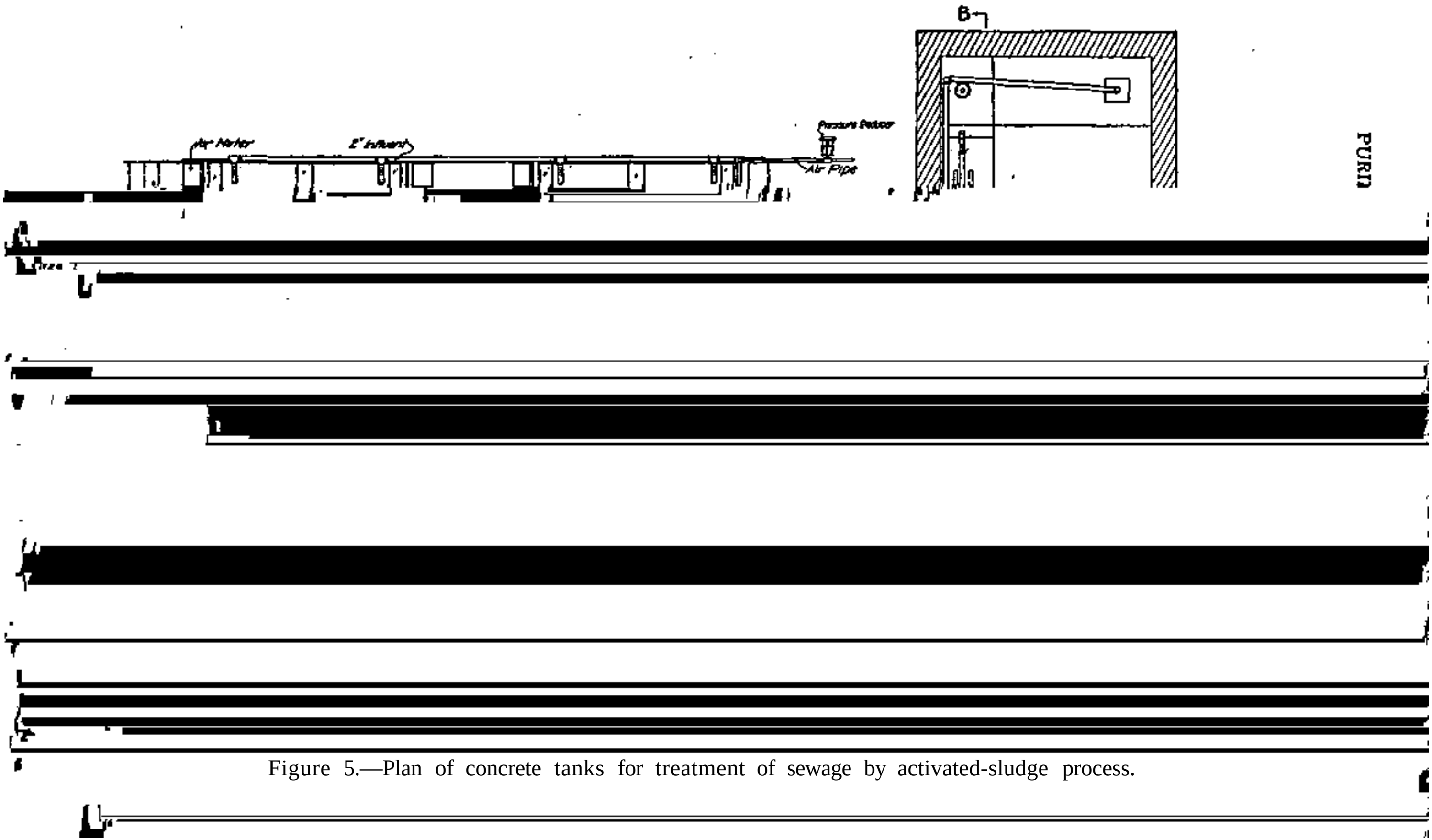


Figure 5.—Plan of concrete tanks for treatment of sewage by activated-sludge process.

boilers and conditions were similar to those which would be obtained 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.OI

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.

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 cond9dhi cond9dhi 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 thee

e

"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

Soil.	Milligrams nitrate produced. Without sludge.	With sludge.
Anaheim	6.0	10.0
Davis	4.2	14.0
Oakley	2.2	4.0

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.	[illegible] meal.	Potassium sulfate.	Activated sludge.	Extracted sludge.	Dried blood.
1	19.820	60	6[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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

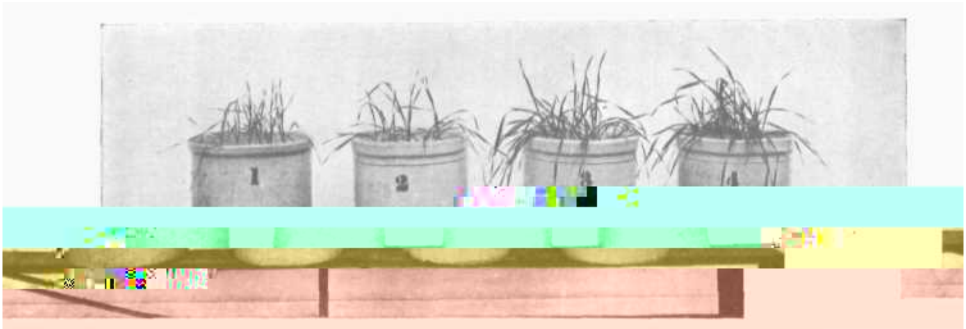


Figure 1.—Pot culture of wheat twenty-three days after planting.

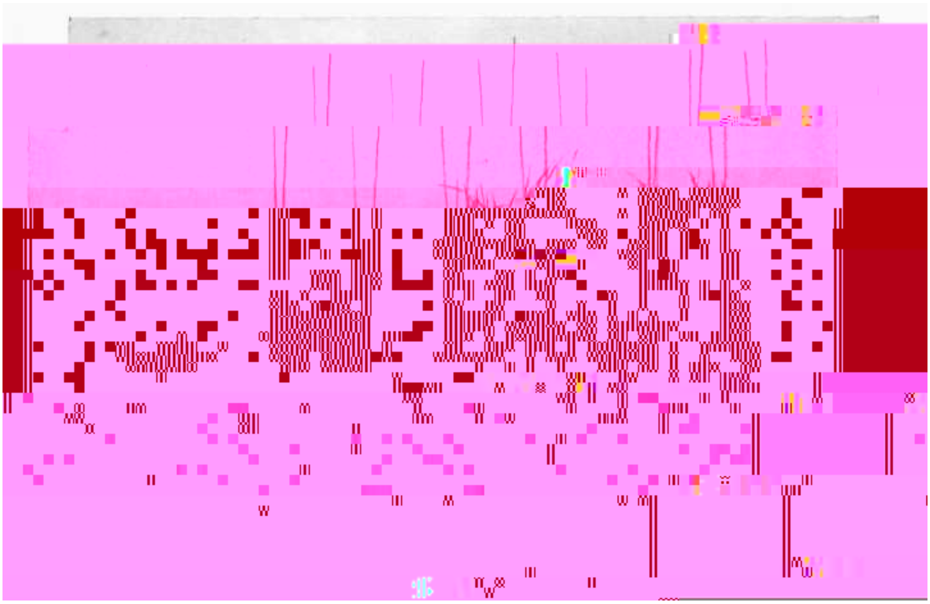
Each pot contains pure white sand to which the same amount of plant foods except nitrogen has been added. No. 3 contains 20 g. dried activated sludge. No. 4 contains the same amount extracted with ligroin. No. 2 contains an equivalent of nitrogen from dried blood and No. 1 contains no nitrogen.

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.	Ether soluble. 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.

ACTIVATED SLUDGE AS A



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 plant

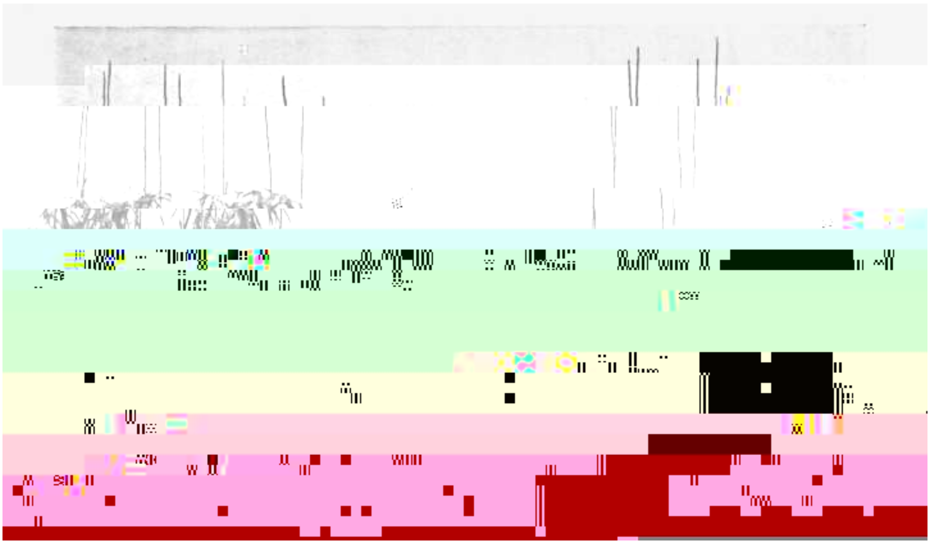


TABLE 1.—AMOUNTS OF WHEAT AND STRAW OBTAINED IN THE FIRST SERIES OF POT CULTURES.

		Yield.			Yield of straw.		
[illegible]	[illegible]	[illegible]	[illegible]	Bu. per A.	Av. stalk.	[illegible]	Tons per A.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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.

Plot.	Treatment.	Wt. of lettuce.	Wt. of radishes.
1	None	4.5 g.	28.4 g.
2	Sludge	6.3 g.	63.0 g.
3	Extracted sludge	6.8 g.	68.0 g.

gen 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.

REFERENCES

1. Anon., Disposal of sewage sludge: Surveyor, 42, 602 (1912).
2. Bach and Frank, Fresh sludge and decomposed sludge: Eng. Eecord, 68, 331 (1913).
3. Bartow, E., and Mohlman, F. W., Purification of sewage by aeration in the presence of activated sludge: J. Ind. Eng. Chem., 7, 318 (1915).
4. British Royal Commission on Sewage Disposal, 5th Report (1908).
5. Clark, H. W., Monthly bull. State Board of Health of Massachusetts, Dec, 1913.
6. Fuller, G. W., Sewage disposal, New York, 449-59 Tw-0.29C71.520 429.840 Td0.t1e Y0

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 whichn verd af 8uspendetfI Tj0.546 Tw0.nhowe(y) Tj0.971 Tw0.214 Tc(an) T

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 ...

ofur(r) Tj1.247 Tw-0.028 T2.36n7the

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 nuisancsh wil

The experimental work described in this paper was undertaken primarily to but is so much improved in quality that it 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
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The worms had disappeared on the sixth day. A small amount of nitrite developed smalb OF

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 minxt18s000 0.00w-0.115agr47 f2w47 f2 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 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 pur 0.000 0000 0.000 rg64.7 purh

Variety.	Group number.	Variety.	Group number.	Variety.	Group number.
1	111.2223022	6	111.2222012	10	111.2222818

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.

REFERENCES

1. Ardern, E. and Lockett, W. T., The oxidation of sewage without the aid of filters: J. Soe. Ohem. Ind. 33, 523-39, 1122-4 (1914).
2. Bartow, E. and Mohlman, F. W., Purification of sewage by aeration in the presence of activated sludge: J. Ind. Eng. Chem., 7, 318 (1915).
3. Beesley, R. M., Experiments on the rate of nitrification: J. Chem Soc., 105, 1014 (1914).
4. Boullanger and Massol, Calmette et Confreres, 1, 89 (1898).
5. Centralblatt für Bakt., Abt., 21, 84.
6. Clark, H. W. and Gage, 8. DeM., Experiments on the purification of sewage and water at the Lawrence experiment station: Massachusetts State Board of Health, Annual report 44, 290-92 (1912); 45, 288-304 (1913).
7. Dibdin, W. J.,e nitrobacssCMassachusetts o

18. Mills, H. F., Filtration of sewage and water at the Lawrence experiment station: Massachusetts State Board of Health, Report for 1888-9 (1890).

19. Moigno, Abbe F., Mouras' automatic scavenger: Inst. of 0. E., 68, 35(Mills) 10.000

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

*Abstract of thesis submitted in partial fulfillment of requirements for the degree of Master of Science by H. J. Weiland, June 1915. The authors wish to thank C. B. Anderson, of the Illinois State Geological Survey, for his cooperation and sympathetic interest, and to thank all the owners of industral plants in Chicago and vicinity who contributed in an

rock in which are numerous fossils

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

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	Yield.	Pumpage.	Method of pumping.	Place of collection.	Content of hydrogen

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
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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 watersy is

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 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

.000 rg63.600 380.880 Td80.vcEinine Ods2

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	1.35
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

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 possibly 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.nett, on ogf6 fivrr.s 71n.W.....

Whittaker, H. A. Hypochlorite treatment of water supplies.

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.)

Lac 0.191 TsTc ters

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

fev rg45.120 2970.125 Td0.000 Tw99.005 3Tz/F20 8.000 Tf0 Ts-0.263s0.0sewaget at.... sew Tw0.0112