UNIVERSITY OF ILLINOIS BULLETIN

VOL. 8 FEBRUARY 6, 1911 No. 23

(ENTERED AT URBANA, ILLINOIS, AS SECOND-CLASS MATTER)

CHEMICAL AND BIOLOGICAL SURVEY OF THE WATERS OF ILLINOIS

REPORT FOR 1909 AND 1910

EDWARD BARTOW
DIRECTOR

WATER SURVEY SERIES No. 8

URBANA, ILLINOIS
PUBLISHED BY THE
UNIVERSITY

PUBLICATIONS OF THE STATE WATER SURVEY.

No. I. Chemical Survey of the Waters of Illinois. Preliminary Report. 98 pp., 3 pl., I map. 1897. (Out of print).

No. 2. Chemical Survey of the Waters of Illinois. Report for the years 1897-1903. XVI+254 pp., 44 pl. 1904. (Out of print).

No. 3. Chemical and Biological Survey of the Waters of Illinois. Report for year ending August 31, 1906 30 pp., 5 cuts. 1906.

No. 4. Mineral Content of Illinois Waters. VIII+192 pp. 1908.

No. 5. Municipal Water Supplies of Illinois. VIII+123 pp. Map. 1907. (Out of Print.)

No. 6. Chemical and Biological Survey of the Waters of Illinois. Report, September I, 1906, to December 31, 1907. 88 pp., 3 cuts, 9 pl. 1908.

No. 7. Chemical and Biological Survey of the Waters of Illinois. Report for 1908. 204 pp., 4 cuts. 1909.

No. 8. Chemical and Biological Survey of the Waters of Illinois. Report for 1909 and 1910. 150 pp. 1911. Price 75 cents.

NOTE—For copies of these reports or information address, Director, State Water Survey, University of Illinois, Urbana, Illinois.

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FLANIGAN-PEARSON CO.
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Samuel Wilson Parr, M.S	Consulting Chemist
Arthur Newell Talbot, C.E	Consulting Engineer
*Lewis Isaac Birdsall, B. A	Chemist
**Frank Bachmann	Bacteriologist
**Andrew Jacobson, B. S	Chemist
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‡ Walter Bernreuter, B. S.	Bacteriologist
Benjamin Harrison, B. S	Laboratory Assistant
† Andrew Clifford Wilkins	Clerk
††Carmen Florence Harnack	Clerk
†††Marie Jester	Stenographer

BOARD OF TRUSTEES OF THE UNIVERSITY OF ILLINOIS,

1911-1912.

*To Sept. 1909
**To June 1910
***From June 1909
†To Feb. 1910
††From May 1909
†††From Feb. 1910
‡From June 1910

LETTER OF TRANSMITTAL.

STATE WATER SURVEY.

UNIVERSITY OF ILLINOIS,
Urbana, Illinois, February 1, 1911.

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

SIR: Herewith I submit a report of the work of the State Water Survey for two years ending December 31, 1908 and request that it be printed as a bulletin of the University of Illinois, State Water Survey Series No. 8.

The report includes a description of the work done in the laboratory during the period stated. It includes a summary by years of the work done since the foundation of the Survey and a summary by months of the waters analyzed during the past two years. It includes also severa1 special articles which describe the experimental work done in the laboratory.

Thanks are due to the regular laboratory staff for the interest taken in the work described in this bulletin and to G. A. Van Brunt and W. C. Marti for their assistance in the prepartation of special articles. Credit is given in appropiate places for the part each has taken.

Respectfully Submitted,
EDWARD BARTOW,
Director.

GENERAL REPORT.

GENERAL STATEMENT FOR TWO YEARS.

January 1909 to December 1910.

From the time of its foundation in September 1895 to December 31, 1910, the State Water Survey has received 21715 samples of water. Of these 12457 were sent by private citizens, health officers or water works officials. The remaining samples, with the exception of 2,800, collected in connection with the investigation of the Chicago Drainage Canal, have been collected by members of the staff or under their direction for the study of special problems. During the year 1909, 1724 samples were received, 1651 having been sent to the laboratories by health officers or private citizens. During the year 1910, 1302 samples were received, 1201 having been sent by private citizens, health officers or water works officials. The number received from outside parties was greater in 1909 than in any previous year except 1900. (See Table I) The number of such samples received during each year, 1908 and 1909, was greater than the total number examined during any preceeding year except in 1898 and 1899 when analyses were being made for the Sanitary District of Chicago. The demand for this work for outside parties had become so great that almost the entire time of the staff was occupied, leaving no time for special surveys. Owing to the fact that the 46th General Assembly decreased the appropriation for the work of the Water Survey, it was impossible to make, free of charge, analyses for all who desired such work. Beginning with July 1910 a small fee was charged to cover the cost of analyses. Owing to this charge the number of samples sent in by outside parties dropped. The effect of the charge is seen in the decrease of the number of analyses to 410, during the latter half of 1910 compared with 1072 during the latter half of 1909.

The decrease in the appropriation made it necessary to employ one less assistant and to transfer the Director for part of his time to the Division of Analytical Chemistry. No report for 1909 could be published owing to the lack of funds for the printing and lack of assistance in the compilation. The money received from the fees allows the employment of additional assistants and the compilation and printing of this report.

During the period no change has been made in the methods of sanitary analysis and there has been no change in the circular entitled

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

SOURCES	October 1895 to Dec. 31	YEARS .														Total for each source
	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	
Surface waters, rivers, lakes and ponds	69	72	102	54	59	61	97	75	80	107	304	336	356	372	428	2572
Springs	16	21	34	23	22	35	28	18	28	41	63	52	68	62	41	552
Cisterns	12	19	17	7	7	3	10	6	7	5	13	29	28	31	21	215
Natural ice	4	12	1	11	9	4	9	3	12	6	……..	1	5	1	12	90
Artificial ice	……..	1	……..	2	1	……..	1	1	1	……..	4	……..	……..	0	0	11
Water for artificial ice	3	……..	……..	3	……..	1	1	……..	5	2	1	……..	1	2	0	19
Water for natural ice	……..	2	……..	……..	……..	3	1	1	2	……..	6	……..	……..	3	0	18
Shallow wells in rock	28	16	8	22	12	22	10	17	25	25	19	45	32	53	43	377
Deep wells in rock	58	48	34	26	36	56	59	23	28	66	170	159	258	345	207	1373
Flowing wells in rock	45	8	16	12	13	14	3	8	9	11	22	17	43	3	2	226
Shallow wells in drift	500	245	168	243	274	209	243	245	270	292	142	514	683	614	344	5286
Deep wells in drift	64	68	43	30	24	36	63	54	51	40	114	154	160	159	95	1155
Flowing wells in drift	63	5	4	9	4	……..	3	5	5	12	19	25	2	1	7	164
Sewage	37	……..	21	25	10	……..	1	7	2	6	5	33	46	5	1	199
Total samples from citizens	899	517	448	467	471	444	529	463	525	613	1182	1365	1682	1651	1201	12457
Other samples	888	811	988	1579	1866	778	147	418	555	466	445	55	87	73	101	9258
Total for year	1787	1328	1436	2046	2337	1222	676	882	1080	1079	1627	1420	1769	1724	1302	21715

"Interpretation of Results". This circular is not reprinted in this bulletin but may be obtained by application to the Director of the Survey.

We have followed the method of classification used in previous bulletins and show in Table I the number of waters examined at the request of private citizens or health officers since the foundation of the Survey. For the whole period the number of waters from shallow wells is the greatest. This is no doubt due to the fact that the individual supplies are more frequently obtained from shallow wells, and because such wells are more frequently polluted. Surface waters are next in number; because of the frequent control necessary on account of the variation of the character of a surface water with the seasons. During the dry season the suspended matter decreases, the soluble matter increases. While during a wet season there is a larger amount of matter in suspension and less matter in solution.

During the year 1910, the number of waters from shallow wells decreased whereas the number of waters from surface supplies increased. This we judge is due to the fee charged. The private citizen, even though suspecting his well, is often unwilling to pay the fee, whereas the water department or water company desiring analyses for filter control does not hesitate to pay the charges.

In Tables II and III the summary of analyses is given by months for the years 1909 and 1910. As in previous years, the greatest demand for analyses was during the summer and autumn. The minimum number of samples was sent to the laboratory in January of 1909. Fewer samples were received monthly after July 1910 when we began charging for analytical work.

1724 samples of water were received for examination during the year 1909. There were made 1383 sanitary-chemical examinations, 1541 bacteriological examinations, 47 analyses for the determination of the composition of the mineral content, and 70 special examinations for the determination of the character of micro-organisms or for the determination of the value of the water for use in boilers. Of the samples examined, 299 were sent in by representatives of Boards of Health, 310 by physicians, 611 by private citizens and 441 by authorities in charge of city supplies. Wells and springs furnished 1273 samples. 372 were surface waters; 32 were from cisterns; 4 were samples of sewage; 4 were samples of ice, or water from which ice is made, and 69 were miscellaneous samples.

Of the 1302 samples of water received for examination during 1910, 971 sanitary-chemical examinations and 194 bacteriological examinations were made. 55 analyses were made to determine the mineral composition of these waters and 62 special examinations were made to determine the character of micro-organisms or to determine

TABLE II, SHOWING THE NUMBER OF WATER SAMPLES EXAMINED BY REQUEST DURING THE YEAR ENDING DECEMBER 31, 1909, ARRANGED BY MONTHS ACCORDING TO THE NATURE OF THE SOURCE.

SOURCES	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Surface waters, rivers, lakes and ponds	26	26	31	23	33	35	32	31	28	26	32	49	372
Springs	1	6	4	3	8	2	9	9	4	5	10	1	62
Cisterns	1	2	4	0	3	2	1	6	6	2	4	0	31
Natural ice	1	0	0	0	0	0	0	0	0	0	0	0	1
Artificial ice	0	0	0	0	0	0	0	0	0	0	0	0	0
Water for artificial ice	0	0	0	0	0	0	1	0	1	0	0	0	2
Water for natural ice	0	0	0	0	0	0	1	1	1	0	0	0	3
Shallow wells in rock	4	3	1	2	6	1	8	6	7	9	4	2	53
Deep wells in rock	13	21	23	19	22	45	36	50	28	37	32	19	345
Flowing wells in rock	1	0	0	0	1	0	0	0	0	1	0	0	3
Shallow wells in drift	24	33	28	30	27	58	57	77	100	71	76	33	614
Deep wells in drift	9	7	13	8	9	7	7	29	29	14	14	13	159
Flowing wells in drift	0	0	0	0	0	0	1	0	0	0	0	0	1
Sewage	0	0	0	0	0	2	0	0	1	0	1	0	4
Total samples by request	80	98	104	85	109	152	153	209	205	165	173	117	1650
Other samples	12	9	4	3	1	2	0	0	1	0	14	27	73
TOTAL FOR THE MONTH	92	107	108	88	110	154	153	209	206	165	187	144	1723
Bacteriological analyses	77	98	98	62	99	146	148	196	198	145	159	115	1541
Mineral analyses	5	4	6	2	6	4	8	2	4	1	4	3	49

TABLE III, SHOWING THE NUMBER OF WATER SAMPLES EXAMINED BY REQUEST DURING THE YEAR ENDING DECEMBER 31, 1910, ARRANGED BY MONTHS ACCORDING TO THE NATURE OF THE SOURCE.

SOURCES	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Surface waters, rivers, lakes and ponds	39	58	54	54	67	51	29	10	21	11	12	22	428
Springs	2	0	4	9	6	4	1	2	2	7	2	2	41
Cisterns	2	1	1	5	1	3	1	0	0	5	1	1	21
Natural ice	2	1	6	0	1	1	0	0	0	0	0	1	12
Artificial ice	0	0	0	0	0	0	0	0	0	0	0	0	0
Water for artificial ice	0	0	0	0	0	0	0	0	0	0	0	0	0
Water for natural ice	0	0	0	0	0	0	0	0	0	0	0	0	0
Shallow wells in rock	8	0	4	3	3	1	7	2	3	10	1	1	43
Deep wells in rock	10	11	17	24	30	31	26	8	10	27	6	7	207
Flowing wells in rock	0	0	0	1	0	0	0	0	0	1	0	0	2
Shallow wells in drift	19	33	40	36	38	55	37	20	17	16	21	12	344
Deep wells in drift	4	5	8	12	2	18	13	8	4	9	4	8	95
Flowing wells in drift	0	0	0	3	2	0	0	1	0	0	1	0	7
Sewage	0	0	1	0	0	0	0	0	0	0	0	0	1
Total samples by request	86	109	135	147	150	164	114	51	57	86	48	54	1201
Other samples	24	5	26	3	10	3	18	4	0	7	0	1	101
Total for the month	110	114	161	150	160	167	132	55	57	93	48	55	1302
Bacteriological analyses	87	108	150	146	153	167	119	54	52	89	42	51	1218
Mineral analyses	7	2	1	8	8	3	4	2	4	3	1	12	55

the value of the water in boilers. Of the samples examined, 170 were sent in by representatives of Boards of Health, 203 by physicians, 507 by private citizens and 352 by authorities in charge of city supplies. There were 752 samples collected from wells and springs; 428 were surface waters; 21 were from cisterns; 12 were samples of ice or water from which ice is made; and 24 were miscellaneous samples.

The following table gives a summary showing the relative purity of water from wells of different depths.

SUMMARIES FOR 1909 AND 1910.

1909

	Depth.					
	Under 25′	25′-50′	50′-100′	Over 100′	Unknown	Total
Number examined	242	354	161	376	72	1137
Number condemned	183	226	54	62	38	573
Per cent condemned	75+	63+	33+	16+	52+	50+

1910

	Depth.					
	Under 25′	25′-50′	50′-100′	Over 100′	Unknown	Total
Number examined	148	201	90	205	67	711
Number condemned	118	137	46	43	35	379
Per cent condemned	79+	65+	51+	20+	52+	53+

A comparison of the percentage of well-waters condemned during the year 1909 with those condemned in 1910 shows practically the same percentage of polluted water. A similar percentage of the well water examined during 1908 was condemned*. It may be said that the relative purity of the water from these wells varies with the depths. 75% of those less than 77 ft. were condemned, whereas only 18% of those 100 ft. deep or more were condemned. We should note that some of these deep wells were condemned because of high mineral content and not because of any possibility of the presence of disease bearing organisms. While these tables are very suggestive we believe that they do not give a true idea of the general condition of the well waters of the State; because the majority of the samples sent to the Water Survey are sent because of suspected contamination. There were 638 of these samples reported as having been collected from wells within 100 feet of privies, 307 were from wells located within 100 ft. of stables; 236 were near dumping grounds for slops; 112 were near cess pools; and 136 were located in or near feed lots.

The work done by the Water Survey has been distributed over practically the whole of the State. Since the Survey was organized samples have been sent to the Survey from 971 towns scattered through all of the 102 counties of the State. During the year 1909 samples

*University of Illinois bulletin. State Water Survey Series No. 7, p. 10.

were sent to the Survey from 306 towns in 92 counties. During the year 1910 samples were sent to the Survey from 252 towns in 86 counties.

The Water Survey should be used as a clearing house by water-works officials. The business of furnishing water is different from the ordinary lines of business in that there is no competition between water-works of different towns. Information obtained by one company may help another company without injury to the first. If information is obtained by the Water Survey of assistance to one plant, it should be the Water Survey's business to pass the good word along to plants in similar situations. If water-works officials state their troubles to the State Water Survey, it will help to the best of its ability. It should have sufficient help to work out any problem presented. There should be engineers in addition to the chemists and bacteriologists. It is not meant that there should be engineers who should look after the construction of the water-works plant, but engineers who should give suggestions as to the best methods of engineering work and who should inspect and approve plans for new construction.

A conservative estimate of the value of the water-works plants of the State outside of Chicago indicates that upwards of $15,600,000 is invested. Not only is a considerable *sum* of money involved but also the *health* and *welfare* of a large proportion of the inhabitants. In the towns outside of Chicago that are supplied by water-works there are 1,129,000 people. This represents an investment of $13.85 for each person. With this amount of capital invested and wtih so many people needing pure water there should be a State Bureau with sufficient personnel and equipment.

Sixty water supplies obtain their water from streams. The water-works officials of these supplies, whether they be owned by private companies or by the municipalities, have a common problem, namely, stream pollution. The more pollution there is in the streams the more difficult it is to filter the water and the more liability there is that contamination may pass the filters into the water supply. The company or officials will then be blamed for the difficulty. The water-works men, not only those who use stream supplies, but all others, should demand the passage of a streams pollution bill. Laws have been passed in Ohio and Indiana, which could well be imitated in Illinois.

CO-OPERATION WITH THE STATE BOARD OF HEALTH.

The co-operation with the State Board of Health was continued through the years 1909-10. Water analyses for the State Board of Health have been made when requested. After it became necessary to charge fees for the analytical work, arrangements were made by which samples of water could be analysed free of charge on application to the State Board of Health. Reports summarizing the work done under this co-operative agreement have been published in the monthly bulletins of the State Board of Health. (May 1910, page 32 and December 1910, page 554).

ILLINOIS CO-OPERATION.

The data obtained from investigation of the character of the water of the streams of Illinois, carried on under the co-operative agreement,* has been published as water supply paper No. 239 of the United States Geological Survey. It can be obtained by application to the Director, State Water Survey, Urbana, Illinois, or to the Director, United States Geological Survey, Washington, D. C. The report gives the results of several thousand analyses of water from Illinois streams showing the mineral condition and fitness or unfitness for industrial purposes.

The results are summarized as follows:

1. Compared with surface waters of the United States as a whole, the surface waters of Illinois are fairly uniform in quality throughout the State.
2. The best large supply of water in the State is Lake Michigan.
3. Water in the reservoirs and rivers of the southern part of the State is softer than that of northern rivers. The turbidity is less in the northern rivers and is much more easily removed than that of the southern streams.
4. None of the river waters are clear enough to furnish a satisfactory city supply without treatment. Treatment which will clarify the water and give it a pleasing appearance can be made to yield from most rivers a water safe for drinking.
5. The value for industrial use of nearly all the surface waters may be greatly increased by softening.
6. The daily and seasonal variations in quality render necessary careful daily supervision to insure the best results in any form of purification.

*University of Illinois Bulletin, Water Survey Series, No. 3, 1906, p. 19; No. 6, 1907, p. 17.

7. The quality of Illinois River water is made more uniform by the operation of the Chicago drainage canal.
8. The impounding of flood waters for the purpose of regulating the discharge of the rivers would greatly improve the quality of the water. The turbidity would be decreased, and the variations in amount of dissolved material would be much less. The extreme values occur in the times of very high and very low water, which would be eliminated by the impounding.

ASSOCIATIONS AND COMMISSIONS.

Lake Michigan Water Commission.

The object of the Lake Michigan Water Commission which was established in 1908 is to investigate the sanitary conditions of the lake with a view to conserving a supply of pure water for those cities and towns which depend upon Lake Michigan for their source of supply. The members of the commission are appointed by the governors of the States and the mayors of the several large cities which border the lake and also by two Federal Departments of the United States.

Meetings are held at intervals at which the experimental work which has been carried on is reported.

Illinois Water Supply Association.

The Illinois Water Supply Association is composed of persons interested in the water works and water supplies of Illinois. The annual meeting of the organization is held at Urbana in February, and at this meeting papers dealing with water supply subjects are read.

North Shore Sanitary Association.

Representatives from the municipalities along the North Shore compose the North Shore Sanitary Association. Under the direction of this organization, a survey of the water of Lake Michigan from Evanston to Waukegan and extending from three to five miles into the lake has been undertaken. The analytical work is done in the laboratories of the Chicago Health Department. This survey should furnish valuable information concerning the supplies of the North Shore Cities.

Illinois Society of Engineers and Surveyors.

A large number of the members of this society are men who are directly interested in water supplies and sewage disposal. The annual meeting is held in January, and the place of the 1912 meeting will be Champaign-Urbana. The business of the society is closely related with the water problems of the state.

Sanitary District of Chicago.

The Sanitary District of Chicago has been investigating problems concerning the sewage disposal of that city. The information obtained from these experiments will prove valuable not only to Chicago, but to other cities as well.

EXPERIMENTAL INVESTIGATIONS.

The Water Survey has had more work, both routine and experimental, than it could conveniently handle with its available force. Yet it is always anxious to hear of problems which may prove of interest and which may be studied as time permits. During the years 1909 and 1910, several special problems have been studied by members of the staff. Assistance has also been given by Mr. G. A. Van Brunt, a student in the graduate school, and Mr. W. C. Marti, a student in the College of Science.

These experiments are described fully elsewhere in the bulletin. The following is a brief outline of each experiment:

The Composition and Treatment of Lake Michigan Water.

This subject has been studied by Mr. L. I. Birdsall. Analyses of water from the Lakes show that the waters of all, excepting Lake Superior, are similar in composition. Experiments in the laboratory indicate that mechanical filtration with aluminium sulphate alone, or with lime, or iron sulphate with lime will give satisfactory results. Aluminium sulphate is the more expensive but more reliable.

The Action of Bleaching Powder in Water Purificafion.

Experiments concerning the action of bleach in water purification have been carried on in the State Water Survey laboratories by Mr. G. A. Van Brunt. The results indicate that bleach is an efficient agent for sterilization of water. Practical tests at Quincy and Kankakee show the advantage of using bleach in connection with mechanical filtration.

Treatment of Water with Boiler Compounds.

Mr. W. C. Marti has made a study of the action of boiler compounds upon waters, with respect to scale formation and corrosion. The effect of treatment upon foaming, corrosion, scale formation and chemical composition has been investigated.

Relation of Typhoid Fever and the Water Supplies of Illinois.

The typhoid fever death rate of Illinois appears to be closely related to the character of the water supplies. In those sections of the state where deep drift wells are used or where the cities have municipal supplies, the yearly death rate from typhoid is much less than where shallow wells or streams are used. The data indicate the desirability of establishing municipal supplies wherever possible.

Analytical Control of Water Softening.

During the year 1910, Mr. A. Jacobson of this laboratory was engaged in the investigation of the analytical control of water softening. The methods of analysis in use were tested, and a rapid method for the analysis of a water to determine the quantity of reagents necessary for softening has been selected. A simple formula for calculating the amount of lime and soda ash to be added, when certain analytical data are known has also been devised.

The Nitrite Fermentation Test.

A. W. Sellards* has suggested the fermentation of nitrites by bacteria as a means of determining the bacterial condition of a water. Mr. F. Bachmann has carried on investigations of this method in this laboratory. Peptone increases the nitrite destroying power of cultures while gelatine has the opposite effect. With suitable media the test may be made in twenty four hours.

A Convenient Camera for Color Comparisons in Nessler Tubes.

The camera for color comparisons, described in this bulletin, has been in use in the laboratory of the State Water Survey, and has proved to be very convenient.

Additional Farm Water Supplies.

Bulletin No. 7 contained a list of the results of the analyses of samples of water used as farm supplies in various sections of the state. Since the publication of these analyses, the work has been continued and more data have been collected. The results of these analyses are given in the following pages. In sections, where the water is obtained from deep rock or deep drift wells, the supplies are very satisfactory, but in places where shallow wells must be used conditions are unsatisfactory.

Suggested Disposal of Drainage at Tolono.

In 1908-09, the Director was informed of a plan for the disposal of surface water at Tolono by turning it into wells sunk to the water bearing strata. Such an arrangement would have seriously endangered the water supply. Because of the opinions expressed by representatives of the State Water Survey and State Board of Health, the Tolono City Council passed an ordinance forbidding the use of such wells.

*University of Illinois Bulletin. State Water Survey Series No. 7, page 40.

A Small Water Works Laboratory.

Several small laboratories for filter control have been recently installed in the state. The equipment for making the bacteriological and simple chemical tests is neither large nor expensive, and it is hoped that the number of these laboratories will increase. The list of apparatus necessary for installing such a laboratory is given in this report as a suggestion to those selecting laboratory equipment.

THE LAKE MICHIGAN WATER COMMISSION.

Under date of March 19, 1908, Dr. W. A. Evans, Commissioner of Health of Chicago, recommended to Hon. Fred A. Busse, Mayor of Chicago, the formation of a Lake Michigan Water Commission. Dr. Evans suggested that one delegate be appointed by the United States Public Health and Marine Hospital Service; one by the United States War Department; three by the City of Chicago; two by Milwaukee; one by Grand Rapids; one jointly by the cities of Hammond, Whiting, and East Chicago; and one each by the four states bordering on the Lake.

The duties suggested for the Commission were: (1) To study and report on the amount of pollution emptying into Lake Michigan; (2) the present pollution of the Lake water; (3) the future of the Lake water as regards pollution; (4) the direction of the Lake currents; (5) the distance to which pollution can and does travel in Lake Michigan; (6) the purifying power of Lake Michigan water; (7) the study of the polluted streams emptying into Lake Michigan; (8) the sewage disposal plants of cities, villages and homes situated in the Lake Michigan Basin; (9) the amount of drinking water taken from Lake Michigan; (10) the future use of Lake Michigan water for drinking purposes; (11) the relation of the water intakes to shore line, sewer outfalls and other means of pollution.

Members of the Commission have been appointed by Federal Departments and by the Mayors of the cities and Governors of the states above mentioned:

CHICAGO—
W. A. Evans, M. D., Commissioner of Health.
Adolph Gehrmann, M. D., Columbus Laboratories.
C. D. Hill, Engineer Board of Local Improvements.

GRAND RAPIDS—
Perry Schurtz, M.D., Member Board of Health.

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

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

INDIANA CITIES—

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

ILLINOIS—

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

MICHIGAN—

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

MILWAUKEE—

Sherburn Becker, Milwaukee, Wisconsin.

G. A. Bading, M. D., Commissioner of Health.

UNITED STATES ARMY—

Major W. V. Judson, Milwaukee, Wisconsin.

UNITED STATES PUBLIC HEALTH AND MARINE HOSPITAL SERVICE—

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

WISCONSIN—

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

The plan of organization makes no provision for salaries of members of the Commission, it being supposed that the appointments would be made from officials already engaged in the work. Difficulties were encountered in obtaining funds for the necessary expenses. These difficulties have in part been met by the various state and municipal boards carrying on independent work and collecting and reporting the results in such a way that they may be useful to all the parties concerned.

In this connection it is interesting to compare the appropriation for the work of the New York Harbor Pollutions Commission. This Commission had an original allowance of $15,000. This amount was all used and $75,000 additional was asked to pay the outstanding bills and complete the investigation.

Thus far, the state and municipal bureaus have assisted in the collection of statistics and have carried out the independent examinations as have seemed most suitable to each bureau.

Three meetings of the Commission have been held at Chicago, Grand Rapids, and Milwaukee, and reports have been made. Working more or less independently as mentioned above, different lines of experimental work have been carried on. Michigan and Illinois have obtained quite complete records of the situation in the cities in the

*Deceased.

area in those states which drains into Lake Michigan. The other states will obtain this data later. Indiana established a water testing laboratory at Michigan City where investigations were carried out for one month. This laboratory was later moved to Indiana Harbor and the results obtained are described by Mr. Barnard in the First Report. Wisconsin has been called upon to investigate a typhoid epidemic at Sheboygan and has shown beyond a doubt that the water supply is responsible. The sewage from the city passes into the Lake or into the Sheboygan River and at times reaches the intake. Of the two possible methods of correction, extending the intake and filtration, the State Hygienic Laboratory recommends the latter. Chicago has made special investigations of the persistence of sewage and the quality of the water in and around the Chicago intakes. This is described by Dr. Biehn in the First Report. In Illinois in addition to the collection of statistics concerning the towns in territory tributary to Lake Michigan the State Water Survey has made analyses of water from all but two towns which obtain their water supply from the Lake. These will be examined in a short time. From the data obtained it is noted that none of the cities obtaining the water from Lake Michigan and using it without filtration have a water supply that is above suspicion.

Typhoid fever is usually taken as the means of estimating the purity of a municipal water supply. This is because it is more difficult to trace the diarrheal diseases. An interesting report comes from Major E. L. Munson, Medical Corps, United States Army, Fort Sheridan, where there is a better opportunity to note the relation of the water to illness than in any of the municipalities. As yet no typhoid has been traced to the water supply but sharp outbreaks of diarrheal diseases are apt to occur among those who drink unboiled lake water after storms when the water always becomes turbid. If the trouble from the turbid water at Fort Sheridan can be taken as an indication of similar trouble throughout the area in question, we have an excellent argument for taking steps to provide a water free from turbidity.

Practically none of the sewage entering the Lake is treated. A few towns report treatment plants, but the amount of sewage thus handled is very small. Owing to inefficient supervision the plants already constructed in Illinois are not satisfactory, and it may be said that all the sewage of the Illinois towns outside of Chicago enters the lake unpurified. That this is an unsatisfactory state of affairs which sooner or later will cause trouble is indicated by the report on Lake currents made by Major W. B. Judson of the United States Army. His study of data already at hand concerning the Lake currents has lead the Commission to conclude that occasionally currents of considerably velocity, say several miles per hour, may be expected to arrive from almost any direction at any point reasonably near either shore of the lake; and therefore, while in the opinion of the Commission, the direction of predominating currents should be considered in determining the relative positions of sewer outlets and water-works intakes, nevertheless it is the sense of this Commission that if the waters of the Lake are polluted by the discharge into it of large quantities of sewage, then localities in the lake, even 20 or 30 miles distant from the point of entrance of the sewage, and in any direction therefrom, are not safe places from which to derive water for domestic use.

The typhoid rate in Chicago is about 16 per 100,000 and from the statistics gathered the smaller towns have a larger proportion. Dr. J. A. Amyot* of Toronto gives a typhoid fever rate for lake cities at about 20 per 100,000. Typhoid is transmitted by contact; by polluted water supplies; by infected milk or vegetables; and by flies. In our Lake cities which are well sewered, use very little well water and have a fair milk supply, and are not swarmed with flies, very few show a typhoid rate below 20. Dr. Amyot states that no cities in the temperate zones with unquestioned water supplies show such high typhoid rates. Vienna and Munich with mountain top supplies; Frankfurt and Dresden with artesian supplies in unquestioned soils; Zurich, Hamburg, Rotterdam, and London with properly filtered water, show rates rarely exceeding 7 or 8 per 100,000. They all had high rates before the good water supplies were obtained. Toronto in June of this year voted $3,700,000 for the disposal of its sewage and the filtration of its Lake Ontario water supply.

The work of the Lake Michigan Water Commission should ultimately show whether the typhoid rate of the lake cities comes from their water supply or from the other sources mentioned, and whether these cities will be warranted in taking the steps Toronto has taken.

An interesting and rather significant fact brought out by the preliminary investigation of the Commission is the fact that analyses made by the various laboratories are not comparable. While analyses made in one laboratory may be comparable, it would not be possible to form opinions concerning the variation in the quality of water from two parts of the Lake if the analyses were made in different laboratories.

At the Grand Rapids meeting of the Commission it was voted that the Laboratory men endeavor to obtain uniformity in tests made and methods of analysis. As a preliminary step samples of water from a point in the Lake about 15 miles east of the Chicago River; from a point near the light house a mile from the Chicago River;

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*Pollution of the Great Lakes, paper read before the American Public Health Association at Winnipeg.

and from the Chicago River at the foot of Madison Street, were sent to four laboratories. These samples were analyzed according to the methods in use in each laboratory. A comparison of the results shows different tests in use; different methods of carrying on the same tests and different results when the same methods were used. Without going into detail with regard to the analyses made a few of the significant results may be mentioned. From the sample taken 12 miles out in the Lake the following discrepancies are noted:

Chlorine	3.	4.	4.7	14.
Oxygen Consumed	.8	1.5	2.5	
Albuminoid Ammonia	.09	.12	.065	.154
Hardness	112.	183.		
Bacteria per c. c.	2.	20.	8000.	

From the sample taken from the foot of Madison Street a similar variation was shown:

Chlorine	5.	6.	7.	15.
Oxygen Consumed	3.2	4.5	5.	
Albuminoid Ammonia	.07	.27	.19	.36
Bacteria per c. c.	13000.	85400.		200000.
Colon Bacillus	Present	Present	Present	Absent

As a result of this preliminary test the laboratory men met and agreed on the methods to be used in reporting the analyses of samples of Lake Michigan water and upon the methods to be used in such examination. It is not intended that the methods adopted shall preclude the use of other tests by each laboratory, but in analyses made for the sake of comparison the methods agreed upon are to be used. Another series of waters will be collected and a second comparison of methods will be made.

It is not expected that the commission will be able to give specific advice to individual cities but it will be able to show the actual state of affairs and may be able to show the necessity for a change in the present practice or perhaps to show the wisdom of the course which Toronto is pursuing.

ILLINOIS WATER SUPPLY ASSOCIATION.

In response to an invitation issued by President Edmund Janes James about forty of those interested in obtaining and conserving an abundant supply of pure water for domestic use, met at the University of Illinois on February 16th and 17th, 1909.

The first meting was called to order by the Director of the State

Water Survey. The following letter from President James who was unable to be present at the meeting, was read.

UNIVERSITY OF ILLINOIS.
PRESIDENT'S OFFICE.
URBANA-CHAMPAIGN, ILLINOIS,
February 16, 1909.

Water-Works Conference:

Gentlemen—It is with very great regret indeed that I find it impossible to attend the sessions of this conference.

One of the first things which attracted my attention when I came to the University was what seemed to me the very important duties imposed upon the University by the law creating the State Water Survey and the very meager funds given by the state to enable the University to perform these functions.

With every passing year the question of studying, caring for, and husbanding our water supplies is destined to become more important. It is bound up with nearly every other question of vital importance to the public. The whole question of public sanitation is perhaps more closely connected with the water supply, using that term in the large sense, than with any other. Whether we can continue to use our streams as open sewers, or if the time has come when this must be stopped in the interest of public health, how we can treat our sewage, the question of drainage in a large way, the very possibility of developing a manufacturing industry—all these and many others turn upon an adequate supply of usable water. These are perhaps secondary in importance to the single problem of securing an adequate supply of potable water.

You have met to confer about some of the most important public interests of this state. I wish I might be present and acquire the additional information which I am sure attendance at your sessions would give me. I wish you the very heartiest success and hope that something of substantial benefit to the state will result from your deliberations.

Faithfully yours,
EDMUND J. JAMES.

President James also forwarded to the Conference the following letter received from Governor Deneen in response to an invitation:

STATE OF ILLINOIS,
EXECUTIVE DEPARTMENT.
SPRINGFIELD, February 15, 1909.

Dear Dr. James—I am in receipt of your letter of February 10th, inviting me to attend the conference of water-works officials and the State Water Survey to be held at the University of Illinois February

16th and 17th. I appreciate the invitation highly but am obliged to decline it because official duties will prevent my leaving Springfield on the dates mentioned. I am in accord with the objects of the conference and should have been pleased to have heard the discussions of the important subjects with which it is to deal. Water for domestic and manufacturing purposes is one of the most important of our natural resources and I trust that the discussion will lead to the adoption of plans for its better conservation. I should like to be informed of such action as may be taken by the conference.

Thanking you for your courtesy in this matter, I am,

Yours truly,

C. S. DENEEN.

Dr. Edmund J. James, Urbana, Illinois.

Mr. Dabney H. Maury of Peoria was chosen temporary chairman of the meeting. Later a permanent association was organized to be known as the Illinois Water Supply Association. The following officers were elected:

President, Dabney H. Maury; First Vice-President, C. E. Slocum; Second Vice-President, Owen T. Smith; Third Vice-President, R. R. Parkin; Secretary-Treasurer, Edward Bartow.

Abstracts from the Constitution are given to show the purposes and aims of the organization. It is hoped that each town in the State may soon be represented.

CONSTITUTION OF THE ILLINOIS WATER SUPPLY ASSOCIATION.

ARTICLE I. Section 1. The name of this association shall be the Illinois Water Supply Association.

Section 2. Its object shall be the advancement of knowledge relating to water-works and water supply, the conservation of water supplies for public use, and the encouragement of social intercourse among its members.

ARTICLE II. Section 1. The membership of the association shall consist of members, honorary members, and associates.

Section 2. Any person interested in the water-works or the water supplies of the State of Illinois, or in the advancement of knowledge concerning the same shall be eligible to membership.

Section 3. Members only shall be eligible to office and entitled to the right to vote.

Section 4. Honorary members shall be men eminent in some line of work connected with hydraulic engineering or water supply.

Section 5. Associates shall be firms or representatives of firms engaged in dealing in supplies used by water-works.

Section 6. Application for admission to the association as members or associates shall be endorsed by two members of the association on forms provided for the purpose. They shall be forwarded to the secretary, accompanied by the regular initation fee and dues for one year.

Section 7. The vote of a majority of the executive committee shall elect to membership.

Section 8. Honorary members may be proposed by the executive committee and elected by the association at any regular meeting.

ARTICLE III. Section 1. The initation fee shall be for members, $1.00, for associates, $5.00.

Section 2. The annual dues shall be for members, $2.00, for associates, $5.00.

ARTICLE IV. Section 1. The officers of this association shall be a president, three vice-presidents, and a secretary-treasurer.

Section 2. The officers of the association, with the retiring president shall constitute an executive committee.

Section 3. The president shall preside at all meetings. In his absence one of the vice-presidents shall preside.

Section 4. The Executive Committee shall have the management of the affairs of the association, the arrangement of the programs for the meetings, and the expenditure of the funds of the assoeiaion, provided that no indebtedness shall be incurred exceeding the amount of the funds in the hands of the treasurer.

Section 5. It shall be the duty of the secretary-treasurer to keep the minutes of all meetings, to conduct all correspondence, to receipt for fees and dues, and pay all demands against the association when approved by the president. He shall exhibit an annual report of the funds of the association.

ARTICLE V. Meetings shall be held annually, at such time as shall be ordered by the Executive Committee. The place of meeting shall be the University of Illinois, Urbana-Champaign, unless otherwise ordered by the said Executive Committe.

The following papers were published in the first volume of proceedings published of the Association:

Address by E. J. Townsend, Dean, College of Science, University of Illinois.

Response by Dabney H. Maury, Engineer, Peoria Water Works Company, Peoria, Illinois.

Duty of Pumping Engines and Cost of Pumping Water, H. M. Ely, Engineer, Parker Washington Co., Chicago, Illinois; C. H. Cobb, Superintendent, Kankakee Water Company, Kankakee, Illinois; C. R. Henderson, Manager, Waterloo Water Co., Waterloo, Iowa.

Specifications for the Purchase of Coal, S. W. Parr, Professor of Applied Chemistry, University of Illinois.

The Relation of the State Water Survey to Municipal Water-Works, Edward Bartow, Director, State Water Survey, University of Illinois,

The Sanitary Condition of the Southern End of Lake Michigan, Bordering on Lake County, Indiana, H. E. Barnard, Chief Chemist, Indiana State Board of Health, Indianapolis, Indiana.

Pollution and Purification of Streams, T. J. Burrill, Professor of Bacteriology, and Vice-President, University of Illinois

Methods of Bacteriological Examination of Water, Frank Bachmann, Bacteriologist, State Water Survey, University of Illinois.

Methods of Chemical Examination of Water, Lewis I. Birdsall, Chemist, State Water Survey.

On the Correlation of Deep Well Records, J. A. Udden, Deep Well Specialist, Illinois State Geological Survey, and Professor of Geology, Augustana College, Rock Island, Illinois.

Advantages of a Filtered Water Supply from a Business Standpoint, Owen T. Smith, Secretary and Superintendent Freeport Water Company.

A Water-Works Laboratory, C. H. Cobb, Superivtendent, Water-Works, Kankakee, Illinois.

Suggested Disposal of Drainage at Tolono, Illinois, Edward Bartow, Director, State Water Survey, University of Illinois.

Number and Size of Fire Streams for Fire Protection, George C. Habermeyer, Instructor in Municipal and Sanitary Engineering, University of Illinois,

Methods of Measuring Water, A. N. Talbot, Professor of Municipal and Sanitary Engineering, University of Illinois.

The membership of the Association during 1909 included 77 members, and 7 associates.

The second meeting of the Illinois Water Supply Association was held at the University of Illinois, March 8th and 9th, 1910.

Officers for the ensuing year were elected as follows: Mr. C. E. Slocum, President; Mr. O. T. Smith, First Vice-President; Mr. R. R. Parkin, Second Vice-President; Mr. C. H. Cobb, Third Vice-President; Mr. E. Bartow, Secretary-Treasurer.

The following papers were read and published in the second volume of the Proceedings of the Association.

President's Address, Dabney H. Maury, Consulting Engineer, Peoria, Illinois. .

The Greatest Need of the Water Supply Industries of Illinois, W. F. M. Goss, Dean College of Engineering, University of Illinois.

Experience with Deep Well Pumps, F. C. Amsbary, Superintendent and Manager Champaign and Urbana Water Co., Champaign, Illinois.

Shall we as Water Companies Furnish the Private Services of our Patrons Free up to and Including the Meters? E. P. Wheeler, Superintendent and Manager Lake Forest Water Co., Lake Forest, Illinois.

Notes on the Chances of Pollution in Shallow Wells, C. B. Burdick, Hydraulic and Sanitary Engineer, Alvord & Burdick, Chicago.

Comparison of Hydrated Lime with Ordinary Lime in Water Treatment, C. E. Thomas, General Foreman Water Works, I. C. R. R. Co., Chicago, Illinois.

The Quality of Surface Waters in Mississippi River Basin, R. B. Dole, U. S. Geological Survey, Washington, D. C.

Sanitary Conditions of Inlet Tunnel Water Supplies Immediately after Completion, John W. Alvord, Consulting Engineer, and L. I. Birdsall, Chemist with Alvord & Burdick, Chicago, Illinois.

A Simple Instance of the Determination of the Rate of Flow Into Wells, A. N. Talbot, Professor of Municipal and Sanitary Engineering, University of Illinois.

The Significance of the Term Alkalinity in Water Analysis and the Determination of the Alkalinity by Means of Indicators (Experimental), E. W. Washburn, Associate in Physical Chemistry, University of Illinois.

Action of St. Louis Water on Metals and Alloys, W. F. Monfort, Chemist, Water Department, St. Louis, Missouri.

A State Bureau of Municipal Information, J. W. Garner, Professor of Political Science, University of Illinois.

Water Works Franchises, M. H. Robinson, Professor of Commerce, University of Illinois.

Legislation in Relation to Stream Pollution, H. M. Ely, Superintendent Water Co., Danville, Illinois.

Water Supply and Sewage of Lake Shore Towns of Lake County, W. C. Bouton, M. D., Waukegan, Illinois.

The Relation of Typhoid Fever and the Water Supplies of Illinois, Edward Bartow, State Water Survey, University of Illinois.

The Operation of Mechanical Filters, J. H. Brewster, Water Chemist, State Board of Health, Indianapolis, Indiana.

Modern Filter Plants (Illustrated), J. Langdon Pearse, Assistant Engineer, Sanitary District of Chicago.

The Field for Water Disinfection from a Sanitary Standpoint, Prof. C. E. A. Winslow, Massachusetts Institute of Technology, Boston, Massachusetts

Bleaching Powder as an Adjunct to Filtration at Quincy, Illinois, W. R. Gelston, Superintendent Citizens Water Works Co., Quincy, Illinois.

Practice in the Use of “Hypo” and Devices used in Applying it, H. E. Jordan, Chemist Indianapolis Water Company, Indianapolis, Indiana.

A City Water Supply from Wells, O. T. Smith, Superintendent Water Company, Freeport, Illinois.

The membership of the Association in 1910 included 143 members and 17 associates.

COMPOSITION AND TREATMENT OF LAKE MICHIGAN WATER.*

The Great Lakes contain an inexhaustible supply of orginally pure water, which is used for drinking purposes by more than one-hundred American and Canadian cities, many of which may attribute their present location to this abundant water supply. Most of these cities empty their domestic and manufacturing wastes into the same body of water that furnishes their supply of drinking water. Very few cities are as conveniently located as Chicago, where the sewage is diverted through a drainage canal into the Illinois River. Pollution of the Lake waters has continued to such an extent that at the present time many of the lake cities are obtaining a more or less polluted water supply. Only the very largest cities are able to extend their intake pipes into the lake beyond the zone of pollution and to a point at which they may reasonably expect to find pure water for drinking purposes. Even at Chicago where the intake pipes extend from two to four miles into the lake, Barnard and Brewster† have traced pollution from the Calumet River five miles into the lake. Under such conditions the smaller lake cities, which must from financial necessity have their intakes near the shore, frequently obtain a more or less polluted water.

The presence of turbidity in the water of the Great Lakes is usually apparent at all times near the shore but it varies in amount with the distance from shore and the occurence of storms. Even the large lake cities, such as Cleveland and Chicago, with intakes far from shore, have at times a decidedly turbid water which must exert a deleterious influence upon those who drink it. A turbid water does not necessarily contain typhoid germs, but it does not present an attractive appearance and may even be harmful as has been demonstrated at Fort Sheridan, Illinois.‡ There, it has been found that acute attacks of diarrhoeal diseases occur among the soldiers when the Lake water, which they drink, is turbid.

Because of the constantly increasing pollution of the Great Lakes, the time is approaching when many purification plants must be installed. The method of purification is dependent on the amount and the character of the mineral content and suspended solids. The com-

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*From thesis prepared by Lewis I. Birdsall under the direction of Edward Bartow.

†First Report of Lake Michigan Water Commission, p. 193.

‡First Report of Lake Michigan Water Commission, p. 41.

position of the mineral residue from the water of the Great Lakes is well shown in the results of analyses reported by R. B. Dole and R. G. Roberts of the United States Geological Survey.[*] Each analysis in Table I represents the average analysis of twelve monthly samples collected during 1906-07. In every case the samples were collected at the outlet of the lake in order to give as far as possible the average composition of the water. The mineral content of the water in the various lakes, excepting Lake Superior, is very similar and what will be true of the treatment of the water of one lake will be in a great measure true for the others. Lake Superior must be considered by itself, for owing probably to the crystalline character of the rocks in its drainage area, the mineral content is very low. In order to determine the relative proportions of the various ions we have made hypothetical combinations[†] which appear in Table II.

TABLE I.

AVERAGE COMPOSITION OF THE WATER FROM THE GREAT LAKES IN PARTS PER MILLION.

Source	Lake Superior	Lake Huron	Lake Michigan	Lake Erie	St. Lawr'ce River
Turbidity	2	trace	trace	41	45
Silica SiO_2	7.4	12.0	10.0	5.9	6.6
Iron Fe	0.06	0.04	0.04	0.07	0.05
Calcium Ca	13.0	24.0	25.0	31.0	31.0
Magnesium Mg	3.1	7.0	8.2	7.6	7.2
Sodium Na and Potassium K	3.2	4.4	4.7	6.5	6.3
Carbonate radicle CO_3......	0.0	1.8	2.9	3.1	2.9
Bicarbonate radicle HCO_2	56.0	100.0	112.0	114.0	116.0
Sulphate radicle SO_4........	2.1	6.2	7.2	13.0	12.0
Nitrate radicle NO_3.........	0.5	0.4	0.3	0.3	0.3
Chlorine C1	1.1	2.6	2.7	8.7	7.7
Total solids	60.0	108.0	118.0	133.0	134.0

It is readily seen from the hypothetical combinations that the principal mineral constitutents are the carbonates of calcium and magnesium. With the exception of Lake Superior, the nitrate, chloride and sulphate ions are present in sufficient quantities to more than neutralize the sodium ions. There will be, therefore, a small amount of magnesium sulphate.

A study of the effect produced by different chemicals upon Lake Michigan water has been undertaken in the laboratory in order to determine the smallest amount of chemicals necessary to obtain a sat-

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[*] The Waters of the Great Lakes, R. B. Dole. Paper presented before Am. Pub. Health Assn. at Winnipeg, Manitoba, August 1908.

[†] The Mineral Content of Illinois Waters. University of Illinois bulletin, State Water Survey Series No. 4, p. 26.

TABLE II.

AVERAGE COMPOSITION OF WATER FROM THE GREAT LAKES.

HYPOTHETICAL COMBINATIONS.

	Lake Superior		Lake Huron		Lake Michigan		Lake Erie		St. Lawrence River	
	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon
Sodium Nitrate $NaNO_3$	.7	.04	.5	.08	.4	.02	.4	.02	.4	.02
Sodium chloride NaCl	1.8	.10	4.3	.25	4.5	.26	14.4	.84	12.7	.74
Sodium sulphate Na_2SO_4	3.1	.18	8.0	.47	8.6	.50	2.2	.13	3.7	.22
Sodium carbonate Na_2CO_3	3.0	.17	—	—	—	—	—	—	—	—
Magnesium sulphate $MgSO_4$	—	—	1.0	.06	1.8	.11	14.4	.84	11.9	.69
Magnesium carbonate $MgCO_3$	10.7	.62	23.5	1.37	27.0	1.57	16.3	.95	16.6	.97
Calcium carbonate $CaCO_3$	32.4	1.89	60.0	3.50	62.4	3.64	77.4	4.51	77.4	4.51
Iron carbonate $FeCO_3$	.1	.01	.1	.01	.1	.01	.1	.01	.1	.01
Silica SiO_2	7.4	.43	12.0	.70	10.0	.58	5.9	.34	6.6	.38
Total solids	60.0	3.44	110.0	6.39	115.0	6.69	131.0	7.64	130.0	7.54

TABLE III.
COMPOSITION OF LAKE MICHIGAN WATER.
PARTS PER MILLION.
IONS.

Number	1	2	3	4	5	6	7	8	9	10	Average
Samples from	Chicago	Chicago	Chicago	Chicago	Chicago	Milwaukee, Wis.	Milwaukee, Wis.	Milwaukee, Wis.	Chicago	South Chicago	
Analysed by	State Water Survey	State Water Survey	C.B.&Q. R. R.	C.B.&Q. R. R.	C.&N.W. R. R.	M.&St.P. R. R.	M.&St.P. R. R.	M.&St.P. R. R.	M.&St.P. R. R.	B. & O. R. R.	
Potassium K and Sodium Na	5.6	8.3	3.1	3.8	3.1	3.5	6.6	4.8	4.5	2.6	4.5
Magnesium Mg	11.7	10.9	10.9	10.9	10.9	10.3	10.6	11.1	10.7	9.9	10.8
Calcium Ca	36.2	28.2	32.4	32.3	32.1	31.8	31.9	34.0	34.9	35.3	32.9
Oxide of Iron Fe_2O_3 and Alumina Al_2O_3	....	......	5.0	5.0	.3	1.5	....	4.5	6.2	3.1	3.6
Nitrate NO_3	2.4	1.0	....	....	....	....	....	....	....	....	1.7
Chloride Cl	4.8	4.2	2.4	2.6	2.3	2.9	7.2	3.1	2.7	4.1	3.6
Sulphate SO_4	12.0	10.0	7.1	8.1	6.8	6.9	9.1	8.1	9.4	9.5	8.7
Silicia SiO_2	6.7	1.9	5.3	....	5.1	....	....	....	....	....	4.8

TABLE IV.
COMPOSITION OF LAKE MICHIGAN WATER.
HYPOTHETICAL COMBINATIONS

	1		2		3		4		5		6		7		8		9		10		Average	
	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon	Parts per Million	Grains per Gallon
Sodium nitrate $NaNO_3$	3.3	.19	1.4	.08	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.3	.13
Sodium chloride NaCl	7.9	.46	6.9	.40	4.0	.23	4.3	.25	3.8	.22	4.8	.28	11.9	.69	5.1	.30	4.5	.26	6.6	.38	5.9	.34
Sodium sulphate Na_2SO_4	5.0	.29	16.0	.93	4.6	.27	6.5	.38	4.9	.29	4.9	.29	5.9	.34	8.6	.50	8.3	.48	....	....	4.9	.29
Magnesium sulphate $MgSO_4$........	10.8	.65	....	....	5.0	.29	4.6	.27	4.4	.26	4.5	.26	6.4	.37	2.9	.17	4.8	.28	11.9	.69	6.8	.40
Magnesium carbonate $MgCO_3$	33.2	1.93	38.0	2.20	34.3	2.00	34.6	2.01	34.6	2.01	32.6	1.90	32.2	1.88	36.4	2.12	33.6	2.00	26.0	1.52	32.6	1.90
Calcium carbonate $CaCO_3$	90.5	5.28	70.3	4.08	80.9	4.72	80.6	4.70	80.2	4.68	79.4	4.62	79.6	4.65	84.9	4.95	87.1	5.08	88.1	5.14	82.1	4.79
Oxide of Iron Fe_2O_3 and Alumina Al_2O_3	5.0	.29	.7	.04	5.0	.29	5.0	.29	.3	.02	1.5	.09	....	....	4.5	.26	6.2	.36	3.1	.18	3.6	.21
Silica SiO_2	14.2	.83	4.1	.24	5.3	.31	....	....	5.1	.30	....	....	....	....	....	....	....	....	....	....	4.8	.28
Total solids	170.0	9.92	137.0	7.97	139.0	8.10	136.0	7.90	134.0	7.78	128.0	7.44	136.0	7.93	142.0	8.30	145.0	8.46	136.0	7.91	143.0	8.34

isfactory filtered water, and the amount of chemicals necessary to accomplish a maximum softening of the water. The experiments have been confined to water from Lake Michigan but we believe that the results obtained are applicable to water from the other lakes, excepting Lake Superior. As a preliminary step, data concerning the composition of Lake Michigan water were collected. The data presented in ionic form in Table III and in hypothetical combinations in Table IV show ten independent analyses of water from the southern end of Lake Michigan. The samples were taken from the lake at points near enough to the shore to be available for use by municipal water works. The analytical data represent fairly the mineral content of the water from the southern end of Lake Michigan. A comparison of these results with results obtained by examining the water from the outlet of the lake shows a somewhat higher mineral content at the southern end. This may be due in part to a higher mineral content in the streams at the southern end.

The amount of matter in suspension in the water near the shore varies greatly with the weather. The turbidity is much higher after storms which stir up the finely divided matter from the lake bottom. Determinations of turbidity in samples of lake water collected at Lake Forest and Evanston from June 1907 to June 1909 illustrate very

TABLE V.

TURBIDITY OF LAKE MICHIGAN WATER.
PARTS PER MILLION OF SILICA.

Date	Lake Forest	Date	Evanston
June 3, 1907	40	June 4, 1907.......................	5
July 1, 1907	20	Tune 25. 1907......................	8
July 29, 1907.......................	15	August 26, 1907...................	20
August 26, 1907	5	September 9, 1907...................	5
October 14, 1907...................	25	September 30, 1907..............	40
January 6, 1908.....................	50	October 14, 1907.................	30
January 27, 1908...................	170	November 11, 1907.............	30
March 9, 1908.....................	100	January 13, 1908................	180
April 6, 1908.......................	60	March 2, 1908.....................	40
April 27, 1908...................	80	April 6, 1908.................	70
May 11, 1908.....................	90	May 4, 1908...................	30
June 15, 1908.....................	10	May 25, 1908.....................	35
July 6, 1908....................	5	July 20, 1908.....................	20
August 10, 1908....................	3	August 17, 1908..................	20
September 8, 1908.................	5	November 30, 1908.............	20
October 13, 1908...................	30	December 14, 1908.............	55
January 4, 1909..................	2	February 1, 1909..............	200
January 18, 1909..................	30	March 30, 1909..............	20
February 8, 1909..................	110		
March 8, 1909......................	75		
April 12, 1909......................	60		
May 10, 1909.......................	30		

well the variations in the amount of suspended matter. These turbidity determinations have been made on samples of water forwarded to the Water Survey Laboratory for sanitary-chemical examination. While there are not enough determinations to form definite conclusions, it can be seen that the turbidity is probably greatest during the winter. This variation in the turbidity would influence to some extent the amount of chemicals to be added to the lake water for purification. It would also influence the cost of such purification.

The alkalinity of water is an important item in chemical control. In Lake Michigan this alkalinity is due to the carbonates of calcium and magnesium. From alkalinity determinations made during 1908-09 at Lake Forest, Evanston and Winnetka, the alkalinity is seen to vary from 109 to 138 parts per million. These limits may be considered as fairly constant for the purposes of water treatment. It will not be necessary to modify the treatment as suddenly as in the case of a river water, where a flood may so lower the alkalinity because of the dilution, that lime, or some similar substance, must be added in order to cause the coagulating chemical to form a floc.

TABLE VI.
ALKALINITY OF LAKE MICHIGAN.
PARTS PER MILLION AS $CaCO_3$

Month	Lake Forest	Evanston	Winnetka	Average
January 1908	116	128	126	123
February 1908	130	.....	130	130
March 1908	124	124	124	124
April 1908	124	124	138	132
May 1908	126	120	113	119
June 1908	112	118	112	112
July 1908	122	114	114	116
August 1908	110	116	.....	113
September 1908	112	.....	109	110
October 1908	118	.....	122	120
November 1908	.....	112	120	116
December 1908	.....	124	124	124
January 1909	126	130	116	124
February 1909	122	......	......	122
March 1909	117	121	119	119

Either slow sand filtration or mechanical filtration can be used to purify Lake Michigan water. In the first method the polluted water is allowed to flow at a rate of about 3 million gallons per acre per day through a bed of fine sand. The suspended particles form a gelatinous film on top of the sand layer by which the water is clarified and the bacteria removed. Slow sand filtration can be used with satisfaction only where the turbidity is low (below 50) for the reason that with high turbidity the filters quickly become clogged. The method of cleaning is tedious and expensive and it is necessary to have extra filters in order that they may be properly cleaned. The slow sand filters also take up considerable space as the rate of filtration is much slower per acre per day than in the mechanical filter. In cold climates the filters must be covered or ice will prevent their satisfactory operation. Slow sand filters do not do efficient work until the water has been passed through them for a considerable period of time and until there has formed on the surface the gelatinous layer called by the Germans "Schmutzdecke".

The second method known as mechanical filtration differs from the slow sand filtration method in that the water to be filtered is first treated with some chemical or chemicals to form a floc which takes the place of the "Schmutzdecke" of the slow sand filtration. The mechanical filter does not occupy as much space as the slow sand filter for the reason that the rate of filtration is much greater, 125 million gallons per acre per day. The smaller area required can be more readily covered so that less difficulty is experienced in the colder climates. Mechanical filters are cleaned by reversing the flow of water and by agitating the sand with rakes or compressed air. The particles of silt are removed and carried away into the sewers. The operation of washing takes but a few minutes and the filters can soon be placed in commission again. The gelatinous surface film is very quickly formed. Very turbid and very highly polluted waters may be satisfactorily purified by mechanical filtration. The number of cities in the United States now using mechancial filtration is steadily increasing and already as shown by Hazen* the number of cities having mechanical filtration plants is neary three times the number of those which are using slow sand filtration. We have undertaken the collection of experimental data with a view to determining the best chemicals or combinations of chemicals for use in the mechanical filtration of Lake Michigan water and also the smallest amount of coagulants which may be used to produce a satisfactory floc.

CHEMICAL TREATMENT OF LAKE MICHIGAN WATER.

The water used in all the experiments described below was obtained from the Fourteenth Street Pumping Station of the Chicago city water works.

In experiment I varying amounts of solution of lime water containing 1.11 milligrams of calcium oxide per c.c. was added to 1000 c.c. portions of water. The results are given in Table VII and illustrated diagramatically on Plate I.

The alkalinity was determined by means of fiftieth normal sulphuric acid with phenolphthalein and methyl orange as indicators. The hardness was determined by the Clark soap method, and shows approximately the combined calcium and magnesium content of the

TABLE VII.

TREATMENT OF LAKE MICHIGAN WATER WITH LIME ALONE.

No.	Lime added, grains Per gallon CaO	Alkalinity to Phenolphthalein	Alkalinity to methyl orange	Hardness
		Cor. for volume. Parts per million as $CaCO_3$	Cor. for volume. Parts per million as $CaCO_3$	Cor. for volume. Parts per million as $CaCO_3$
1	.0	0	110	135
2	.58	0	117	139
3	1.16	0	99	124
4	1.75	0	85	106
5	2.33	0	67	89
6	2.92	0	57	73
7	3.50	8	49	66
8	4.08	13	50	62
9	4.67	17	51	63
10	5.25	27	51	66
11	5.83	36	57	72

*Hazen. Clean Water and How to Get it. p. 80.

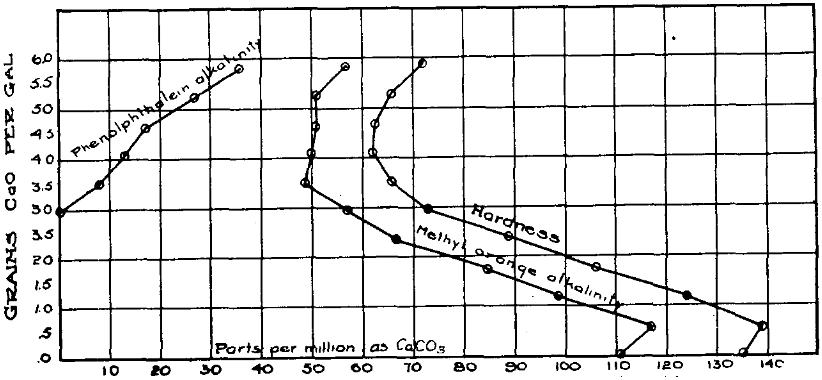

Plate I. Treatment of Lake Michigan Water with Lime.

untreated and treated water after filtration. The results indicate that the lime first combines with the free carbon dioxide to form soluble calcium acid carbonate. The hardness and methyl orange alkalinity are increased. With the addition of more lime the hardness and methyl orange alkalinity show that calcium and magnesium are being removed. The minimum is reached when 4½ grains per gallon of lime are added. A further addition of lime causes an increase in the hardness and methyl orange alkalinity in proportion to the amount added. The maximum softening is indicated when the alkalinity to phenolphthalein is equal to one-half of the alkalinity to methyl orange. The chemical reactions which take place are as follows:

$$Ca(OH)_2 + 2CO_2 = CaH_2(CO_3)_2$$
$$Ca(OH)_2 + CaH_2(CO_3)_2 = 2CaCO_3 + 2H_2O$$
$$2Ca(OH)_2 + MgH_2(CO_3)_2 = 2CaCO_3 + Mg(OH)_2 + 2H_2O$$

The reaction with lime is rapid and the precipitate settles quickly. Lime, therefore, serves as a good reagent for softening the Lake

TABLE VIII.

TREATMENT OF LAKE MICHIGAN WATER WITH ALUMINIUM SULPHATE.

No.	Amount of alum used. Grains per gallon $Al_2(SO_4)_3$	Alkalinity to phenolphthalein	Alkalinity to methyl orange	Hardness	Time required for floc to form	Time required for sedimentation
		Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$		
Blank	....	4.0	118	135	....	....
1	.5	4.0	116	120	6 hrs.	10 hrs.
2	1.0	4.0	114	......	4 hrs. 15min.	8 hrs. 30 min.
3	1.5	2.0	106	......	2 hrs.	8 hrs.
4	2.0	2.0	101	......	2 hrs.	7 hrs.
5	2.5	2.0	99	126	50 min.	3 hrs. 20 min.
6	3.0	.0	95	......	35 min.	2 hrs. 35 min.
7	3.5	0	89	......	35 min.	2 hrs. 20 min.
8	4.0	0	85	......	35 min.	2 hrs. 20 min.
9	4.5	0	79	127	15 min.	2 hrs.
10	5.0	0	75	......	15 min.	1 hr. 15 min.

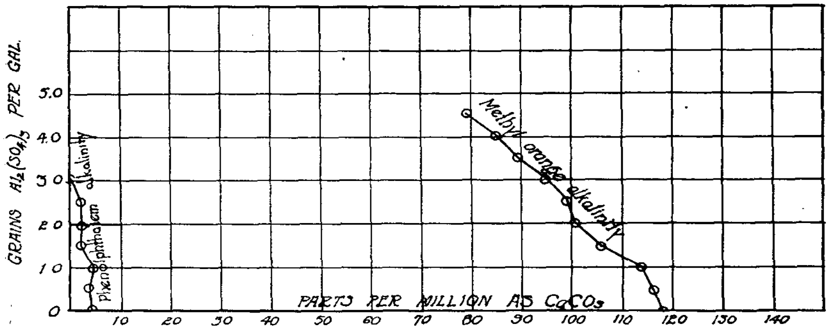

Plate II. Treatment of Lake Michigan Water with Alum.

water but the precipitate formed is too crystalline to serve as a good coagulant in water filtration.

In experiment II varying amounts of aluminium sulphate were added to portions of the water of 1000 cubic centimeters each. The results are shown in Table VIII and illustrated diagramatically in Plate II. The aluminium sulphate contained approximately 18% of alumina. The solution was made by dissolving 4.28 grams in a liter of water. One cubic centimeter of the solution added to a liter of water was equivalent to one quarter of a grain per gallon. As shown in Plate II, the alkalinity decreases steadily in proportion to the alum added. The hardness is practically unchanged since the carbonates of calcium and magnesium are changed to the sulphates of the same metal by the addition of aluminium sulphate.

It is important in mechanical filtration that the floc should form quickly and settle out readily. If the precipitation is rapid, smaller sedimentation basins may be used. The length of time required for the formation of a floc with aluminium sulphate and the relative length of time required for sedimentation are given in Table VIII. Owing to the lack of agitation the small section of the glass cylinders used and the friction on the sides of the glass, these data can be considered only as relative. A good floc was obtained in less than one hour when 2½ grains of aluminium sulphate were used. The State Board of Health of Ohio* has carried out experiments with aluminium sulphate which tend to show that comparatively large amounts of this chemical are necessary to form a floc in clear waters. It was also found that the addition of clay to clear water causes a floc to form much more readily and with smaller amounts of aluminium sulphate.

In experiments III, IV and V, lime was used with aluminium sulphate in the hope that a floc might be obtained at a lower cost for chemicals. In experiment III varying amounts of aluminium sulphate were used with an equivalent amount of lime. The effect of this treatment is shown in Table IX and illustrated diagramatically on Plate III. By comparing Table IX with Table VIII and Plate III with Plate II it is seen that practically no advantage is gained by adding varying amounts of aluminium sulphate with the molecular equivalent of lime. The principal effect is seen to be an increase in the hardness and less reduction in the methyl orange alkalinity. The amount of floc found is practically the same as when aluminium sulphate alone is used, and there is little difference in the time required for the reaction and sedimentation.

In experiment IV, aluminium sulphate with an excess of lime

TABLE IX.

LAKE MICHIGAN WATER TREATED WITH VARYING AMOUNTS OF ALUMINIUM SULPHATE AND EQUIVALENT AMOUNTS OF LIME.

No.	Amount of alum used. Grains per gallon $Al_2(SO_4)_3$	Amount of lime used. Grains per gallon CaO	Alkalinity to phenolphthalein	Alkalinity to methyl orange	Hardness	Time required for floc to form	Time required for sedimentation.
			Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$		
Blank	....	...	4	118	128	....	....
1	.5	.12	2	116	128	7 hrs.	12 hrs.
2	1.0	.25	4	118	......	5 hrs.	10 hrs.
3	1.5	.38	4	114	135	1 hr. 50 min.	9 hrs.
4	2.0	.51	4	110	......	1 hr.	8 hrs.
5	2.5	.64	4	109	139	50 min.	6 hrs.
6	3.0	.77	4	107	......	30 min.	5 hrs. 20 min.
7	3.5	.90	4	103	140	20 min.	5 hrs. 20 min.
8	4.0	1.03	4	102	......	15 min.	2 hrs. 30 min.
9	4.5	1.16	2	102	142	15 min.	2 hrs. 30 min.
10	5.0	1.29	4	102	......	10 min.	1 hr. 40 min.

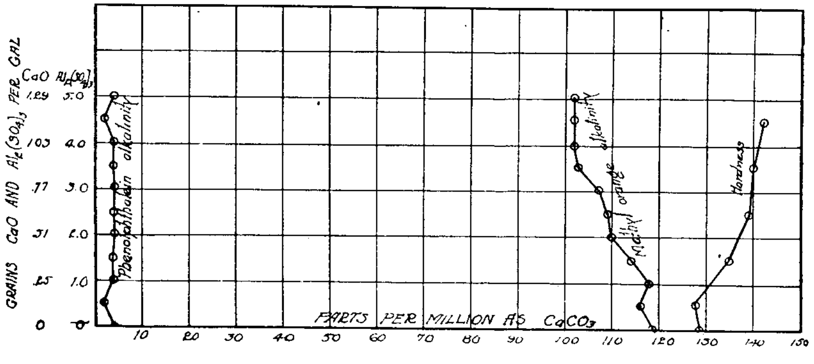

Plate III. Treatment of Lake Michigan Water with Alum and Equivalent Amounts of Lime.

water was used. The results are given in Table X and illustrated diagramatically on Plate IV.

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*Water and Sewage Purification in Ohio. State Board of Health Report, 1908 p. 309.

TABLE X.

LAKE MICHIGAN WATER TREATED WITH ALUMINIUM SULPHATE AND AN EXCESS OF LIME.

No.	Amt. of alum used. Grains per gallon $Al_2(SO_4)_3$	Amt. of lime used. Grains per gallon CaO	Alkalinity to phenolphthalein	Alkalinity to methyl orange	Hardness	Time required for floc to form	Time required for sedimentation
			Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$		
1	.5	3.49	4.0	38	41	40 min.	2 hrs. 10 min.
2	1.0	3.75	4.0	41	....	12 min.	1 hr. 10 min.
3	1.5	4.01	4.0	43	49	12 min.	1 hr. 10 min.
4	2.0	4.27	4.0	44	....	12 min.	1 hr. 10 min.
5	2.5	4.53	2.0	44	58	7 min.	40 min.
6	3.0	4.79	2.0	46	....	5 min.	40 min.
7	3.5	5.05	2.0	46	68	7 min.	40 min.
8	4.0	5.31	2.0	46	....	5 min.	40 min.
9	4.5	5.57	2.0	49	78	7 min.	40 min.
10	5.0	5.83	2.0	49	....	5 min.	40 min.
Blank	....	....	0	118	135		

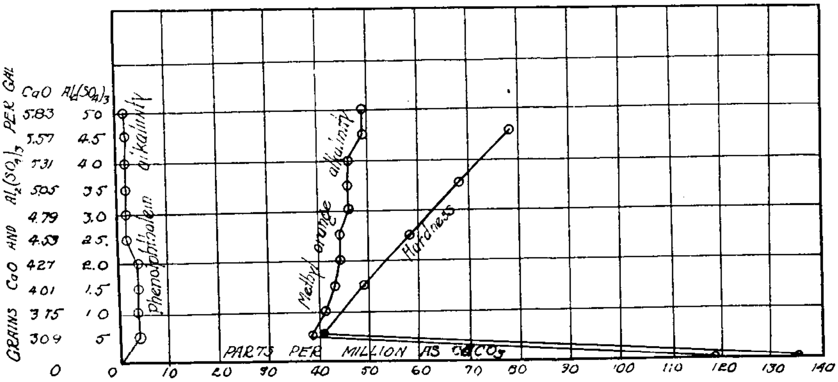

Plate IV. Treatment of Lake Michigan Water with Alum and Excess of Lime.

The floc formed in a few minutes and settled rapidly. The softening action of the lime is well shown on Plate IV. In this experiment the amount of lime used is excessive and would probably result in the deposition of lime on sand grains of the filter. Such an effect

TABLE XI.

LAKE MICHIGAN WATER TREATED WITH CONSTANT AMOUNTS OF ALUMINIUM SULPHATE AND VARYING AMOUNTS OF LIME.

No	Grains per gallon $Al_2(SO_4)_3$	Grains per gallon CaO	Alkalinity to phenolphthalein	Alkalinity to methyl orange	Hardness	Time required for floc to form	Time required for sedimentation
			Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$		
1	1.5	......	0	105	125	3 hrs.	$3\frac{1}{2}$ hrs.
2	1.5	.19	0	111	126	3 hrs.	$3\frac{1}{2}$ hrs.
3	1.5	.38	0	112	121	2 hrs.	$3\frac{1}{2}$ hrs.
4	1.5	.76	4	112	121	2 hrs.	$3\frac{1}{2}$ hrs.
5	1.5	1.19	6	100	103	2 hrs.	3 hrs.
6	1.5	1.52	6	90	101	2 hrs.	3 hrs.
7	1.5	1.99	6	79	78	$\frac{1}{2}$ hr.	$2\frac{3}{4}$ hrs.
8	1.5	3.62	11	46	60	$\frac{1}{4}$ hr.	$2\frac{1}{2}$ hrs.
Blank	......	......	0	118	135	....	....

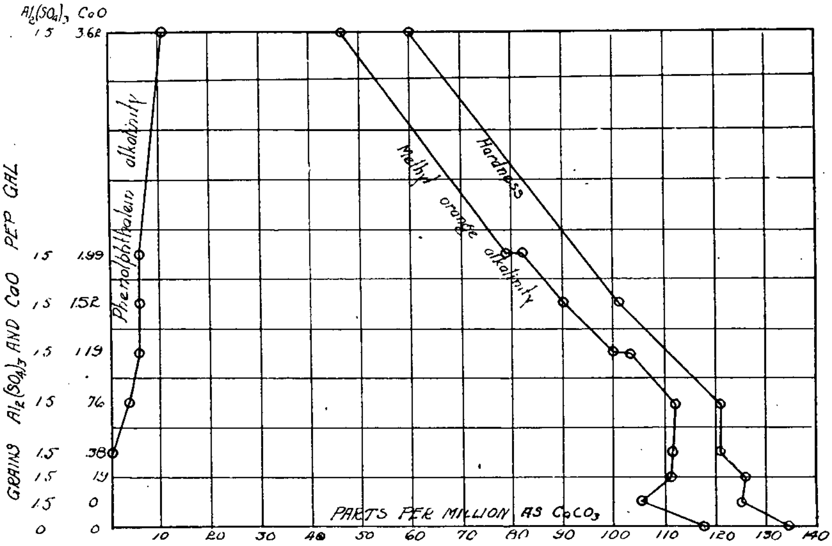

Plate V. Treatment of Lake Michigan Water with Alum and Varying Amounts of Lime.

was observed in Loraine, Ohio*, when an excess of lime was used with iron sulphate.

In experiment V, an attempt was made to find an amount of lime which added with aluminium sulphate would cause a slight softening effect and yield a satisfactory floc which would settle quickly. The results of this experiment are shown in Table XI and illustrated diagramatically on Plate V. A satisfactory floc was obtained with 1.5 grains of aluminium sulphate and 2 grains of lime. The floc formed in ½ hour and settled readily.

This comparison of the treatment shows that there is a saving of chemicals of $1.14 per million gallons.

TABLE XII.

COMPARISON OF COST OF TREATMENT OF LAKE MICHIGAN, WATER WITH ALUMINIUM SULPHATE ALONE AND WITH ALUMINIUM SULPHATE AND LIME.

Grains per gallon $Al_2(SO_4)_3$ used	Grains per gallon CaO	Cost $Al_2(SO_4)_3$ per million gallons of water treated	Cost CaO per million gallons of water treated	Total cost per million gallons of water treated
2.5	......	$4.46	......	$4.46
2.0	......	$3.57	......	$3.57
1.5	1.99	$2.68	$.64	$3.32

In experiment VI, varying amounts of aluminium sulphate with equivalent amounts of sodium hydroxide were used. The results of this method of treatment show that the methyl orange alkalinity and the hardness are practically unchanged. A floc was formed at about the same rate as when aluminium sulphate and an equivalent amount of lime were used.

In experiment VII, varying amounts of aluminium sulphate with equivalent amounts of sodium carbonate were used. The results of this experiment show that practically the same results were obtained as when using aluminium sulphate and equivalent amounts of sodium hydroxide. The only advantage gained by using sodium hydroxide or sodium carbonate instead of lime is that the hardness is not increased by the addition of the base. This advantage is offset, however, by the greater cost of sodium hydroxide and sodium carbonate. Lime is the cheapest base obtainable.

In experiment VIII, iron (ferrous) sulphate was substituted for aluminium sulphate and the experiment carried out in the same way as in experiment II. The iron sulphate solution used contained 4.28

*Water and Sewage Purification in Ohio. State Board of Health Report, 1908. p. 164.

milligrams of ferrous sulphate ($FeSO_4$, $7H_2O$) so that 1 cubic centimeter of the solution added to a liter of the water was equivalent to one quarter of a grain of $FeSO_4$, $7H_2O$ per gallon of water. Ferrous sulphate alone did not yield a floc when added to Lake Michigan water. Some base is needed to react with the iron sulphate in order to form the flocculent iron hydroxide.

In experiment IX, varying amounts of ferrous sulphate with an equivalent amount of lime were added to the water. The results of this experiment are shown in Table XIII and illustrated diagramatically on Plate VI. The methyl orange alkalinity gradually decreases, while the hardness at first increases and then decreases. The time required for the floc to form and for sedimentation is much greater than is required when aluminium sulphate and an equivalent amount of lime are used. At the end of 24 hours cylinder No. 1 (Table XIII) had not yet shown any floc. In this cylinder a color* of 10 parts per million developed. No color was visible in the other filtrates. Thus if water treated with iron and lime is filtered before the reaction is complete the filtered water is liable to be more or less colored. If the reaction has not proceeded far enough before the water is filtered, there is also a

TABLE XIII.

LAKE MICHIGAN WATER TREATED WITH VARYING AMOUNTS OF FERROUS SULPHATE AND AN EQUIVALENT AMOUNT OF LIME.

No.	Amt. of iron used. Grains per gallon $FeSO_4$	Amt. or lime added. Grains per gallon CaO	Alkalinity to phenolphthalein	Alkalinity to methyl orange	Hardness	Time required for floc to form.	Time required for sedimentation
			Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$		
Blank	....	....	4.0	118	140	....	....
*1	.5	.20	2.0	112	148	no floc in 24 hrs.	....
2	1.0	.40	2.0	111	147	$9\frac{1}{2}$ hrs.	20 hrs.
3	1.5	.60	4.0	110	148	$3\frac{1}{2}$ hrs.	$11\frac{1}{2}$ hrs.
4	2.0	.80	6.1	106	142	$2\frac{1}{4}$ hrs.	$7\frac{1}{2}$ hrs.
5	2.5	1.00	4.1	102	140	2 hrs.	$7\frac{1}{2}$ hrs.
6	3.0	1.20	2.0	93	135	1 hr.	$7\frac{1}{2}$ hrs.
7	3.5	1.40	1.0	91	132	50 min.	4 hrs.
8	4.0	1.60	0	81	132	50 min.	4 hrs.
9	4.5	1.80	0	79	125	40 min.	4 hrs.
10	5.0	2.00	0	77	118	40 min.	4 hrs.

*color equaled 10

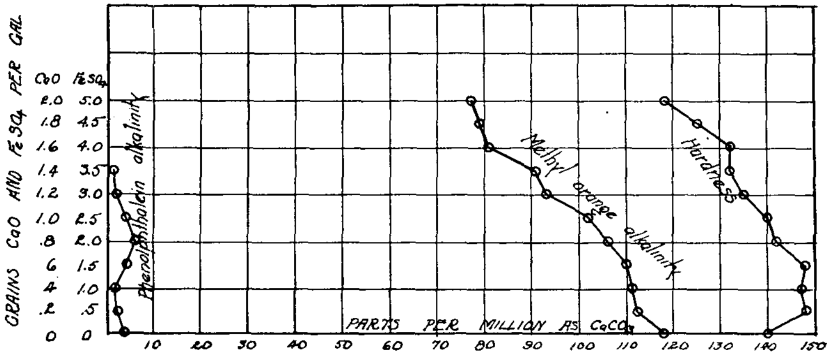

Plate VI. Treatment of Lake Michigan Water with Ferrous Sulphate and Equivalent Amounts of Lime.

danger of the formation of a precipitate in the filtered water. Such a precipitate would be injurious in certain industrial processes. For example, white fabrics washed in such water would be stained by the iron precipitate.

In experiment X an excess of lime was tried to see if the reaction could be hastened. The results are shown in Table XIV and illustrated diagramatically on Plate VII. The softening action of the lime is well shown by the reduction in the alkalinity and hardness. The speed of reaction increases greatly with the increase in the amount of lime, and the precipitate settles readily. As mentioned above, a large excess of lime tends to cause incrustations on the sand grains of the filter. Such an excess of lime as is shown in Table XIV would, therefore, be impracticable unless a sufficient time could be allowed for the reaction to be entirely completed.

In experiment XI, 2½ grains per gallon of iron sulphate with varying amounts of lime were used. The results are shown in Table XV and illustrated diagramatically in Plate VIII. The methyl orange alkalinity and the hardness decrease regularly with the increase in the amount of lime. The phenolphthalein alkalinity is nearly constant until three grains per gallon of lime are used, after which the alkalinity steadily rises. The maximum amount of lime which could be safely used without overtreating is 4½ grains per gallon. With 2.5 grains per gallon of iron sulphate and 2 grains per gallon of lime, a floc was obtained in one hour which required one hour for sedimentation. With 2.5 grains per gallon of lime, ¾ of an hour was re-

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*Standard Methods of Water Analysis p. 21.

quired. With iron sulphate at $9.00 per ton and lime at $4.50 per ton the cost of treatment would be as indicated on Table XVI.

By comparing Table XVI with Table XII, it is seen that the

TABLE XIV.

LAKE MICHIGAN WATER TREATED WITH VARYING AMOUNTS OF FERROUS SULPHATE AND AN EXCESS OF LIME.

No.	Amt. of iron used. Grains per gallon $FeSO_4$	Amt. of lime used. Grains per gallon CaO	Alkalinity to phenolphthalein	Alkalinity to methyl orange	Hardness	Time required for floc to form	Time required for Sedimentation
			Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$	Cor. for vol. Parts per million as $CaCO_3$		
1	.5	3.43	17	51	69	1 hr. 40 min.	2 hrs. 40 min.
2	1.0	3.64	17	49	69	1 hr. 10 min.	2 hrs. 10 min.
3	1.5	3.84	19	48	69	1 hr.	2 hrs.
4	2.0	4.04	19	43	69	50 min.	1 hr 40 min.
5	2.5	4.24	19	43	70	40 min.	1 hr. 40 min.
6	3.0	4.44	21	44	73	25 min.	1 hr. 25 min.
7	3.5	4.64	21	44	73	25 min.	1 hr. 25 min.
8	4.0	4.84	21	44	73	15 min.	1 hr. 20 min.
9	4.5	5.04	24	44	74	10 min.	40 min.
10	5.0	5.24	26	46	74	10 min.	40 min.
Blank	....	......	4	118	140	....	....

Color of all samples O

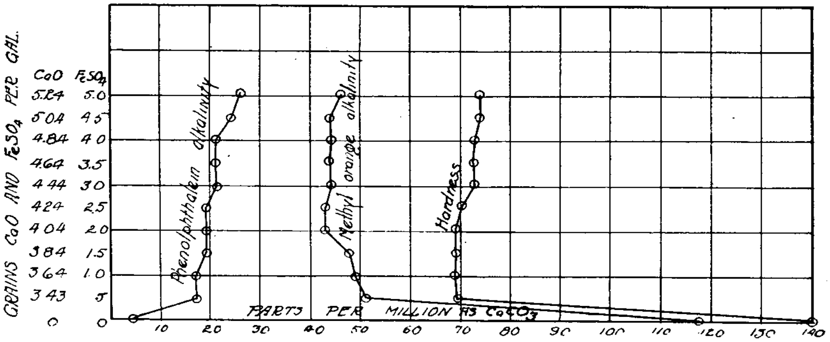

Plate VII. Treatment of Lake Michigan Water with Ferrous Sulphate and Excess of Lime.

TABLE XV.

LAKE MICHIGAN WATER TREATED WITH CONSTANT AMOUNTS OF FERROUS SULPHATE AND VARYING AMOUNTS OF LIME

No.	Grains per gallon $FeSO_4$	Grains per gallon CaO	Alkalinity to phenolphthalein Cor. for vol. Parts per million as $CaCO_3$	Alkalinity to methyl orange Cor. for vol. Parts per million as $CaCO_3$	Hardness Cor. for vol. Parts per million as $CaCO_3$	Time required for floc to form	Time required for sedimentation
Blank	....	....	4.0	116	125		
1	2.5	1.0	4.0	117	128	2 hrs.	1¼ hr.
2	2.5	1.5	2.0	93	120	11 hrs.	1 hr.
3	2.5	2.0	2.0	77	108	1 hr.	1 hr.
4	2.5	2.5	4.0	64	87	40 min.	45 min.
5	2.5	3.0	4.0	56	82	40 min.	45 min.
6	2.5	3.5	12.0	50	78	25 min.	30 min.
7	2.5	4.0	15.0	44	71	25 min.	30 min.
8	2.5	4.5	18.0	40	67	21 min.	30 min.
9	2.5	5.0	20.0	38	59	19 min.	30 min.

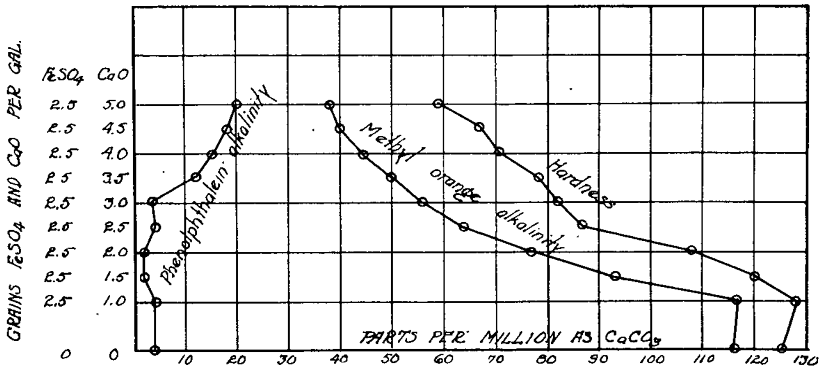

Plate VIII. Treatment of Lake Michigan Water with Ferrous Sulphate and Varying Amounts of Lime.

TABLE XVI.

Grains per gallot $FeSO_4$	Grains per gallon CaO	Cost $FeSO_4$ per million gallons of water treated	Cost CaO per million gallons of water treated	Total Cost per million gallons of water treated
2.5	2.0	$1.61	$.64	$2.25
2.5	2.5	$1.61	$.80	$2.41

substitution of iron sulphate for aluminium sulphate decreases the cost of treatment materially.

In experiment XII, varying amount of iron sulphate were used with an equivalent amount of sodium hydroxide. A more gelatinous floc is obtained with hydroxide than with lime, but the greater cost of the sodium hydroxide offsets this advantage. The time of reaction and sedimentation are practically the same for both bases.

In experiment XIII, iron sulphate and sodium carbonate were used. The floc produced is gelatinous and similar to that produced by sodium hydroxide. The greater length of time required for the reaction makes the sodium carbonate less desirable than the sodium hydroxide. Because of the greater cost it is not so practical as the use of lime with the iron sulphate.

CONCLUSIONS.

A careful consideration of the preceeding data shows that

I. Lake Michigan water from points near the Illinois shore should be purified before it is used, for drinking purposes.

2. Mechanical filtration will be the most satisfactory and the most economical method of purification.

3. Treatment with lime softened the water, but did not yield a satisfactory floc for filtration.

4. Two and one-half grains per gallon of aluminium sulphate must be used in order that a good floc might form in less than one hour.

5. With 1.5 grains of aluminium sulphate and 2 grains lime per gallon a good floc was obtained in ½ hour. It is probable that the effect of the lime was largely mechanical in that it produced artificially a turbidity in the water as clay does. The water was also partially softened at the same time. The cost of this method of treatment would be $1.14 less per million gallons of water treated than if aluminium sulphate was used alone. The hardness of the water was reduced from 125 to 75 parts per million.

6. The use of sodium hydroxide or sodium carbonate with aluminium sulphate would increase the cost of treatment and would not yield any practical advantage over the treatment with lime and aluminium sulphate.

7. With 2.5 grains of iron sulphate and 2 grains of lime per gallon a satisfactory floc was formed in one hour. The cost for chemicals would be $2.25 per million gallons of water treated. There would be a saving of $2.41 over the cost when aluminium sulphate

alone is used and $1.07 over the cost when aluminium sulphate and lime are used.

8. The substitution of sodium hydroxide or sodium carbonate for lime with iron sulphate offers no advantage.

9. When iron sulphate is used there is danger of iron appearing in the filtered water unless the reaction is completed before the water passes to the filter. The use of lime hastens the reaction and decreases the danger.

10. Aluminium sulphate, although more expensive, is more effective than iron sulphate. It can not leave a residual color as may be the case when iron sulphate is used. Our results indicate that treatment of Lake Michigan water with lime and aluminium sulphate will be satisfactory. Similar experiments on a larger scale should be tried.

THE ACTION OF BLEACHING POWDER IN WATER PURIFICATION.*

The first attempt to purify water by filtration on a large scale was made by the London Waterworks Company in 1829. Since then the science of water filtration has developed rapidly until it is now one of the most important methods of securing a safe supply of drinking water. Filtration works, however, are expensive and in the case of a water having practically no color or turbidity, filtration would be superfluous; provided that the bacteria and the dissolved organic matter in the water could be removed by some other means, as, for example, by chemical sterilization. In certain cases where the filtration plant fails to remove the undesirable bacteria from the water, a method of sterilizing the filtered water would be of great value.

Many different methods of water sterilization have been devised but few of them have proved to be a commercial success. Boiling water continually for a period of one-half hour will kill practically all of the bacteria present and will also destroy the spores. Many methods depending on the oxidizing or toxic effect, or both, of various chemicals have been suggested. Maumene† proposes the use of potassium permangante ($KMnO_4$), Reychlerz mentions the use of chlorine peroxide (ClO_2) as a sterilizing agent for drinking water. Ballner* advocates using chlorine (Cl) and Bromine (Br) together. They may also be used separately. Copper sulphate† ($CuSO_4$) has been used quite extensively to prevent growth of organism in standing water. The salts of copper are toxic to the lower forms of plant life, such as algae and bacteria. Considerable diversity of opinion exists, however, in regard to the advisability of using copper and its salts in sterilizing public water supplies. Still other methods have been devised using hydrogen peroxide (H_2O_2), barium dioxide, (BaO_2), ozone (O_3) and other chemical reagents.

Traube,* in 1894 proposed the use of bleaching powder

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*From thesis prepared by George Athol Van Brunt under the direction of Edward Bartow.

†Journa1 Chemical Society 1895, A. I, p. 260.

‡Jour. Chem. Soc.1901, A. II, p. 548.

*Jour. Chem. Soc. 1904, A. II, 68.

†Twenty second Annual Report Ill. Soc. Eng. and Surveyors, p. 36.

*Zeit. für Hyg. V. 16, p. 149.

(CaClOCl), in aqueous solution. The reaction in aqueous solution are represented in the following equations:

$$2CaClOCl \text{ (in solution)} = CaCl_2 + Ca\,(OCl)_2$$
$$Ca\,(OCl)_2 + H_2CO_3 = CaCO_3 + 2HClO$$
$$2HClO = 2HCl + O_2 \text{ (In the presence of organic matter).}$$

The HCl reacts with the carbonates of the water. The oxygen liberated is in the nascent state and is very active.

Laboratory experiments by Lode,[†] Bassinge[‡] and others[§] have demonstrated the strong antiseptic properties of bleaching powder and its destructive effect upon bacteria pathogenic to man.

In 1897[*] at Maidstone, England, bleaching powder was used for sterilizing the city water mains and pipes and proved to be very effective. Middlekirk, Belgium, employs what is known as the ferro-chlor process in connection with filtration of the water. Ferric chloride is added with the bleaching powder, the following reactions taking place:

$$Fe_2Cl_6 + 3CaO_2Cl_2 + 3H_2O = 3CaCl_2 + 6HClO + Fe_2O_3$$
$$2HClO = 2\,HCl + O_3$$

The ferric oxide acts as a coagulant in connection with the filtration. The process proved to be very satisfactory in removing the bacteria.

One of the latest and most striking examples of the use of bleaching powder in the purification of a grossly polluted water occurs in the Union Stock Yards in Chicago.[†]

The results of our experiments with bleaching powder are given below.

EXPERIMENTAL.

The experimental work done is grouped in four divisions, (1) Determination of the smallest amount of chlorine detectable by taste or smell, (2) Determination of the amounts of chlorine absorbed by

[†] Hygienische Rundshau, 1899. 9, page 859.

[§] Koch, Mittheihungen aus dem Kaiserl, Gesundheitsamte, 1881, 1.

[§] Nissen, Zeitscrift für Hygiene. 8, page 62.

[§] Lancet, Nov. 28, 1908, 175, page 1597.

[*] Eng. Rec. Vol. 41, No. 17, p. 390.

[†] Eng. Record, 58, page 653, 703. First Report Lake Michigan Water Commission, p. 120.

various waters in different periods of time. (3) Determination of smallest amounts of calcium hypochlorite that can be detected by simple chemical tests. (4) Practical application of bleaching powder treatment on a large scale.

Varying amounts of a solution of bleaching powder were added to a series of samples of filtered Mississippi River water in such amount as to give the following concentrations: (1)O parts per million free Cl, (2) 3.84 parts per million free Cl, (3) 7.66 parts per million free Cl, (4) 11.49 parts per million free Cl, (5) 15.32 parts per million free Cl. Chlorine could be detected slightly in No. 3 and fairly strong in No. 4.

Series of ten samples each of (1) double distilled water, and (2) tap water containing from 1 to 10 parts per million of available Cl were prepared. Three persons were asked to taste and to state in which samples the chlorine could be detected. They did not know which contained chlorine, nor the relative amounts. In the series made with double distilled water, the general opinion was that a taste was slightly noticeable in the sample containing three parts per million of available chlorine. They could not detect a taste in the sample containing two parts per million. In the series made with tap water, a taste was apparent in the sample containing four parts per million of Cl and faint in the sample containing three parts.

It appears, therefore, that it is impossible to detect by the taste, less than three parts per million of available chlorine in an ordinary drinking water.

It is easier to detect the taste in the distilled than in the tap water. This is, perhaps, due to the fact that the amount of hypochlorite in the tap water is reduced by the organic matter.

It was stated above that bleaching powder breaks up in aqueous solution, especially in water containing carbonates, the final products being $CaCl_2$, $CaCO_3$ andO. In the presence of oxidizible substances this action takes place much more rapidly than in pure water. A number of experiments were made to determine the quantities of bleaching powder which would be absorbed by various waters in different periods of time. Samples of double distilled water were also run to determine the rate at which the bleaching powder disappears in a pure water. This water was made by taking ordinary distilled water, treating with Br, allowing to stand several hours, then distilling over Na_2CO_3. The first distillate was dicarded. The amount of organic matter contained in this double-distilled water is very small indeed.

Table I gives the results of one of the preliminary tests on the University of Illinois water. Tables II and III show the results of the same tests on raw and filtered Mississippi River water from

Quincy, Illinois. The plus (+) sign indicates that a blue color was obtained by the starch iodide test; the minus (—) sign indicates no color, and shows the period of time after which hypochlorite could not he detected. The starch iodide test was made by adding the reagents to the water in a Nessler tube. The test is very sensitive and a quantity of available Cl as small as .07 parts per million can be detected.

TABLE I.

No.	Pts. Cl. per M.	1 min.	30 min.	1¾ hr.	3 hr.	24 hr.	30. hr.	54. hr.	72 hr.
1	.14	+	—	—	—	—	—	—	—
2	.17	+	+	—	—	—	—	—	—
3	.19	+	—	—	—	—	—	—	—
4	.21	+	+	—	—	—	—	—	—
5	.24	+	+	+	—	—	—	—	—
6	.26	+	+	+	—	—	—	—	—
7	.29	+	+	+	—	—	—	—	—
8	.32	+	+	+	—	—	—	—	—
9	.34	+	+	+	+	—	—	—	—
10	.36	+	+	+	+	—	—	—	—
11	.37	+	+	+	+	—	—	—	—
12	.41	+	+	+	+	+	—	—	—
13	.43	+	+	+	+	+	—	—	—
14	.46	+	+	+	+	+	+	+	—
15	4 8	+	+	+	+	+	+	+	—
16	.50	+	+	+	+	+	+	+	—
17	.53	+	+	+	+	+	+	+	—
18	.55	+	+	+	+	+	+	+	—
19	.57	+	+	+	+	+	+	+	+
20	.60	+	+	+	+	+	+	+	—

TABLE II.

RAW WATER.

No.	Pts. Cl.	1 min.	30 min.	1 hr.	2 hr.	4 hr	6 hr.	24 hr.
1	1.60	+	+	—	—	—	—	—
2	1.25	+	+	+	—	—	—	—
3	1.50	+	+	+	+	—	—	—
4	1.75	+	+	+	—	—	—	—
5	2.00	+	+	+	+	+	+	—
6	2.25	+	+	+	+	+	+	—
7	2.50	+	+	+	+	+	+	—
8	2.75	+	+	+	+	+	+	—
9	3.00	+	+	+	+	+	+	—

TABLE III:

FILTERED WATER.

No.	Pts. Cl.	1 min.	30 min.	1 hr.	2 hr.	4 hr.	6 hr.	24 hr.
1	.50	+	+	+	—	—	—	—
2	.75	+	+	+	+	—	—	—
3	1.03	+	+	+	+	+	—	—
4	1.25	+	+	+	+	+	+	—
5	1.50	+	+	+	+	+	+	—
6	1.75	+	+	+	+	+	+	—
7	2.00	+	+	+	+	+	+	+
8	2.25	+	+	+	+	+	+	+
9	2.50	+	+	+	+	+	+	+

After having made these preliminary tests, we were able through the courtesy of the Lake Forest Water Company to try the use of bleaching powder on the Lake Forest Water supply. The water was taken from Lake Michigan and filtered through pressure filters. The addition of the bleach was helpful but not entirely satisfactory owing to the inadequacy of the filters. The capacity of the filters has since been doubled and the use of bleach continued with satisfaction.

Through the courtesy of Mr. C. H. Cobb of the Kankakee Water Works Company, the use of bleach was next tried at the Kankakee water works. Tests on the raw water at the time of the trial showed very low bacterial counts and the absence of gas formers. It was, therefore, impossible to obtain conclusive results, and the test at Kankakee was discontinued. Since that time a permanent installation has been placed at Kankakee, and whenever necessary, bleaching powder is used in connection with alum in the treatment of the Kankakee water. The success of the treatment was shown by Mr. C. H. Cobb at the 1910 meeting of the Illinois Water Supply Association.* Not only was there a very satisfactory removal of bacteria when bleaching powder was used, but gas formers were entirely absent in the filtered water, there was a saving of $94.00 in the bill for coagulants in 57 days, with a pumpage of two million gallons of water per day.

After the discontinuance of the trial at Kankakee, through the courtesy of Mr. W. R. Gelston, the use of bleach was begun in the purification of Mississippi River water at Quincy, Illinois. A laboratory was installed for the trial, test and arrangements made so that bacteriological control could be continued by the operators of the

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*Proceedings of the Illinois Water Supply Association 1910, p. 198.

plant. The results of the trial are best given by abstracting an article by Mr. Gelston.*

The laboratory was fitted up and the first satisfactory counts were made on samples plated April 6, 1909. Since that date the plant has been operated for several periods without the use of bleaching powder while various amounts of bleaching powder have been used during other periods of sufficient length to give fairly reliable comparative results. No attempt was made to reduce the amounts of Sulphate of Iron and Lime ordinarily used, because there are certain defects in the construction and arrangement of the plant which prevent a high efficiency even when the condition of the river water is most favorable. The use of bleaching powder was, therefore, entirely for the purpose of increasing the efficiency of the plant.

The bleaching powder solution was introduced into the settled water at the point of overflow from the basin, and as the water flows through about one hundred feet of twenty inch pipe before reaching the filters, the bleach solution was quite thoroughly mixed with the water.

During April, the work was under the supervision of Mr. G. A. Van Brunt and samples were plated each forenoon and afternoon when the plant was in operation. Later, there were usually plated each day one sample from the river, one from the effluent from the settling basin and one from a filtered water tap on the water chamber of the high duty pump. Occasionally samples from individual filters were plated.

For the purpose of showing the effect of treatment with bleaching powder, a table (Table IV) was prepared in which will be found for each period of operation amounts of bleach, the average turbidity of the river water, the average alkalinity of the river and tap waters, the average stage of the river, the amount of bleach used in grains per gallon, the average number of colonies of bacteria per c.c. in the river and tap waters and the average per cent of bacterial removal; also the number of positive and negative tests for gas formers in the river and tap waters.

During the first period of operation, from April 6 to April 13, no bleach was used and the regular operation of the plant was in no way disturbed. On April 14, the use of bleaching powder was begun at the rate of 0.25 grains per gallon of water treated and this amount was continued until the morning of April 17, when complaints were received of a medicinal taste in the water. The amount of bleach was at once reduced and until April 27 various quantities from

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*Proceedings of the Illinois Water Supply Association, 1910, p. 193.

TABLE IV.

DATE, FROM—	Average Turbidity of River.	Average Alkalinity.		Average Stage of River.	Bleach Gr. Per Gallon	Averane No. Bacteria Per C. C.		Average Per Cent of Removal.	Gas Formers.	
		River.	Tap.			River.	Tap.		River.	Tap.
4- 6-09 to 4-13-09	1,230	120	73	10.0	0.0	8,836	276	96.9	8 +	4 + 4 —
4-14-09 to 4-27-09	557	102	65	13.6	0.14 to 0.25	5,423	15	99.7	13 + 2 —	6 + 17 —
4-28-09 to 5- 3-09	257	108	63	14.7	0.0	2,193	493	77.5	5 +	4 + 4 —
5- 4-09 to 6- 9-09	362	115	71	12.9	0.14	3,986	154	96.1	25 +	14 + 16 —
6-11-09 to 6-23-09	578	119	76	13.2	0.0	53,443	2,038	96.8	9 + 1 —	9 + 1 —
6-24-09 to 6-25-09	180	128	75	10.5	0.10	2,030	36	98.2	2 +	2 +
6-26-09 to 7- 2-09	567	125	83	11.4	0.0	7,870	1.265	83.8	4 +	5 + 2 —
7- 6-09 to 7-16-09	498	132	93	13.1	0.07	22,790	853	96.3	9 +	9 +
7-17-09 to 8- 5-09	150	158	98	6.5	0.10	6,283	265	95.8	9 +	3 + 1 —
8- 6-09 to 8-23-09	138	153	98	4.7	0.0	3,437	942	72.6	5 + 1 —	6 —
8-24-09 to 8-27-09	262	123	79	5.4	0.07	6,127	139	97.7	4 +	1 + 3 —
8-28-09 to 10- 9-09	165	140	91	3.9	0.0	6,098	96	98.4	22 +	18 + 4 —
10-11-09 to 10-12-09	90	144	86	2.8	0.035	2,695	22	99.2	2 +	2 —
10-13-09 to 10-28-09	94	151	96	2.8	0.07	3,161	64	98.0	8 +	2 + 5 —
10-30-09 to 11- 8-09	94	149	90	3.0	0.10	4,337	72	98.3	3 + 1 —	4 —

0.25 down to 0.14 grains per gallon were used. Complaints about the water were still received. No bleach was used, therefore, from April 28 until May 3, and a remarkable loss of efficiency for the plant was noticed, the percentage of bacterial removal for this period being 77.5 compared with 99.7 for the period during which 0.14 to 0.25 grains were used and 96.9 for the period before any bleach was used at all. It was very unfortunate that the first attempt to use bleaching powder resulted in an overdose, because this experience developed an abnormal sense of taste and smell in some of the consumers and complaints about the water were constantly received for several months. Some of the complaints were just, but a large majority of the complainants were unable to produce any bad water when called upon to furnish samples. Mr. Gelston does not believe that there was ever any odor or taste due to bleaching powder when less than 0.14 grains per gallon were used. Nevertheless, the first difficulty had an intimidating effect upon the operating officials and the use of bleach was discontinued whenever complaints were made.

From April 6, 1909 to November 8, 1909, the plant was operated during six different periods of time without bleaching powder, with a maximum average removal of bacteria of 98.4 per cent and a minimum of 72.6 per cent, the average for the six periods being 87.7 per cent. Within the same limits of time, there were nine periods of operation with different amounts of bleach, from 0.035 to 0.25 grains per gallon, with a maximum average removal of 99.7 per cent and a minimum of

95.5 per cent, the average for the nine periods being 97.7 per cent or ten per cent higher than the average for the six periods without the bleach.

A comparison of the results of tests for gas farmers shows that 96.2 per cent of all samples of river water indicated the presence of gas farmers; 65.6 per cent of all samples of filtered water tested when bleaching powder was not used gave positive results, while 46.7 per cent of all samples of filtered water tested when bleaching powder was used gave positive results. In the report on gas formers, the term "doubtful" was not used. If there was any gas in the closed arm of the Smith tube, the test was marked positive.

The use of bleach was of advantage even in the experimental stage. The results as the trial proceeded showed increased efficiency in the working of the plant.

Experience at Quincy certainly indicates an advantage in using bleaching powder in connection with mechanical filtration.

TREATMENT OF WATER WITH BOILER COMPOUNDS.*

The ideal water for boiler use is seldom if ever met with in a natural state. Natural waters are desirable or undesirable boiler waters according to the amount of scaling, corrosion or foaming that they produce.

Scale is the deposit formed on the inside of the boiler shell and on the inside of the tubes in a water tube boiler, and the outside of the tubes in a fire tube boiler. It is caused by certain impurities in the water that are left behind as the water evaporates. Perfectly pure water does not form any scale. The character and hardness of the scale varies with the composition of the mineral matter dissolved in the water. The carbonates of calcium and magnesium form a soft scale or sludge which may be blown out of the boiler, while the sulphates of the same metals together with the oxides of iron and aluminium form a very hard scale that can only be removed by chipping. Various mixtures of the carbonates and sulphates form scales having a hardness intermediate between the extremes mentioned above.

Boiler scale is a poor conductor of heat. As the scale collects, the amount of heat transferred to the water becomes less and less. It is, therefore, necessary to increase the amount of coal burned in order to produce a greater amount of heat and thus keep up the required amount of steam. Boiler scale, moreover, because of its low conductivity of heat frequently causes overheating of the boiler shell or tube beneath the scale and thus may lead in turn to a boiler explosion.

Corrosion is the eating away of the metal portions of the boiler. It is caused by the presence in the water of dissolved gases, such as oxygen and carbonic acid gas; of acids, such as hydrochloric acid, and of salts, such as magnesium chloride, which give off acids when their solutions are heated. The corrosive action of the gases is more noticeable in comparitively pure waters. Corrosion frequently leads to boiler explosion.

Foaming occurs on account of dirty or greasy waters or on account of an excess of alkalies in the water. The chief objection to foaming is that it causes wet steam which lowers the efficiency of the

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*From thesis prepared by William Christoph Marti under the direction of Edward Bartow and submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Chemical Engineering in the College of Science of the University of Illinois, June 1909.

boiler. It may also cause a wrong reading of the water level in the gauge glass, and so, through an insufficient amount of water, produce overheating of the boiler plates.

A water that shows one or more of these undesirable features may be treated either outside of the boiler before it enters the boiler feed-water pipe, or else it may be treated after it has, entered the boiler. The first of these two methods is the more desirable for the reason that wear on the boiler is increased by causing chemical reactions to take place in it. Because of the cost of installing and properly operating a treatment plant, the owners of small manufacturing and heating plants usually rely on the treatment within the boiler. This latter phase of boiler water treatment is one dealt with in this paper.

Various substances, the action of which are purely mechanical have been used in the past to bring about a greater efficiency in the boiler. Among these may be mentioned potatoes, sand and kerosene. Certain chemicals when added to the water in the boiler give better and more rapid results. These chemicals are sold under the name of “Boiler Compounds”.

An ideal boiler compound would be one that would prevent scaling, corrosion. and foaming. None of the compounds manufactured thus far have been able to prevent all of these troubles. There can be no universal compound. One must be made to fit each individual case.

The boiler compounds on the market are many and various. Most of them are of some value, and there are some which give very excellent results. The great majority of the better compounds contain a large proportion of sodium carbonate or a sodium salt of a weak acid, the action of which is purely chemical and depends on the ability of the sodium salts to change the sulphates, chlorides or nitrates of calcium and magnesium to insoluble compounds. The reactions are illustrated as follows:

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$
$$MgSO_4 + Na_2CO_3 = MgCO_3 + Na_2SO_4$$
$$MgCl_2 + Na_2CO_3 = MgCO_3 + 2NaCl$$

Caustic soda acts in much the same way as sodium carbonate. Tannin and tannate of sodium are frequently used but are more expensive than sodium carbonate. The tannic acid formed has a strong corrosive action. Tri-sodium phosphate (Na_3PO_4) produces a flocculent, amorphous precipitate which can be easily blown out*. Sodium aluminate has also been used to good advantage; but, like

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*Trans. Amer. Soc. C. E. Vol. LIV. p. 8.

the tri-sodium phosphate, it is too expensive for general use. Some boiler compounds contain molasses or other organic matter mixed with sodium carbonate or caustic soda.

The composition of some boiler compounds are reported as follows:†

1. "Arcanum". Na_2CO_3, 11.6%; NaCl, 1.24%; Fe, Al, Ca, Mg, 0.7%; Organic matter 1.86%; water 84%.
2. "Séfénifuge". Na_2CO_3 and sugar.‡
3. "Anti-Tartre-Végétal-Bretal". 10% solution of organic substances.
4. "Anticarbonit", Tar dyes; Na_2CO_3, 23%; $NaHCO_3$, 62%; $CaCO_3$, 2.5%; NaCl, Na_2SO_4 and water.‡
5. "Sélénige". Soda and Molasses.
6. "Tannate". Sodium tannate, 10%; tannin extract containing saccharine and general inert matter of the extract, 60%; mixture of cane and grape sugar with some soluble starch, 10%*.
7. "Compound No. 1". Sawdust, Na_2CO_3 and some sulphates.*

From this we see that the composition of the various compounds is quite different and it is seldom if ever that the name represents the contents; in fact cases are known where Lake Michigan water slightly disguised has been sold for a boiler compound.†

The experimental work described below was planned with a view to testing several boiler compounds to determine their efficiency. For this purpose the apparatus shown in Plate I as devised.

The water to be tested is placed in a tubulated bottle which serves as a reservoir. The tubulus is fitted with two tubes (C) and (D) one shorter than the other, which dip into a small flask (B) of 500 c.c. capacity, placed at a lower level. From this flask a siphon (E) leads to a heating flask(A) of 1000 c.c. capacity, placed on a level with the flask (B). A sheet of iron (G) of known weight is suspended in the flask (A). After once filling the reservoir, the level of the water in flask A remains automatically constant for as soon as any water boils off in A and the level lowers, the siphon draws over some of the water from flask B, which lowers the level in the latter. Tube C is shorter than D and allows air to pass up into the reservoir, which is otherwise air tight, and water flows down through D until the water

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†Biedermann's Technisch-Chemisches Jahrbuch, 1895-96, 18 page 303.

‡Official Proceedings Western Railway Club. W. H. Edgar, Vol. 15, No. 5, p. 231.

*Analysis by Department of Applied Chemistry, University of Illinois.

†Official Proceedings of Western Railway Club—G. M. Davidson, Vol. 15, No. 6, page 247.

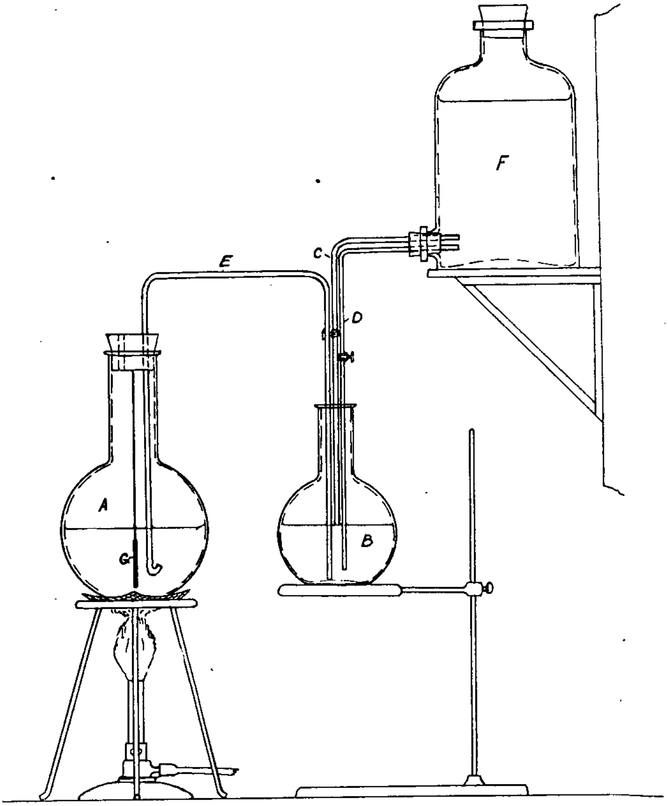

Plate I. Constant Level Apparatus used in Experiments.

level is high enough to seal C again. In this manner the experiment can be started and kept running without much watching on the part of the manipulator.

The flask (A) was weighed before and after the experiment. Any increase in the weight of the flask gave the amount of scale forming material deposited on the walls. The flask was shaken throughly, and washed with distilled water so that loose deposits, which would be carried away by the blowing off of a boiler, would not enter into the increase in weight.

The piece of sheet iron (G) was weighed before putting it into the flask, and after the boilng was completed, it was thoroughly washed and cleaned with fine pumice stone. This latter cleaner was used because in the highly scaling waters a small amount of scale formed on the sheet. It was then dried with alcohol and ether and was placed in a dessicator until ready to weigh. Any loss in the weight of the iron gave the amount of iron eaten away or corroded. It was thought that perhaps some of the iron was removed by the pumice so a blank test was run.

The average loss due to 50 strokes was found to be .0016 grms. and this correction was made in each test.

The following tables give some of the results obtained.

TABLE I.

Concentration of 2000 c.c. of various waters to 500 c.c.

Iron corroded	Scale formed	Source of water.
.0156 gm.	.2461 gm.	Dean Bode Mfg. Co., Champaign, Ill.
.0293 gm.	.1012 gm.	Kankakee River Water.
.0100 gm.	.2578 gm.	Mattoon City Supply.
.0250 gm.	.1979 gm.	University Supply.
.0330 gm.	.0000 gm.	Distilled water.
.0362 gm.	.0000 gm.	Double-distilled.

The chemical composition of the water used in the above experiments is given in Table II together with a reference to the authority for the analysis.

TABLE II.

IONS	Dean Bode Mfg. Co. Champaign, **Ill.** (A) Milligrams per 1000 c.c.	Kankakee River Kankakee, Ill. (B) Milligrams per **1000 c.c.**	City Supply Mattoon, Ill. (C) Milligrams per 1000 c.c.	Univ. of Ill. Supply Urbana, **Ill.** (A) Milligrams per 1000 c.c.	Mississippi River water, filtered. Quincy, Ill. (B) Milligrams per 1000 c.c.
Potassium K	33.4	2.0	4.6	2.6	2.7
Sodium Na	....	5.3	42.2	29.0	4.3
Ammonium (NH_4) ..	....	.1	.5	2.3	
Magnesium Mg	50.0	17.6	49.5	34.9	9.3
Calcium Ca	106.9	56.7	93.6	70.1	18.4
Oxide of Iron and Aluminium	2.2	4.2	.4	1.0	.7
Silica	11.0	37.2	13.9	18.9	6.5
Bases	3.0	16.5	......	......	......
Nitrate NO_3	1.2	5.3	0.7	0.7	3.0
Chloride Cl	24.0	2.0	4.2	3.5	1.5

(A)=University of Illinois bulletin, State Water Survey Series No. 6
(B)=University of Illinois bulletin, State Water Survey Series No. 5
(C)=Analysis by Illinois State Water Survey Laboratory.

Table II Cont'd. HYPOTHETICAL COMBINATIONS.

	Parts per Million	Grains per U. S. Gal.	Parts per Million	Grains per U. S. Gal.	Parts per Million	Grains per U. S. Gal.	Parts per Million	Grains per U. S. Gal.	Parts per Million	Grains per U. S. Gal.
Potassium Nitrate	....	....	5.2	0.30	1.1	9.06	1.1	0.06	4.9	0.29
Potassium Chloride	....	....	....	....	7.9	0.46	2.9	0.17	1.5	0.09
Sodium Nitrate	1.6	0.09	2.9	0.17	....	....	....	....	....	....
Sodium Chloride	39.6	2.31	3.3	0.19	0.8	0.05	3.5	0.20	1.3	0.08
Sodium Sulphate	53.7	3.13	9.9	0.58	129.4	7.55	3.6	0.21	11.7	0.68
Sodium Carbonate	....	....	....	....	....	....	60.5	3.52	....	....
Ammonium Sulphate	....	....	.4	0.02	1.8	0.10	....	....	....	....
Ammonium Carbonate	....	....	....	....	....	....	6.1	0.36	....	....
Maanesium Suluhate	145.7	8.49	53.9	3.14	190.2	11.09	....	....	30.5	1.78
Magnesium Carbonate	36.4	2.12	23.2	1.35	39.1	2.27	121.2	7.07	11.1	0.05
Calcium Sulphate	266.8	15.56	....	....	....	....	....	....	....	....
Calcium Carbonate	....	....	141.5	8.25	233.9	13.64	175.2	10.22	45.9	2.08
Oxide of Iron and Aluminium	2.2	0.13	....	....	....	....	....	....	....	....
Ferrous Carbonate	....	....	8.1	0.51	0.8	0.05	2.1	0.12	1.5	0.09
Alumina	....	....	10.8	0.63	0.8	0.05	2.5	0.15	1.2	0.07
Silica	11.0	0.64	37.2	2.17	13.9	0.81	18.9	1.10	6.5	0.38
Bases	3.0	0.17	16.5	0.96	....	....	....	....	....	....
Total	560.0	32.64	313.5	18.27	619.7	36.13	397.6	23.18	116.1	6.79

The scale formed varies with the amount of $CaCO_3$, $MgSO_4$, and $MgCO_3$ in the water, as can be seen from the composition of the waters. The corrosion varies inversely as the amount of solid matter in solution. Distilled waters are corrosive because of their tendency to satisfy their solvent action.

It was thought best to run tests on the different samples of treated water to determine total hardness, alkalinity, non-carbonate hardness and magnesium.*

TABLE III.

Treatment of University water with Na_2CO_3. 3.5 liters of cold water treated. 500 c.c. used up in making determinations and rest boiled to 500 cubic centimeters.

Average of two sets of determinations.

Amount of Na_2CO_3 added	Iron corroded	Scale formed	Foaming	N.C.H	Mg.	Alk.	Hardness
.2 gm.	.0329 gm.	.221 gm.	slight	-131	77	410	363
.4 gm.	.0337 gm.	201 gm.	high	-177	75	415	345
.6 gm.	.0355 gm.	.160 gm.	high	-221	77	428	327
.8 gm.	.0386 gm.	.142 gm.	high	-280	75	451	318
1.0 gm.	.0407 gm.	.124 gm.	high	-326	79	474	305
untreated	.0387 gm.	.310 gm.	very low	-80	113	355	387

*See Standard Method of Water Analysis.

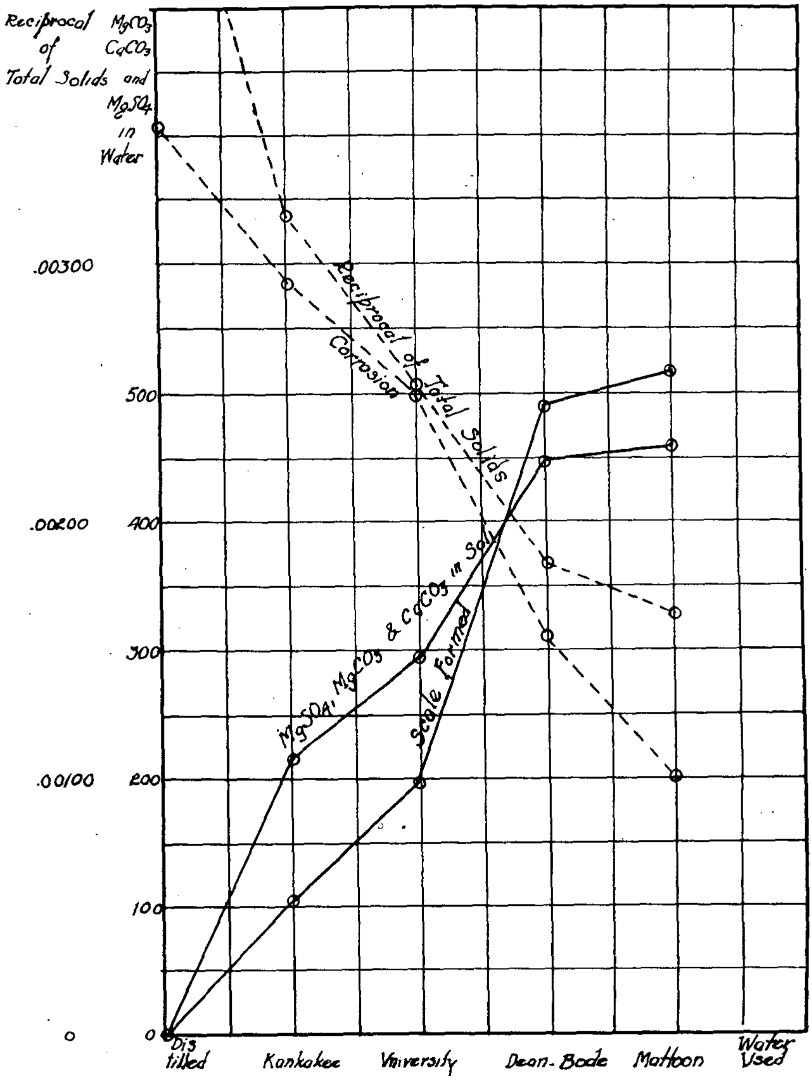

Plate II. Relation of Scale Formation and Corrosion to Mineral Content.

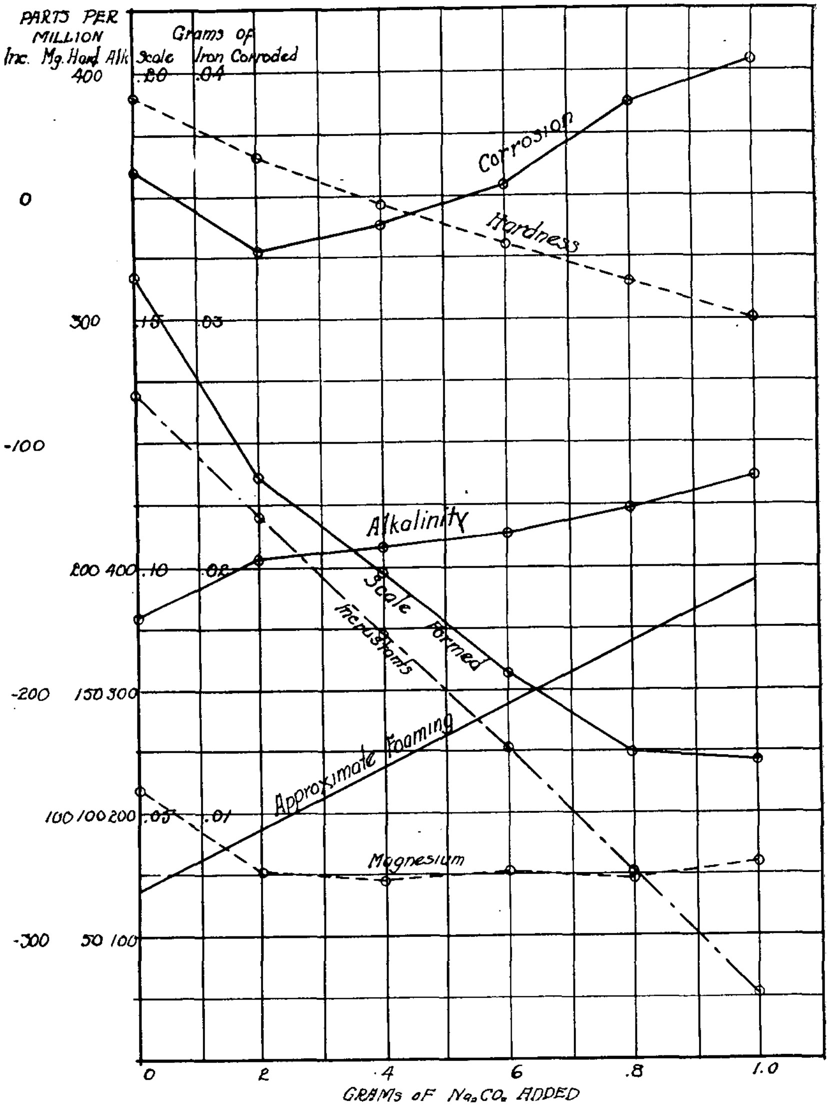

Plate III. Treatment of University Water with Sodium Cabronate.

The corrosion increases slightly with the treatment while scale forming is lowered. The foaming is high, and increases with the alkalinity. The hardness is not changed very much.

TABLE IV.

Treatment of University water with "Arcanum". Two liters of the cold water were treated, and then boiled down to 500 c.c.

Amount of "Arcanum" added	Iron corroded	Scale formed	Foaming	N.C.H.	Mg.	Alk.	Hardness
10 c.c.	.0231 gm.	.103 gm.	high	-207	88	462	375
20 c.c.	.0279 gm.	.122 gm.	high	-282	104	644	350
30 c.c.	.0301 gm.	.093 gm.	high	-327	96	844	295
40 c.c.	.0346 gm.	.046 gm.	high	-372	80	1094	235
50 c.c.	.0372 gm.	.009 gm.	high	-407	104	1296	170
untreated	.0253 gm.	.206 gm.	very low	-82	112	3348	390

The corrosion is increased considerably while the scale formed decreases with the treatment. Foaming, however, is too great for all practical purposes.

TABLE V.

Treatment of University water with 10% solution of potassium fluoride. Two liters of the cold water were treated. Boiled down to 500 c.c.

Amount of fluoride added	Iron corroded	Scale formed	Foaming	V.C.H.	Mg.	Alk.	Hardness
10 c.c.	.0202 gm.	.012 gm.	low	-210	73	332	310
20 c.c.	.0216 gm.	.004 gm.	low	-250	75	335	265
30 c.c.	.0229 gm.	.001 gm.	low	-298	over	347	205
40 c.c.	.0256 gm.	.000 gm.	low	-377	treat-	347	165
50 c.c.	.0262 gm.	.000 gm.	low	-376	ment	347	130
untreated	.0251 gm.	.194 gm.	very low	-79	114	347	385

The corrosion increases slightly with increased treatment. The amount of scale formed is greatly decreased while foaming remains practically the same. The alkalinity is decreased in the first two treatments but after that is the same as in the original water. The total hardness is lowered considerably. The over treatment when more than 20 c.c. of the potassium fluoride solution was used could be told in the test for magnesium by the precipitation of the excess of lime added so that one drop of acid gave a neutral result.

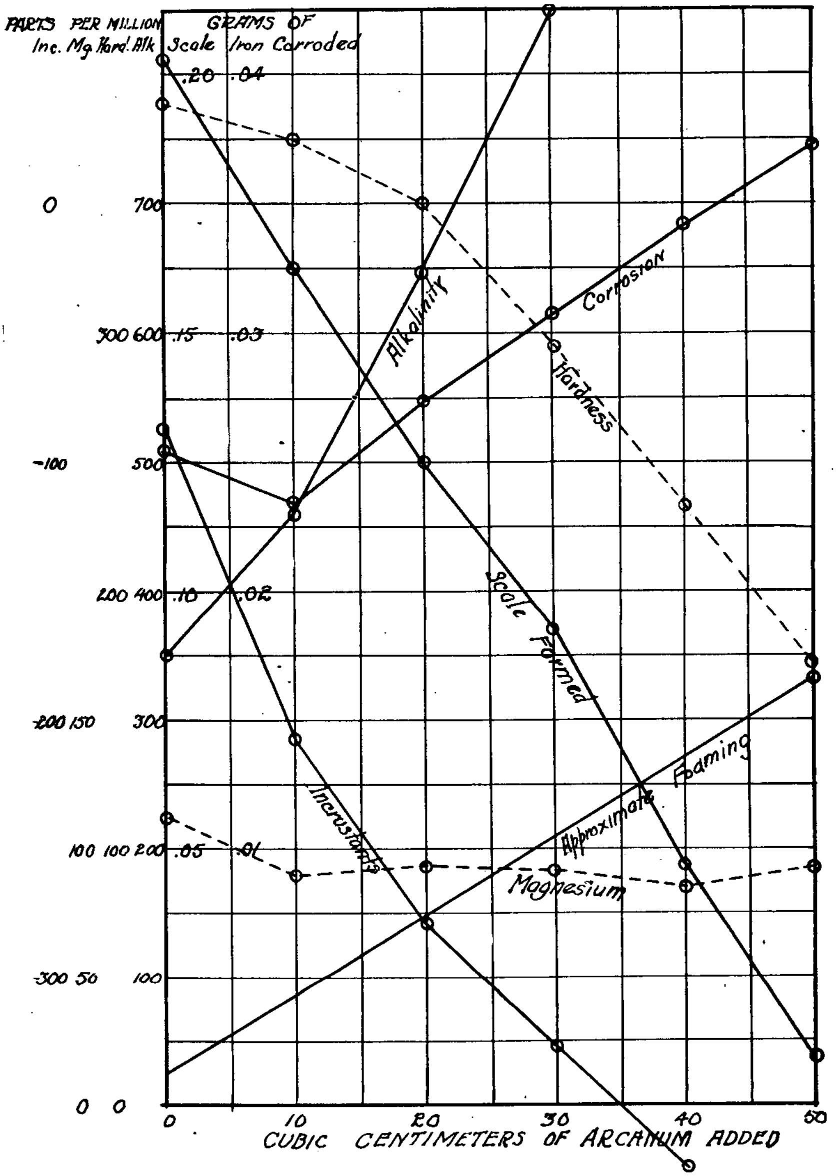

Plate IV. Treatment of University Water with "Arcanum".

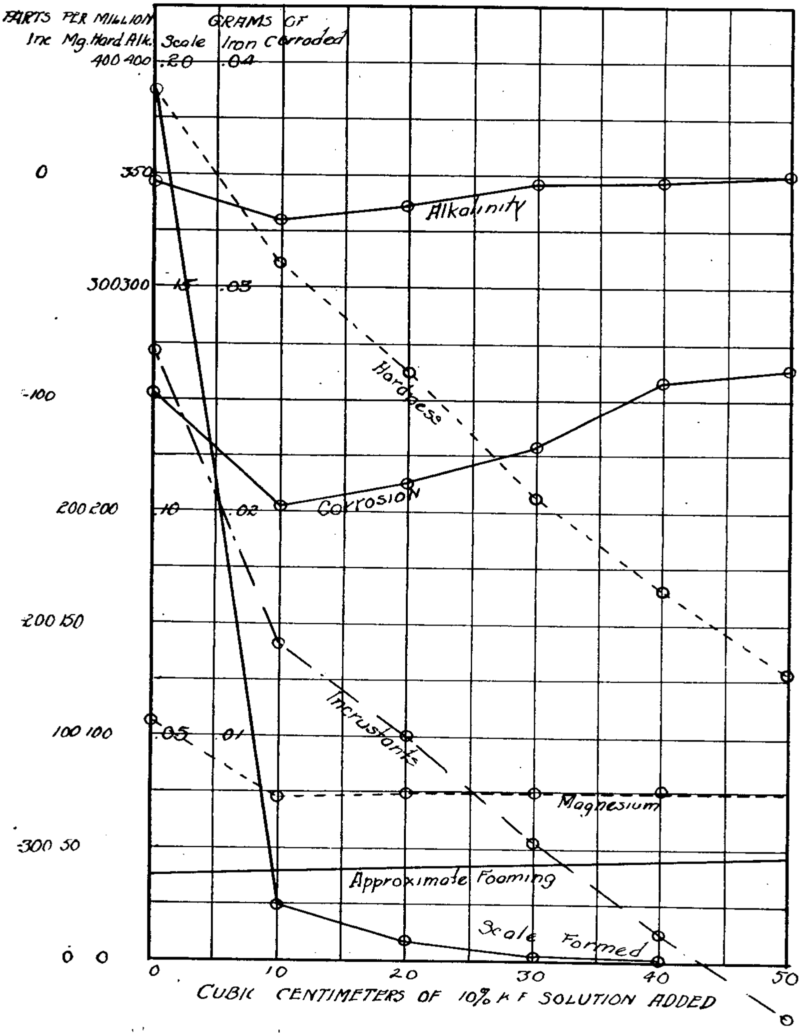

Plate V. Treatment of University Water with Potassium Fluoride.

TABLE VI.

Treatment of University water with sumach extract (tannin) 3.5 liters of cold water treated. 500 c.c. used up in making determinations and rest boiled to 500 c.c.

Average results of two sets of determinations.

Amount of extract added	Iron corroded	Scale formed	Foaming	N.C.H	Mg.	Alk.	Hardness
.1 gm.	.0546 gm.	.274 gm.	low	-86	111	355	368
.2 gm.	.0595 gm.	.209 gm.	low	-82	99	355	360
.3 gm.	.0653 gm.	.151 gm.	low	-86	855	354	358
.4 gm.	.0723 gm.	.089 gm.	low	-92	78	354	350
.5 gm.	.0734 gm.	.057 gm.	low	-104	75	356	345
untreated	.0383 gm.	.302 gm.	very low	-82	115	354	383

The corrosion increases very rapidly, the amount caused by the use of .5 gms. of extract amounting to about twice that of the untreated water. The amount of scale formed is lowered considerably. The foaming remains practically unchanged, as do also alkalinity and hardness while magnesium is lowered only slightly. It appears from the results obtained after heating that decomposition of the tannin has taken place.

TABLE VII.

Treatment of Mississippi River water from Quincy, Illinois with Na_2CO_3. 3.5 liters of cold water treated. 500 c.c. used up in making determinations and remainder concentrated to 500 c.c.

Amount of Na_2CO_3 added	Iron corroded	Scale formed	Foaming	N.C.H	Mg.	Alk.	Hardness
.2 gm.	.0326 gm.	.116 gm.	slight	-30	156	164	135
.4 gm.	.0343 gm.	.099 gm.	slight	-72	152	170	120
.6 gm.	.0356 gm.	.075 gm.	high	-110	148	183	100
.8 gm.	.0383 gm.	.031 gm.	high	-160	128	302	95
1.0 gm.	.0388 gm.	.009 gm.	high	-194	124	223	70
untreated	.0326 gm.	.119 gm.	low	-24	168	116	150

The corrosion is slightly increased while the amount of scale formed is lowered. Foaming is high in the higher treatments. The

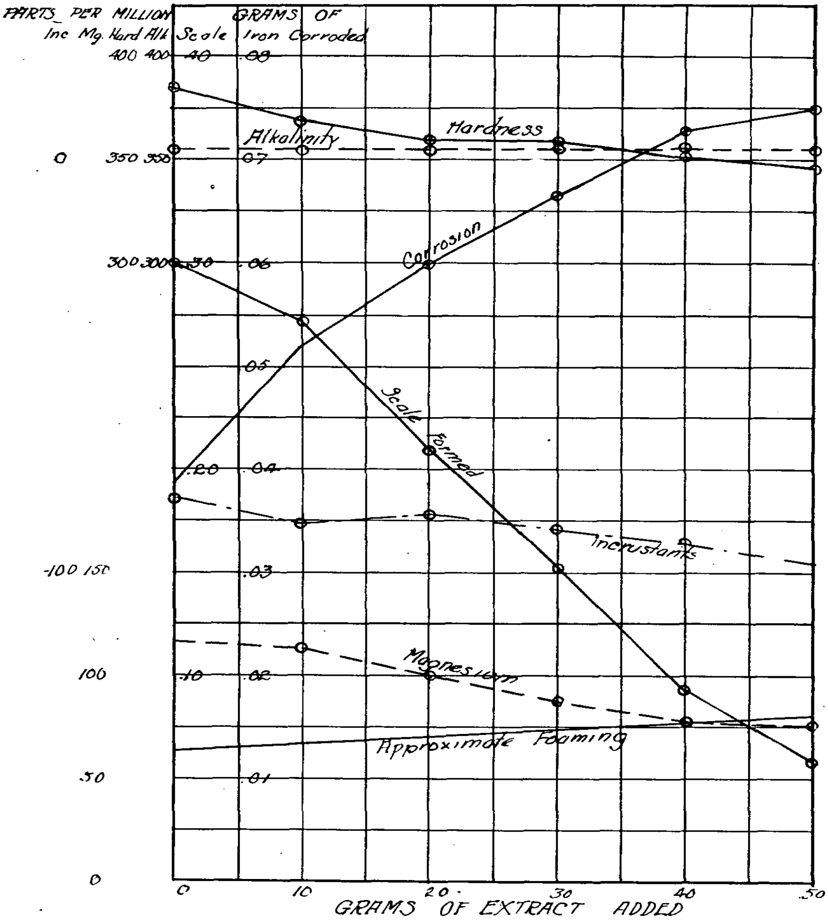

Plate VI. Treatment of University Water with Sumach Extract.

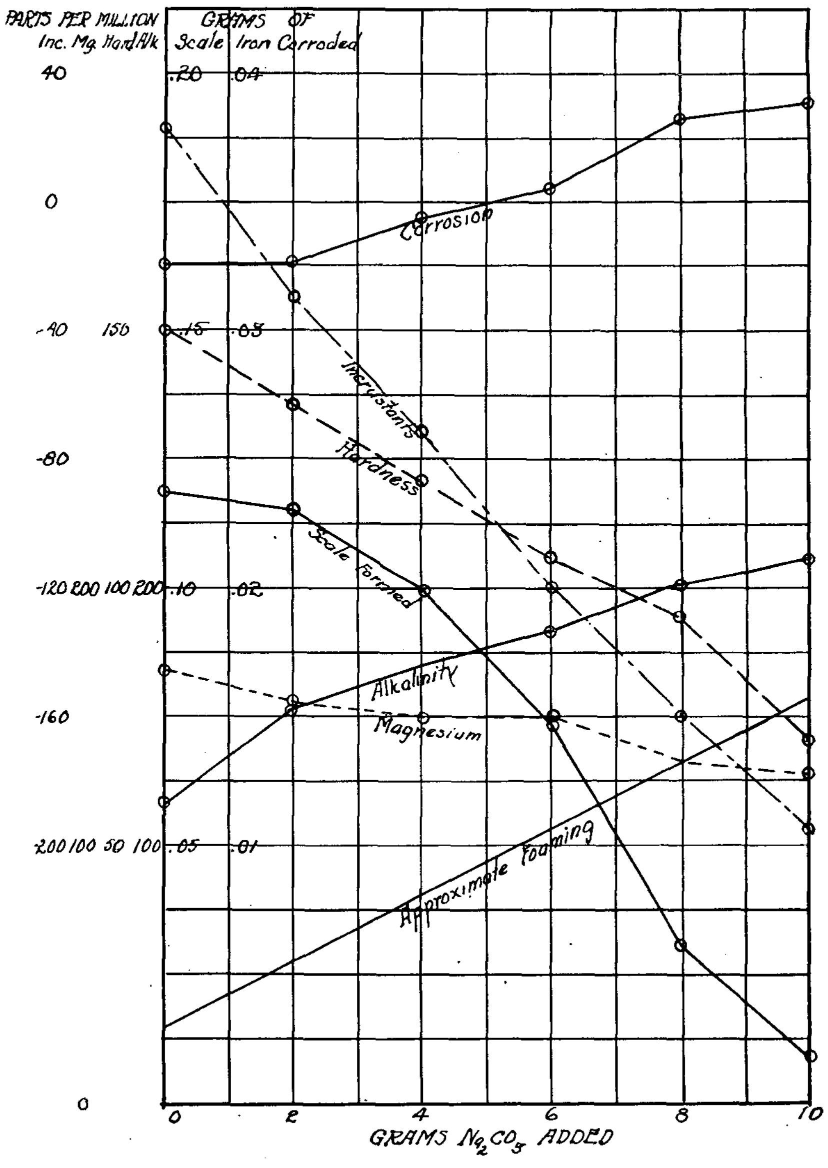

Plate VII. Treatment of Mississippi River Water with Sodium Carbonat.

TABLE VIII.

Treatment of Mississippi River water, from Quincy, Illinois, with Sumach Extract. 3.5 liters of cold water treated, 500 c.c. used for making determinations and the remainder boiled to 500 c.c.

Amount of Extract added	Iron corroded	Scale formed	Foaming	N.C.H.	Mg.	Alk.	Hardness
.05 gm.	.0541 gm.	.102 gm.	low	22	145	116	150
.1 gm.	.0525 gm.	.085 gm.	low	23	103	118	145
.15 gm.	.0570 gm.	.063 gm.	low	20	88	117	155
.20 gm.	.0620 gm.	.041 gm.	low	18	75	116	150
.25 gm.	.0648 gm.	.026 gm.	low	16	70	115	150
untreated	.0322 gm.	.121 gm.	low	24	168	116	150

non carbonate hardness, magnesium and total hardness decreases regularly, while the alkalinity increases with the amount of sodium carbonate added.

The corrosion increases very rapidly. The amount of scale formed is lowered, while the foaming remains almost unchanged. Alkalinity, total hardness and non-carbonate hardness remain practically constant, while the magnesium decreases in proportion to the amount of sumach extract added. The resulting corrosion and the amount of scale formed indicate that some decomposition of the tannin has taken place during heating.

CONCLUSIONS.

1. The corrosion varies with the alkalinity, showing that an increase in alkalinity makes the water less corrosive, due probably to the formation of hydroxide.

2. The waters treated with sumach are an exception. In such waters, alkalinity, non-carbonates hardness and total hardness are almost unchanged, but the amount of scale formed is lowered. The corrosion increases continually.

3. The magnesium does not reach a minimum, which is as low as solubility of the hydroxide.

4. Wherever there is a decrease in the amount of scale formed, the corrosion increases. When sodium carbonate is used, the foaming becomes so prominent that it makes this method of treatment impractical.

5. In none of the experiments tried are the results ideal, and further experiments should be carried on with waters of a different character.

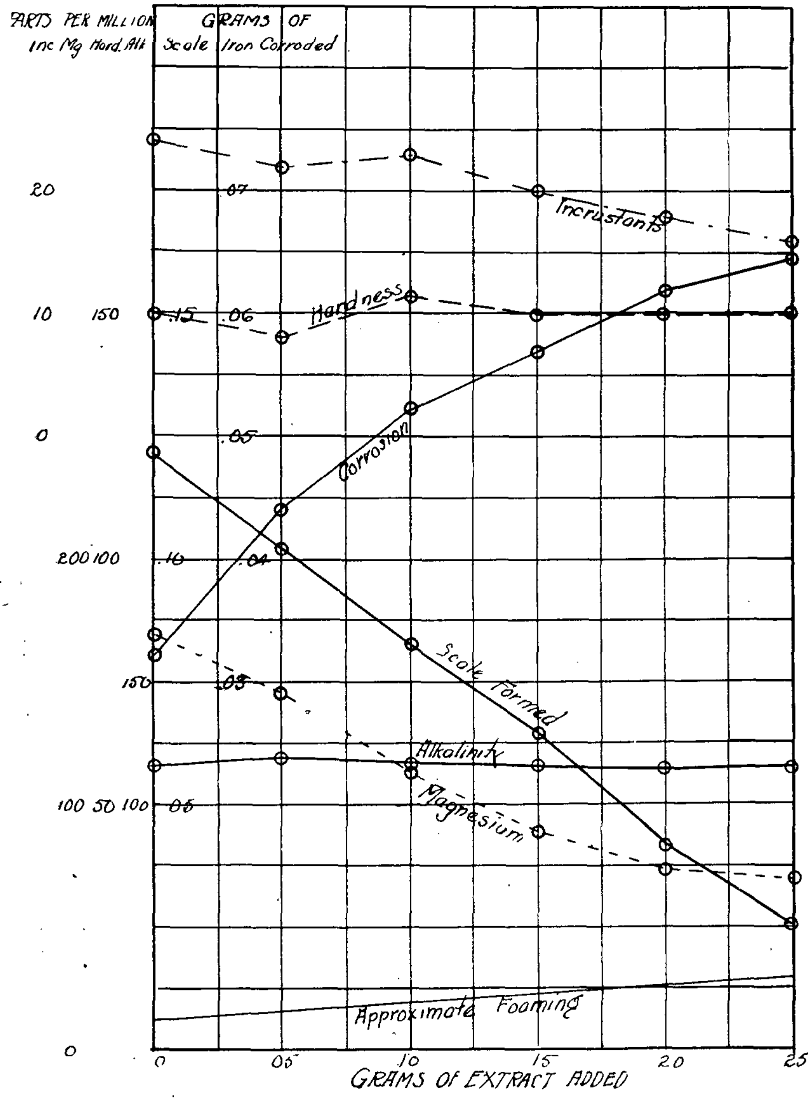

Plate VIII. Treatment of Mississippi River Water with Sumach Extract.

RELATION OF TYPHOID FEVER AND THE WATER SUPPLIES IN ILLINOIS.*

A comparison of the typhoid fever death rate of the city of Chicago with that of the lake cities of northern Indiana showed that the rate of Chicago was very much lower than that of the neighboring Indiana cities. This superiority of Chicago is evidently due to the water. All of these cities obtain their water supply from Lake Michigan, but the water-works intakes of the Indiana cities are near the shore, and the water is shown by the Indiana State Board of Health to be seriously affected by the Calumet River, through which the untreated sewage from a population of 500,000 people is emptied into the lake. The water supply of Chicago has been greatly improved by the extension of the intakes and by the diversion of the Chicago city sewage through the drainage canal and the Desplaines into the Illinois River. By thus improving the water supply the typhoid fever death rate in Chicago has been decreased from 173 per 100,000 in 1891 to 15.6 per 100,000 in 1908.

We might question whether we may expect a still greater reduction of the typhoid fever death rate in the city of Chicago. A further reduction seems possible because cities in the temperate zone which, have unquestioned water supplies have a death rate of only 7 or 8 per 100,000, and what is possible in the cities of Vienna and Munich with mountain-top supplies, Frankfort and Dresden with artesian supplies in unquestioned soils, Zurich, Hamburg, Rotterdam and London with properly filtered water should also be possible in Chicago. The city of Rockford, Illinois, where the drinking water is obtained from artesian wells of unquestioned purity, has a typhoid fever death rate of only 7 or 8 per 100,000. It therefore seemed that it would be interesting to determine the distribution of the typhoid fever throughout the state and thus learn in what parts of the state the greatest effort slould be made to eliminate typhoid fever and to also learn whether the health of Chicago with respect to typhoid fever is more influenced by the typhoid fever throughout the state or whether the health of the rest of the state is influenced by the typhoid fever in Chicago.

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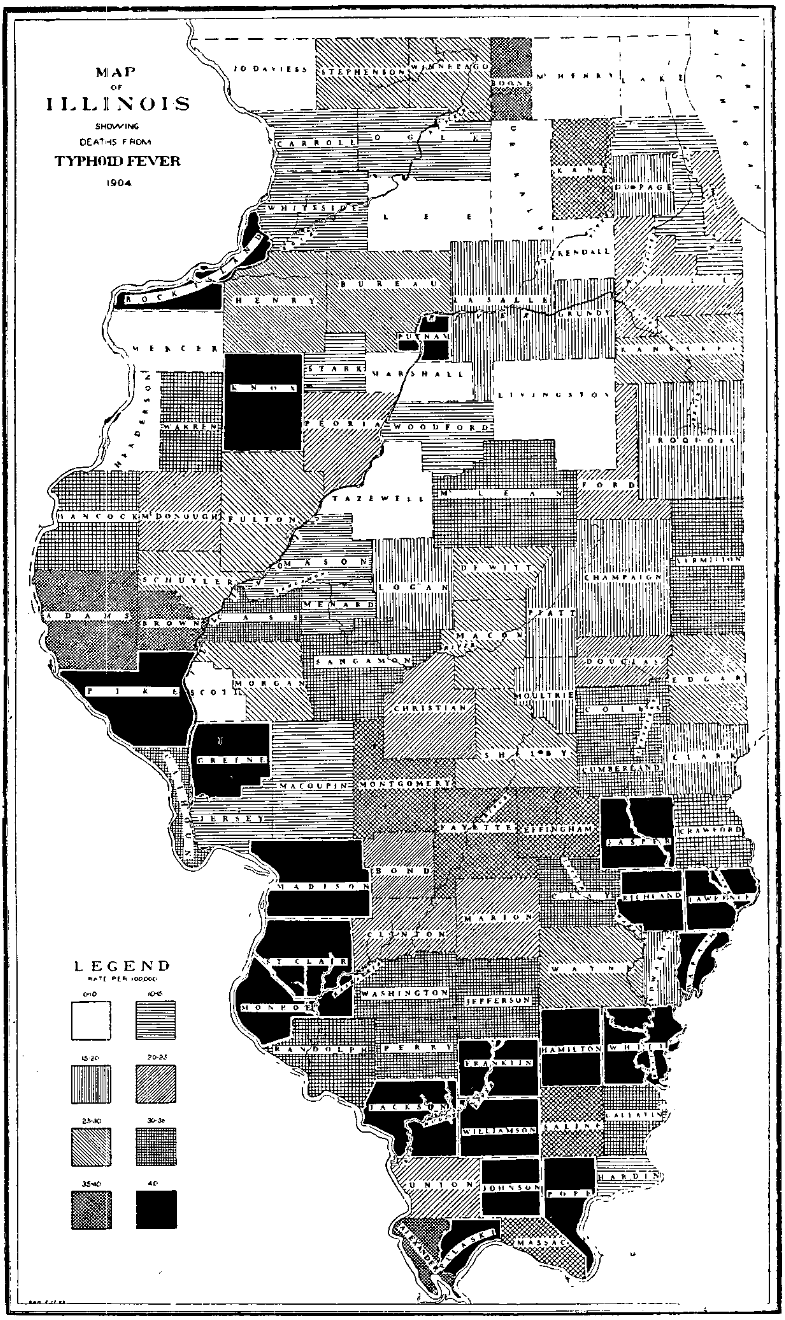
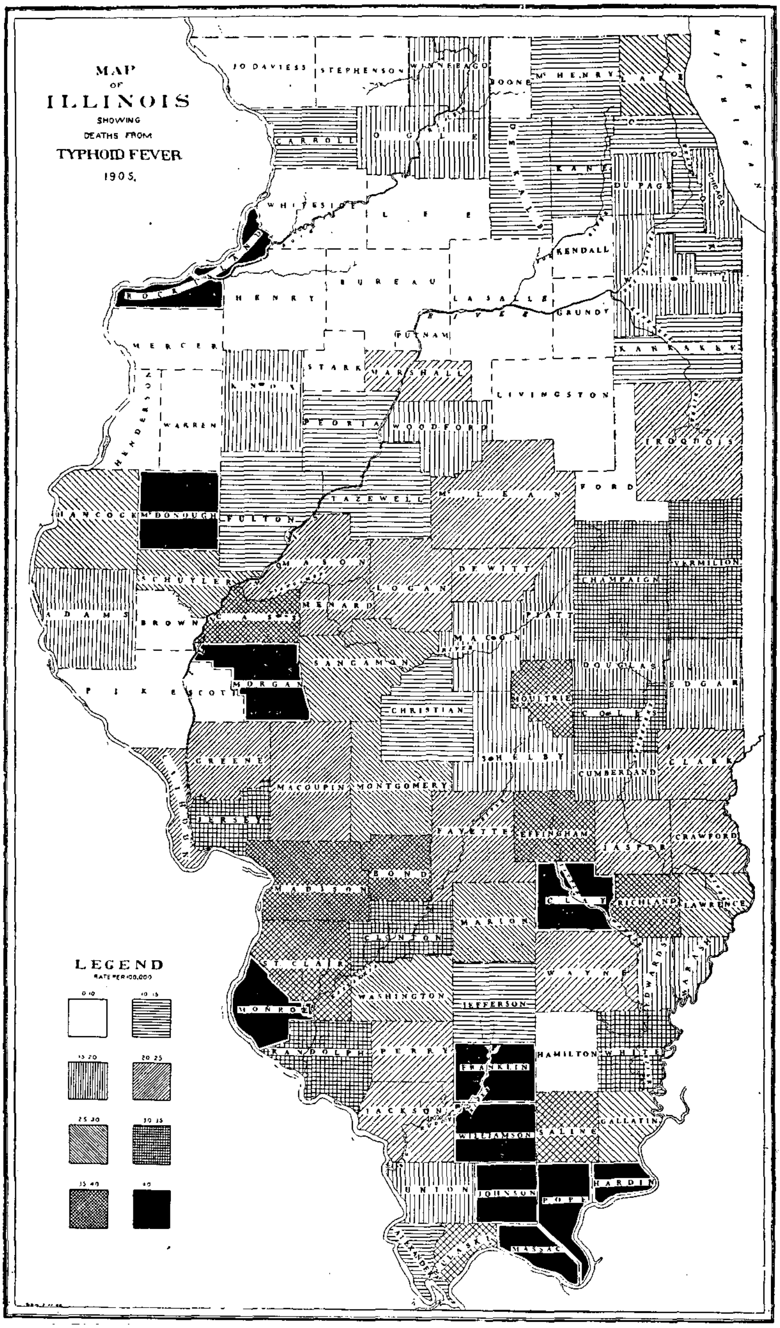
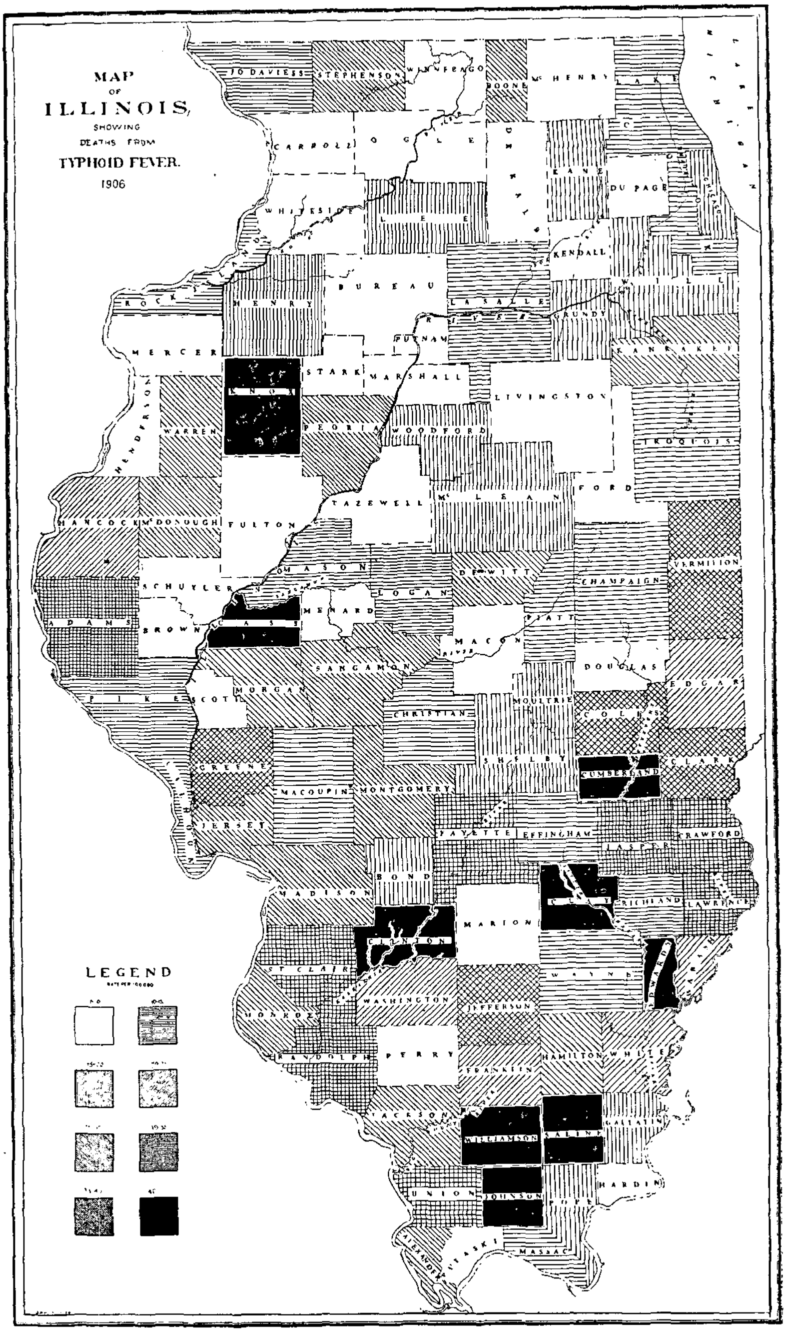
*Reprinted from Proceedings of the Second Meeting of the Illinois Water Supply Association, Urbana, Illinois.



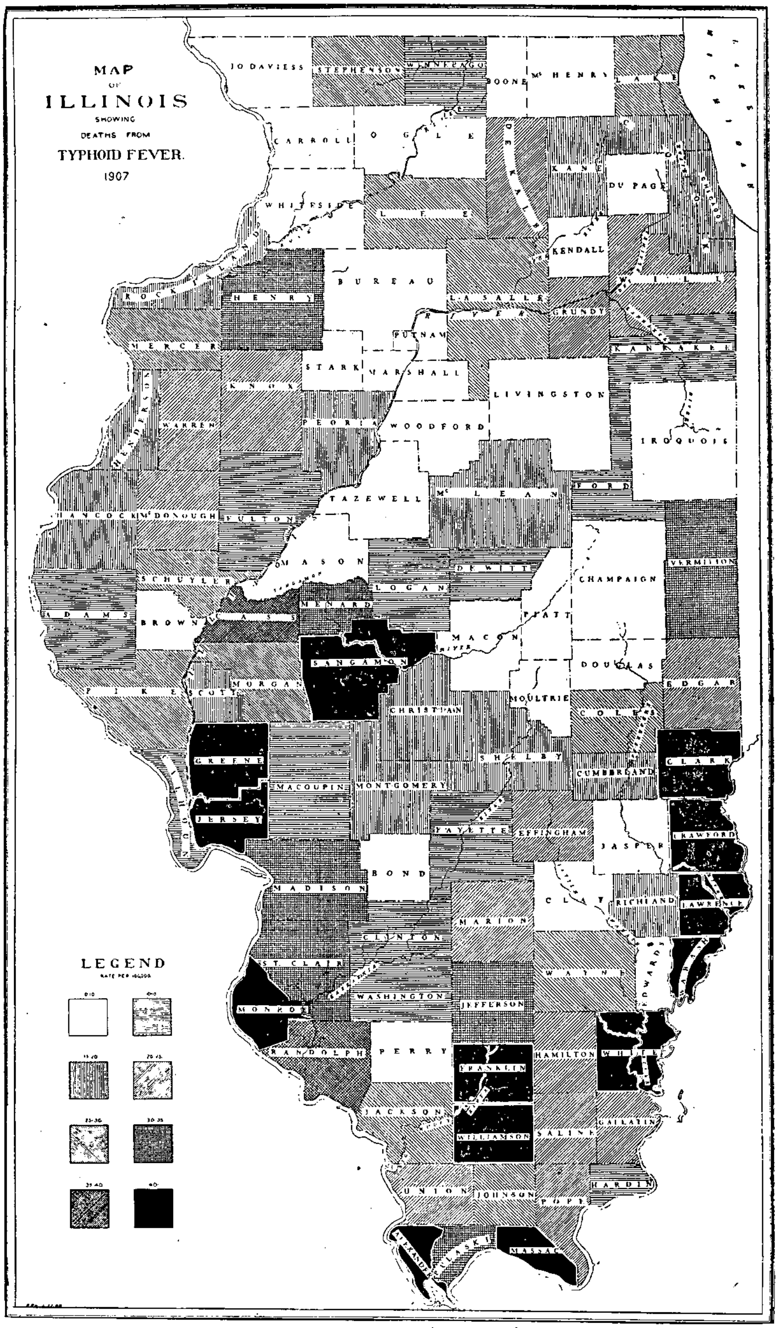
Map of Illinois Showing Distribution of Deaths from Typhoid Fever, 1904.



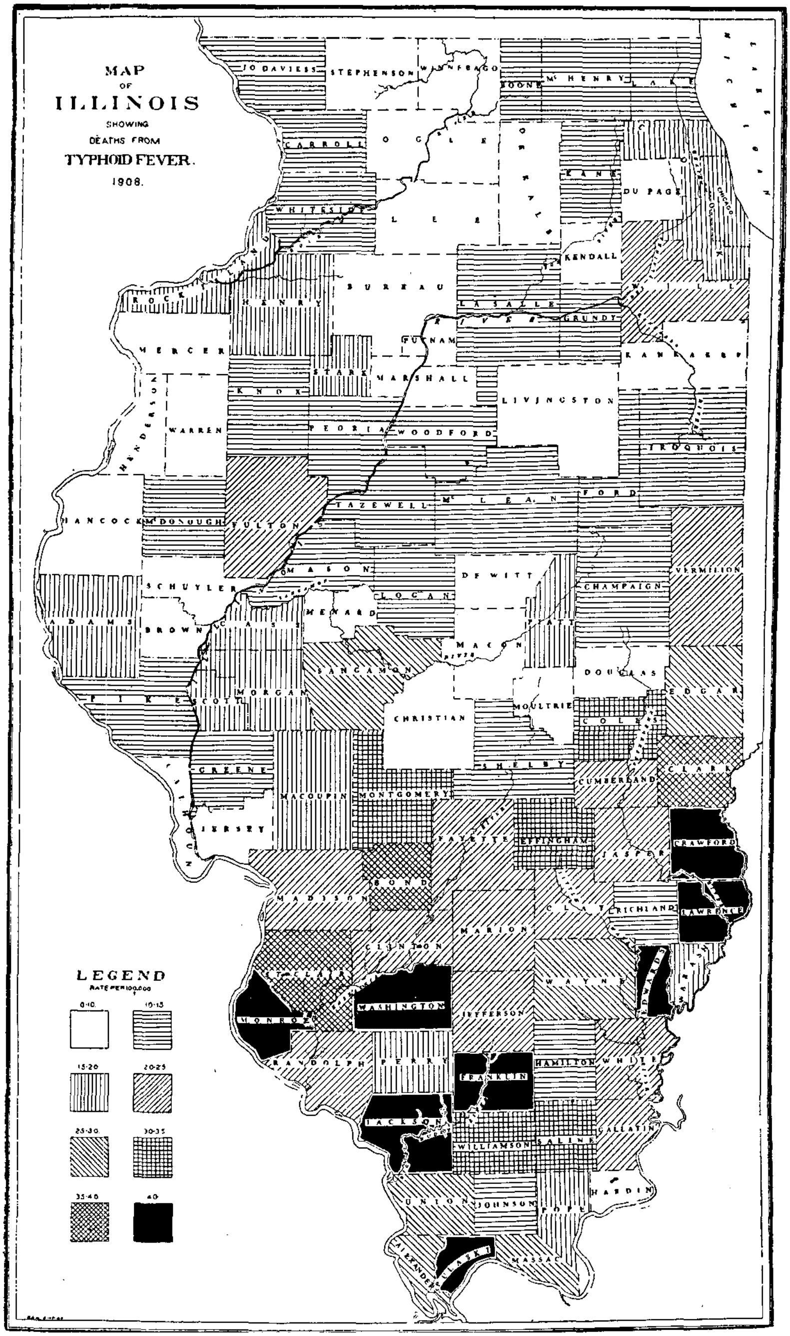
Map of Illinois Showing Distribution of Deaths from Typhoid Fever, 1905.



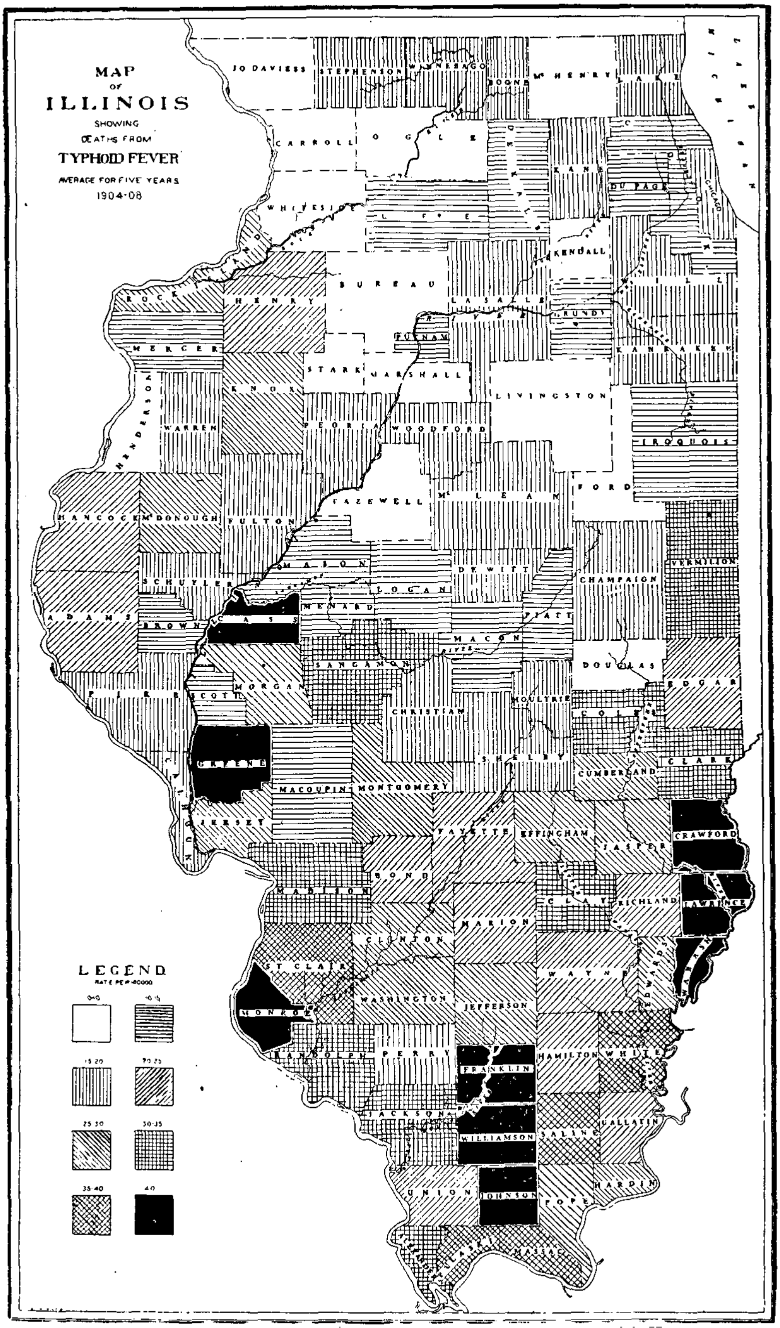
Map of Illinois Showing Distribution of Deaths from Typhoid Fever, 1906.



Map of Illinois Showing Distribution of Deaths from Typhoid Fever, 1907.



Map of Illinois Showing Distribution of Deaths from Typhoid Fever, 1908.



Map of Illinois Showing Distribution of Deaths from Typhoid Fever, 1904-08.

When the study of this subject was begun the only published statistics were those for 1907, State Board of Health bulletin February, 1908. The typhoid fever death rate per 100,000 was calculated from the data there given. An examination of the figures obtained showed that it would be worth while to carry the matter further. The unpublished statistics of the State Board of Health were placed at our disposal through the courtesy of the secretary, Dr. J. A. Egan, and the registrar of vital statistics, Mr. William J. Hoyt. From these statistics the typhoid fever death rate for the years 1904, 1905, 1906, and 1908 was calculated. In making the calculations the population for each year as estimated by Mr. Hoyt was used. Maps were prepared on which was shown graphically the death rate per 100,000 for each county for each year, and there was also prepared a map showing the average for the five years from 1904 to 1908. In preparing the maps the results are given to the nearest whole number, for example, a rate above 9.5 or 14.5 will be shown as 10 and 15 respectively.

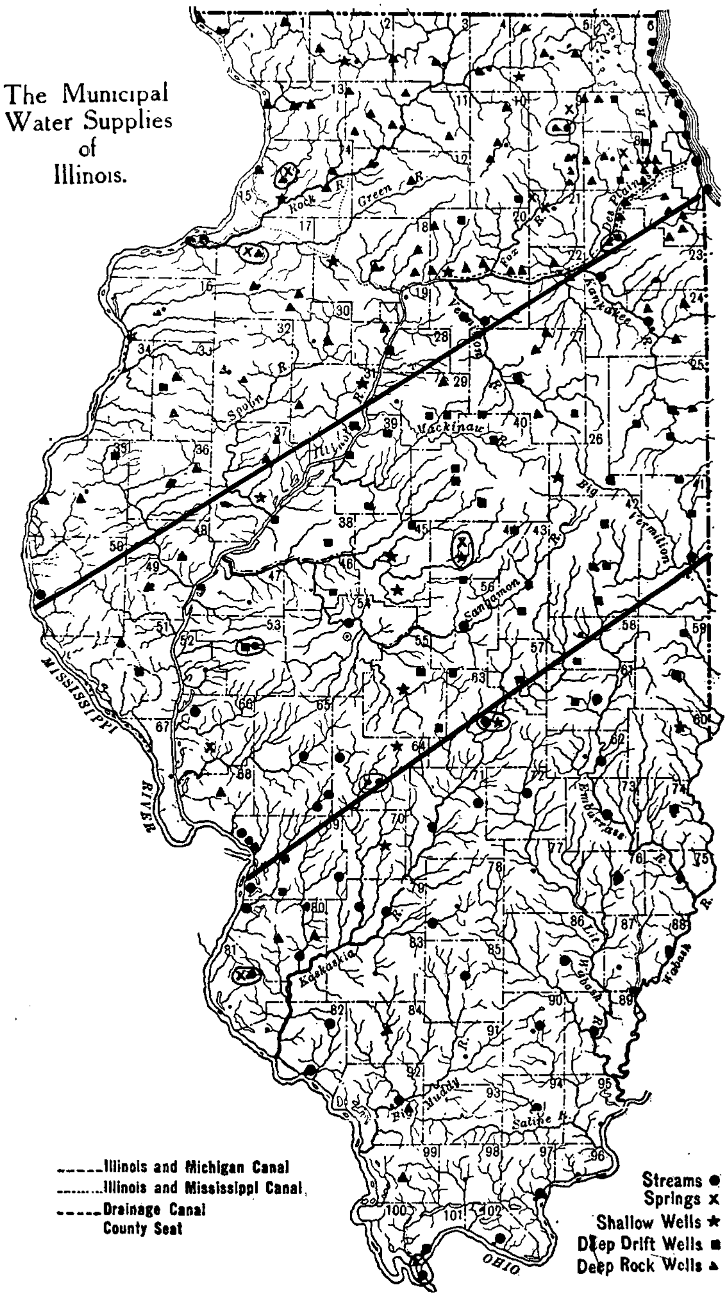
A study of the map shows that it is not advisable to draw definite conclusions from the death rate during any one year. In Putnam county, for example, the death rate was 75 per 100,000 in 1904. There were no deaths in any other year. Putnam county is a small county, so that a typhoid fever death rate of 75 per 100,000 was obtained from three deaths in a population of 4,000. The average for 5 years was 15. A high death rate in any one year may be due to epidemic conditions, for example, an epidemic at Streator in 1907, due to an infected water supply, raised the rate of La Salle county for that year to 30 per 100,000. In the other four years the rate was so low that the general average is 16. From the general appearance of the maps, as also from the table of statistics for the whole state, considerable variation in the death rate is shown from year to year. This may be due to epidemic conditions due to infection of milk, water, vegetables, etc. We note that in Knox county there is a death rate of 40 in 1904 and 1906. The rate was below 25 in 1905 and 1907 and below 15 in 1908. Other examples of this kind may be seen by inspecting the map.

The largest typhoid fever death rate is shown to have been in the southern part of the state. On the map which shows the average for five years we find only one of the 51 southern counties having an average death rate of less than 10 per 100,000. This county, Douglas, is on the line between the two sections, and as will be shown later is in an area of low typhoid fever. Only two other counties, Scott and Macoupin, have a rate below 15. That this average is not accidental and due to epidemics in any one year is shown by the fact that in only two counties was there a rate below 10 in three of the five years. In only three more was there a rate below 10 in two of the five years, and in only 11 counties did the rate go below 10 in any one of the five years. In the 51 northern counties, on the other hand, there are 13 with an average rate below 10 and 10 more with an average rate below15 per 100,000. Only 12 counties did not have in one or more years a death rate below 10 per 100,000.

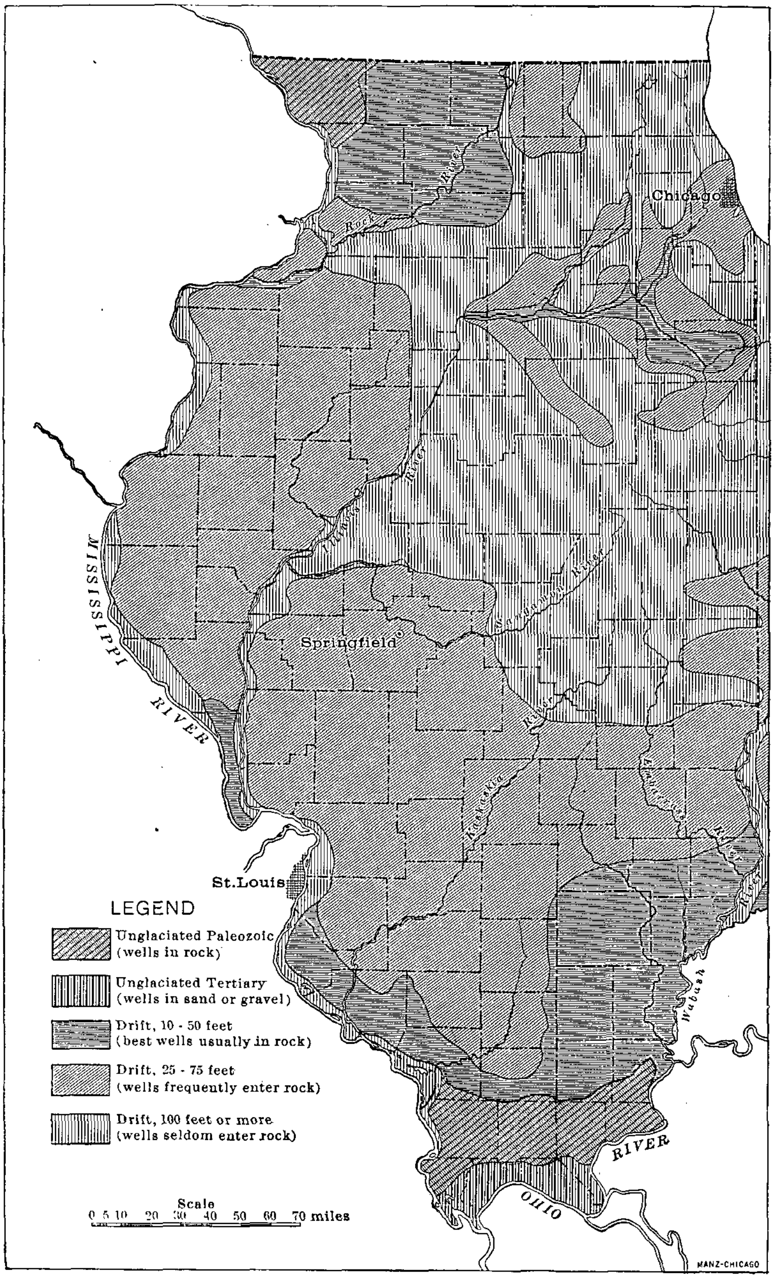
In the southern half, there are 8 counties with an average death rate above 40 per 100,000 and 12 more with an average death rate above 30, whereas in the northern part of the state there is only one Cass county, with an average rate above 40, and this county will be shown later to be in an area of high typhoid fever, and there is only one other having a rate above 30. An inspection of the maps shows that 31 of the 51 southern counties have an average death rate above 40 in one or more years, 14 of these counties having a death rate of more than 40 in two or more years and four of these having a death rate above 40 in three or four years and two in four years. Of the northern counties there are only five which have a typhoid fever death rate above 40 in one year or more, only two counties having a death rate above 40 in two years.

A comparison of the maps showing the distribution of typhoid fever with the map showing the distribution and character of the water supplies of the state shows that the typhoid fever death rate is dependent to a considerable extent on the character of the water supply. In the northern third of the state, or, better, in that part north of a line drawn from Quincy to the point where the Indiana border touches Lake Michigan, the greater number of the municipal water supplies are obtained from deep wells which enter rock and obtain water which, from a sanitary standpoint, is of unquestioned purity. In this section of the state there are only three counties with a death rate above 25 and three more with a rate above 20, and there are 10 with a death rate below 10 per 100,000.

In the east central portion of the state we find an area of glacia1 drift 100 feet or more in depth. This. is very nicely shown by the glacial map of the state which has been kindly furnished by the United States Geological Survey. This drift covers, with slight exceptions, that portion of the state included by a line drawn from Lake Michigan to the southern border of Edgar county, west to the west border of Shelby county, north to Logan county and west to the Illinois River, thence along the Illinois River to Peoria, north to the center of Bureau county and west to the Rock River and northeast along the Rock River to the Wisconsin line. Part of this section forms the area in which the water supplies are obtained from deep



Map Showing the Municipal Water Supplies of Illinois.



Map Showing Drift Areas of Illinois.
(Published by courtesy of the United States Geological Survey.)

wells which enter rock. but over one-half of the area has very few wells of this character because of the large amount of mineral matter in the water from the deep rock wells. The municipal water supplies in this section are obtained from deep wells which do not enter rock but which furnish a water supply of unquestioned purity from a sanitary standpoint. The low typhoid fever death rate in this section is due, therefore, to the satisfactory water supply obtained from these deep drift wells. There are no counties located entirely within this area in which the typhoid fever death rate exceeds 20 per 100,000. Not only can satisfactory municipal water supplies be obtained from deep wells in drift, but many farms and private houses are also supplied from such wells.

It is interesting to note that the one county of the northern 51 counties which has a typhoid fever rate of more than 40 is located outside of the deep-drift area and that the one county in the southern counties having a typhoid fever rate lower than 10 is located within the deep-drift area.

In the southern portion of the state it is impossible to use the water from the deep rock wells for municipal water supplies because of the large amount of mineral matter which they carry. The drift as shown by the map is not deep enough to carry a sufficient supply of water for cities. The municipal supplies, therefore, must necessarily be taken from streams or reservoirs and the water supplies for farms or private houses where no municipal supply is furnished must use shallow wells often of doubtful character. The municipal water supplies are as a rule taken from streams or reservoirs without filtration, in fact only 16 of the 60 water supplies obtained from streams, lakes or ponds within the State have filtered water and only 6 of the supplies in the southern portion of the state are filtered. It is claimed by the authorities in some of these towns that the water is used -only for sprinkling, fire protection or for manufacturing purposes, but it is a difficult matter to prevent the use of such water for drinking purposes and it would be far better to furnish a filtered water than to allow the residents in the cities and villages to rely on individual wells for their drinking water.

It seems very probable that the high typhoid fever rate in the southern part of the State is due to a considerable extent to the lack of satisfactory general water supplies. Several communities are already considering the introduction of filtered water and it is hoped that a better report of the typhoid fever conditions in the southern part of the state may be given in the near future.

It is interesting to compare Macon and Sangamon counties. These two counties are in the same latitude and contain large cities, Decatur and Springfield. The typhoid fever death rate of Macon county is 14 per 100,000, while that of Sangamon is 37. This is undoubtedly due to the fact that Macon county is within the deep-drift area and the water supplies for farms and private individuals can be obtained from deep-drift wells, whereas Sangamon county is outside of the deep-drift area and the farms must rely on the shallow wells for drinking water. Then, too, the city water supply of Decatur in Macon county is filtered, whereas the water supply of Springfield in Sangamon county is sometimes augmented by unfiltered water from the Sangamon River.

An inspection of the map showing the average typhoid fever death rate in Illinois (p. 81) would indicate that the typhoid fever rate of Chicago was not materially increased by infection from the neighboring counties. There are, in fact, no counties within 100 miles of Chicago which have a typhoid fever rate materially greater than Chicago itself.

I wish to quote here an editorial from the Engineering News of February 10, 1910:

"A useful study of the relation between typhoid fever death rates and the character of the local water-supplies in different parts of Illinois has been made by Mr. Edward Bartow, Director of the Illinois State Water Survey. Elsewhere in this issue we publish an abstract of a paper summarizing these studies. While the broad general conclusions of the paper are doubtless well founded, it seems desirable to call attention to the fact that all causes for variation in typhoid rates throughout the State have been ignored except those pertaining to the character of the local water supplies. Any other course would have been very difficult and perhaps impossible in connection with so broad a survey of the subject as this. At the same time, it must be remembered that there are many other factors than water supplies that would cause variatioins in the typhoid rate in various communities and at various dates in the same community.

It is easy to raise questions that cannot readily be answered. Nevertheless we cannot refrain from asking whether the much higher typhoid rates prevailing in the southern as compared with the northern counties of Illinois are due in considerable part to the same general causes, whatever they may be, as produce high typhoid rates throughout the greater part of our Southern States.

We regret the necessity of calling attention to one other factor which has an important bearing upon these Illinois figures. Illinois is not one of the registration states as recognized by the U. S. Bureau of the Census. That is to say, its laws governing the registration of vital statistics are such, in fact and in administration, that the state is not credited as recording as many as 90% of the total deaths that occur within its limits. This being true, it is probable that many typhoid deaths are not recorded, and that the completeness of the typhoid records varies materially in different parts of the state. All this may not materially affect the broad general conclusions drawn by Mr. Bartow, but they should certainly be taken into account by any one who considers his figures in detail. We make this statement not so much to throw doubt upon the value of the figures, as to emphasize the desirability of action on the part of the State of Illinois that will place it within the registration area."

NOTE.—In the Engineering News, 63, 346 (March 24, 1910), Dr. George W. Webster, president of the State Board of Health of Illinois, gives a brief explanation of the situation in Illinois with regard to vital statistics. Attempts have been made by the State Board of Health to obtain suitable legislation, but thus far it has been impossible to do so. The suggestion is made by the editor that the Illinois Society of Engineers and Surveyors, the Illinois Water Supply Association, and the organization devoted to protecting the waters of Lake Michigan, should have taken up this matter in detail before this.

ANALYTICAL CONTROL OF WATER SOFTENING.*

Water is softened to eliminate as far as possible those constituents which make it undesirable for use in boilers and for industrial processes. The undesirable constituents include carbonates, sulphates, chlorides and nitrates of calcium, magnesium, iron and aluminium. Carbonic acid, free hydrochloric and sulphuric acids are sometimes present and also cause trouble.

In 1841 Clark patented his method for the softening of water with lime. Later Porter† modified the process by filtering the water after precipitation with lime, thus making the softening process continuous.

In the Clark-Porter process the amount of lime to be added was calculated from a determination of alkalinity and total hardness. The method removed only the temporary hardness.

Wm. Macnab and G. H. Beckett‡ discovered in 1886 that caustic

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*Abstract of thesis prepared by Andrew Jacobson under the direction of Edward Bartow and presented in partial fulfillment of the requirements for the degree of Master of Science.

†J. S. C. I. Vol. 3, (1884). 51.

‡J. S. C. I. 5-267.

soda or lime and soda ash were absolutely necessary for the removal of all the magnesium. At present, lime and soda ash are invariably used for outside treatment. Sodium carbonate or hydroxide, together with various organic substances, are sometimes used for treatment within the boiler.

Calcium in the form of hydroxide stands first in importance of the substances used in treatment, because of its low cost, effectiveness and ease of application. $CaSO_4$ or $CaCl_2$, however, are not precipitated on the addition of lime. Sodium carbonate must be added to precipitate these salts. Sodium hydrate may be used in place of lime. Its chief objection is its higher cost.

Tri-sodium phosphate may also be used. It reacts with $CaSO_4$ as follows:

$$2Na_3PO_4 + CaSO_4 = Ca_3(PO_4)_2 + 3Na_2SO_4.$$

Sodium phosphate is expensive, and unless some methods are discovered whereby the phosphate may be regained, it will hardly come into general use. Sodium fluoride may be used. Its reaction is identical with that of soda, but it is many times more expensive.

Barium hydroxide is an ideal reagent, because its carbonate and sulphate are insoluble, and it leaves no products of the reaction in solution in the softened water. If the water is to be used for drinking, there is an element of danger from possible overtreatment, since barium salts are poisonous.

Various other reagents have been proposed, such as barium aluminate, sodium aluminate, sodium chromate and sodium oxalate. The chief objection is their high cost.

Oils, fats, starch, glucose and other organic compounds are sometimes fed into the boiler. Their action, is purely mechanical in preventing the sulphates and carbonates from forming a hard scale.

Waters may be divided into three classes according as they contain sodium carbonate, calcium or magnesium sulphate and magnesium chloride, when hypothetical. combinations of the ions according to the scheme used in the laboratory of the Illinois State Water Survey.*

Table I shows the mineral content of three waters which are typical of the three classes as mentioned above. Laboratory number 19169 is typical of Class I. The most important constitutents of this water are the carbonates of sodium, ammonium, magnesium, calcium and iron. This water when used in a boiler will not form a hard scale, but only a soft sludge which may be easily blown off. The

*The Mineral Content of Illinois Waters. University of Illinois Bulletin. State Water Survey Series No. 4. p. 38.

TABLE I.

Ions	Laboratory Number			Hypothetical combinations	Laboratory Number		
	19169	20283	18750		19169	20283	18750
K	5.0	.....	5.4	KNO_3	......	.....	14.0
Na	43.0	14.0	21.5	KCl	9.5	......	......
NH_4	5.0	....	....	$NaNO_3$	.....	.2	36.8
Mg	33.5	34.6	33.3	NaCl	20.6	13.2	29.2
Ca	73.8	77.6	100.1	Na_2SO_4	.....	25.6	......
Fe	4.0	.....	.2	Na_2CO_3	80.3	......	......
Fe_2O_3	....	4.9	......	$(NH_4)_2CO_3$	13.5	......	......
Al_2O_3	4.4	.....	12.6	$MgCl_2$	......	......	16.5
NO_3	.....	.1	35.4	$MgSO_4$		44.8	46.8
Cl	17.0	8.0	30.0	$MgCO_3$	116.0	88.8	68.0
SO_4	.....	53.6	37.3	$CaCO_3$	184.2	193.7	250.0
SiO_2	14.0	29.3	15.6	$FeCO_3$	8.3	....	.2
				Fe_2O_3	....	4.9	....
				Al_2O_3	4.4	....	12.6
				SiO_2	14.0	29.3	15.6
				Total	451.8	400.5	489.7

hardness of this water is about 330 parts per million. According to Whipple's† data, the cost of soap wasted in using this water for household and laundry purposes amounts to about $300 per million gallons. The addition of lime is sufficient to soften this water.

Laboratory number 20283 is an example of the waters of Class II. This water has about the same soap destroying power as the example under Class I. It has, however, a tendency to form a hard scale. Both soda and lime must be used in softening this water.

Laboratory number 18750 illustrates the type of waters in Class III. This water has about the same hardness as examples under Classes I and II, but it is, however, less desirable, because magnesium chloride is present. This substance makes the water corrosive. Both lime and soda are required to completely soften it.

As already stated, lime and soda are the most widely used reagents at the present time because they are the most economical for softening purposes.

Lime reacts with free carbon dioxide, bicarbonates of calcium, magnesium and alkalies and with sulphate and chloride of magnesium. Lime also reacts with salts of iron and aluminium, but these elements are seldom present in quantities large enough to be taken into consideration in water softening.

†The Value of Pure Water by G. C. Whipple.

The reactions of lime in water treatment are:

$$Ca(OH)_2 + CO_2 = \mathit{CaCO_3} + H_2O$$
$$Ca(OH)_2 + Ca(HCO_3)_2 + 2\mathit{CaCO_3} + 2H_2O$$
$$2Ca(OH)_2 + Mg(HCO_3)_2 = \mathit{Mg(OH)_2} + 2CaCO_3 + 2H_2O$$
$$Ca(OH)_2 + MgSO_4 = CaSO_4 + \mathit{Mg(OH)_2}$$
$$Ca(OH)_2 + MgCl_2 = CaCl_2 + \mathit{Mg(OH)_2}$$
$$Ca(OH)_2 + Na_2(HCO_3)_2 = \mathit{CaCO_3} + Na_2CO_3 + 2H_2O$$

Lime precipitates magnesium as an insoluble hydroxide from whatever combination it may happen to be found in water, but, as may be noted in the above reaction, the corresponding calcium salt is formed which is even less desirable than the magnesium salt. Therefore, soda is added to precipitate the calcium in combination with chlorine and the sulphate radicle. The reactions with soda are as follows:

$$Na_2CO + CaSO_4 = \mathit{CaCO_3} + Na_2SO_4$$
$$Na_2CO_3 + CaCl_2 = \mathit{CaCO_3} + 2NaCl$$

The compounds in Italics are insoluble and settle out as a sludge.

Two general types of softening plants are in use at the present time; the intermittent, and the continuous. The chemical reactions involved in either type are the same, but the mechanical devices for accomplishing thorough softening and purification vary.

The elements necessary to produce a satisfactory soft water are addition of definite quantities of reagents, thorough mixing of reagents with the water to be softened, time necessary to complete the reactions and to allow the precipitate to settle.

The simplest form of intermittent softening plant consists of two tanks each holding as much water as will be consumed while the softening process is in progress in the other tank.

Calcium carbonate and magnesium hydroxide settle very slowly in the cold, about 2.5 inches per hour according to Prof. Wanklyn. Some continuous types of softener reduce this time element by reducing the distance which the precipitate has to settle. This is accomplished by superimposed tanks or inclined shelves which catch the precipitate, and allow the softened water to be drawn off without disturbing the sludge.

For ground waters having a fairly constant quantity of dissolved solids, the required lime addition can be regulated to a high degree of accuracy. With surface waters in which the amount of dissolved material varies widely from time to time this type of softener is not entirely satisfactory.

Another method of water softening is to utilize the exhaust steam or flue gases for heating the water to the boiling point before it enters the boiler. At this temperature the bicarbonates are changed to insoluble normal carbonates. Sometimes soda is added to change the chlorides and sulphates of calcium and magnesium to carbonates.

ANALYSIS AND CONTROL.

The determination of the amount of reagents to be added to a water may be effected in several ways. A logical method of accomplishing the result would be to treat a series of samples with varying amounts of the reagent and to analyze the filtrate after the completion of the reaction. This method, however, is not practical.

The most accurate method is to make a complete mineral analysis. This involves the determination of the ions sodium, ammonium, magnesium, calcium, iron, aluminium, nitrate, chlorine, sulphate, carbonate, and silica. From these ions, the amount of reagents to be added may be calculated by the use of proper factors.

There are differences of opinion among authorities as to whether combinations into salts should be made. R. B. Dole* makes the statement, "though salts are probably present in solution the analytical data is insufficient to permit the apportionment of the bases among the acids." F. W. Clarke† says, with reference to hypothetical combinadon, "The result is a meaningless chaos of assumptions and uncertainties." E. G. Bashore‡ presupposes hypothetical combinations when he says, "Each grain of calcium and magnesium bicarbonate reported in the analysis as carbonates," etc. In the laboratory of the Illinois State Water Survey such combinations are generally made.

In examining water for industrial purposes these combinations are not misleading, but show at a glance whether a water will form hard or soft scale, cause corrosion or foaming. While it is true that they are not necessary for the determination of reagents required, they serve admirably the purpose for which they were intended.

Stabler* has deduced a very ingenious formula which is given below for determining from the ions the amount of 90% lime and 95% soda required per 1000 gallons of water treated.

$$\text{Lime required} = .26(rFe + rAl + rMg + rH + rHCO_3 + .0454\ CO_2)$$
$$\text{Soda ash required} = .465(rFe + rAl + rCa + rMg + rH - rCO_3 - rHCO_3)$$

"r" is a constant for each ion, and is the ratio of the valence to the combining weight of each ion.

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*Water Supply Paper No. 236, p. 40.

†Bull. U. S. Geol. Survey, No. 330, 1908. p. 54.

‡M. & C. E. Vol. VIII, No. 1. p. 20.

*Engineering News, Vol. 60, 1908. p. 355.

We believe that the above formula may be greatly simplified by writing:

Lime=.0052(4.16 Mg+Alk+2.27CO_2†) lbs. per 1000 gallons of 90% CaO.

Soda ash=.0093(4.16 Mg+2.5Ca—Alk) lbs. per 1000 gallons of 95% Na_2CO_3.

Iron and aluminium are not figured in the above formula because they are generally low. However, if iron is present as a carbonate it is included in alkalinity. HCO_3 and CO_2 are generally determined by titration, the former by means of a standard acid and the latter by a standard sodium carbonate solution. The error, therefore, will be the same in both formulas.

E. G. Bashore* calculates the lime required by dividing each grain of calcium and magnesium bicarbonate reported in the analysis as carbonate by 5.5. This statement is incorrect in principal because magnesium is not precipitated as a carbonate but as a hydrate. He calculates soda by dividing the number of grains per gallon of magnesium sulphate by 8 and the number of grains of calcium sulphate by 8.75. The quotient represents pounds per 1000 gallons.

In order to show that the same results are obtained by calculating the lime and soda required according to the methods already suggested, analysis No. 20578 has been calculated according to Stabler's formula, our simplified formula, and hypothetical combinations.

Ions		Hypothetical Combinations	
Na	52.	NaCl	41.
Mg.	24.3	Na_2SO_4	112.
Ca	68.8	$MgSO_4$	76.4
Fe	.2	$MgCO_3$	32.6
Al_2O_3	1.8	$CaCO_3$	167.0
Cl	25.0	$FeCO_3$	.4
SO_4	137.0	Al_2O_3	1.8
SiO_2	18.7	SiO_2	18.7
			449.9

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*M. & C. E. Vol. VIII, No. 1. p. 20.

†If CO_2 is reported in parts per million as $CaCO_3$ the factor is I.

Stabler's formula.

Lime=.26(.0333 x 123.6+.0821 x 24.3)=1.58

Simplified formula.

Lime=.0052(4.16 x 24.3+206)=1.58

Hypothetical combinations.

$MgSO_4$	76.5	x	.46	=35.2
$MgCO_3$	32.6	x	1.33	=43.3
$CaCO_3$	167	x	.56	=93.5

Total lime in parts per M 172.0

90% lime per 1000 gallons .0092 x 172=1.58

Stillman* has proposed a scheme for the rapid analysis of boiler waters which is an improvement over the complete mineral analysis in that it takes less time. The desired amount of water is evaporated and the residue weighed, thus giving total solids. The residue is then ignited, weighed, moistened with water, placed in an atmosphere of CO_2 and weighed. The last operation gives total mineral matter. The non scale-forming ingredients are separated from the scale-forming by extraction with 50 c.c. of distilled water, filtered and the residue treated with HCl. SiO_2, Al_2O_3, Fe_2O_3, Ca, Mg and SO_4 are determined gravimetrically.

The methods mentioned thus far are accurate but they have the disadvantage of requiring considerable time.

The need for a method which is rapid, fairly accurate and in which the apparatus and reagents used are reduced to a minimum is apparent. Such a method must show clearly the character of the water and present the data in such a form that the amount of reagent to be added may be readily calculated.

In order to find such a method, the literature on the subject was searched and a number of methods were tried. Each one, however, failed in one or more important details to satisfy the above conditions.

The simpliest of these methods is that credited to Dr. Dudly, former chemist of the Pennsylvania Railroad. The residue on evaporation is treated with 70% alcohol, the insoluble residue is called scale-forming. This treatment gives simply the total hardness. It is, however, of value as a substitute for the soap test.

A. Elliott Kimberly† proposes a method of rapid analysis for

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*Engineering Chemistry, Second Edition. p. 53.

†Journal of Infectious Diseases. Supp. May 1905, p. 157.

water softening. He says, "To calculate the chemicals necessary for the treatment of magnesium water, the following data are necessary:

1. Free and half bound carbonic acid.
2. Alkalinity.
3. Non-carbonate hardness (Incrustants).
4. Total magnesium.
5. Total calcium.
6. Incrusting calcium hardness.

Numbers 1, 2, 3 and 4 are determined according to Standard Methods. Total calcium is calculated by deducting total magnesium (as $CaCO_3$) from total hardness (as $CaCO_3$). Incrusting calcium is determined by concentrating 500 c.c. to 200 c.c. then filtering and determining Ca gravimetrically in the filtrate. An allowance is made for the solubility of normal $CaCO_3$ which is taken as 20 parts per million.

From the data thus obtained, the component bases of alkalinity and non-carbonate hardness are calculated. That quantity of calcium present combined with acids other than carbonic is subtracted from the total calcium. The remaining calcium may be assigned to carbonate. The difference between alkalinity determined by titration and that portion due to calcium must be the magnesium component of alkalinity.

Non-carbonate hardness. Calcium is determined directly as described above. The difference between total magnesium and that attributed to alkalinity gives non carbonate magnesium.

He gives the following data obtained from an analysis by the above scheme:

constituents expressed in parts per million.

		as $CaCO_3$
Alkalinity as $CaCO_3$	252.	252.
Non-carbonate hardness as $CaCO_3$	174.	174.
Total magnesium as Mg	44.	182.
Total calcium as Ca	98.	244.
Non carbonate calcium as Ca	25.	63.

Calculation of lime required to soften above water:

$$\text{Alkalinity}\begin{cases}\text{Ca as } CaCO_3 \ \ 183 \times .56 = \text{lime required} = 102\\ \text{Mg as } CaCO_3 \ \ 70 \times 1.12 = \text{lime required} = 77\end{cases}$$

Non carbonate Mg as $CaCO_3$ 112 x .56=lime required=63

Total lime. . . .242

Calculation of sodium carbonate required to soften the above water:

$$\text{Non carbonate} \left\{ \begin{array}{l} \text{Ca as } CaCO_3 \quad 62 \times 1.06 = Na_2CO_3 \text{ required} = 65. \\ \text{Mg as } CaCO_3 \quad 112 \times 1.06 = Na_2CO_3 \text{ required} = 119. \end{array} \right.$$

Total soda. . . . . .184.

By means of very simple formulae, identical results may be obtained using only a part of Mr. Kimberly's data.

Data required:	Pts. per mil. as $CaCO_3$
Non-carbonate hardness	174.
Total Mg.	182.
Alkalinity	252.

Formulae:
.56(Mg+Alk.)=lime required.
1.06 x non-carbonate hardness=Na_2CO_3 required.

From a consideration of the above it is obvious that the determination of total calcium and incrusting calcium is superfluous. It does not throw any additional light on the character of the water.

It is Mr. Kimberly's contention that the above method of analysis is especially adapted to waters containing large amounts of magnesium.

Two methods of analysis used by the Pittsburg Testing Laboratories, J. O. Handy, Chief Chemist, are given in the Chemical Engineer.*

Method I. 250 c.c. are evaporated and total residue determined. This residue is treated with, CO_2 free, distilled water and filtered. The filtrate contains the alkali salts together with the sulphates and chlorides of iron, aluminium, calcium, and magnesium. The insoluble residue consists of carbonates of lime and magnesium with some silica. The soluble and insoluble portions are analyzed separately. Alkalies are determined indirectly. The insoluble carbonates are dissolved in dilute HCl. The iron is precipitated with NH_4OH, dissolved in dilute H_2SO_4 and titrated with standard $KMnO_4$ solution after reduction with zinc. Calcium is precipitated with ammonium oxalate dissolved in hot 2% H_2SO_4 and titrated with $KMnO_4$. The magnesium is precipitated by the addition of a phosphate and NH_4OH. The precipitate is dried, dissolved in H_2SO_4 and the excess titrated back with $^N/_{10}$ NaOH, using methyl orange indicator. The insoluble part is acidified with HCl and the iron, calcium and magnesium determined as above.

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*Anon. Chemical Engineer. Vol. XI, No. 2, Feb. 1910.

Chlorine is determined by titrating 100 c.c. with standard $AgNO_3$ using K_2CrO_4 as indicator.

Sulphuric anhydride is determined in a separtate portion as $BaSO_4$.

Nitric anhydride is determined by the phenolsulphonic acid method.

Alkalinity is determined by titrating 100c.c. with H_2SO_4.

Acidity is determined by adding to 100 c.c. a measured amount of $^N/_{10}$ H_2SO_4 boiled to drive off CO_2 and titrated back with $^N/_{10}$ NaOH.

Free CO_2 is determined by Seyler's method.

Silica is determined in a separate portion in the usual manner.

Bases and acids are combined by calculating the insoluble iron, calcium and magnesium to carbonates. If the sum is less than alkalinity, the difference is Na_2CO_3. The soluble iron, aluminium, calcium and magnesium are calculated first to sulphate then nitrate and finally to chlorides. The residual acid radicals are calculated to sodium salts.

The amount of chemicals required for softening is determined by calculating

One	equivalent	of	lime	for	one	equivalent	insoluble Ca
Two	“	“	“	“	“	“	“ Mg
one	“	“	“	“	“	“	soluble Mg
“	“	“	“	“	“	“	free acid
“	“	“	“	“	“	“	insoluble Fe
“	“	“	soda ash	for	one	“	soluble Ca
“	“	“	“ “	“	“	“	“ Mg
“	“	“	“ “	“	“	“	free H_2SO_4

The first method of analysis and the calculation of chemicals required is correct, but it has no great advantage over the ordinary mineral analysis.

In the second method a peculiar inconsistency is noticeable. The author says, “The tests necessary for calculating treatment of hard water are: (1) Hardness, (2) Alkalinity, (3) Acidity (free CO_2).”

Hardness is determined by titrating 100 c.c. with N/10 soap solution.

Alkalinity is determined by titrating 100 c.c. with $^N/_{50}$ H_2SO_4 using methyl orange as indicator.

Acidity is determined by titrating 200 c.c. with $^N/_{50}$ NaOH using phenolphthalein as indicator. Calculations are made as follows:

Lime. Alkalinity+Acidity x .056 lbs. = lime required for 1000 gallons of water.

Soda Ash. Hardness—Alkalinity x .093 lb. = soda ash required for 1000 gallons. This is inconsistent with the first method and is evidently erroneous, as it does not take into account the facts that lime reacts with the magnesium present as non carbonate and that magnesium present as bicarbonate must be precipitated as hydroxide.

A comparison will show this more clearly.

METHOD I.

Laboratory No. 20283.

Parts per 100,000
CaO (insoluble) 10.8 x .0925 = .999
MgO (insoluble) 4.2 x .26 = 1.094
MgO (soluble) 1.5 x .13 = .195

Total. . . . . .2.288 lbs. per 1,000 gallons
Commercial lime (90%)

CaO (soluble) 0.
MgO (soluble) 1.5 x .233 = .34 lbs. per 1000 gallons
Soda ash (95%)

METHOD II.

Laboratory No. 20283.

Lime

Alkalinity + Acidity		Parts per 100,000 as $CaCO_3$	Pounds per 1000 gallons
30.0 + 0	=	30.0 x .056 =	1.68

Soda Ash

Hardness — Alkalinity
33.7 — 30.0 = 3.7 x .093 = .34

As would be expected, the total lime required is entirely too low as determined by Method II.

Using the same data as in Method I the total lime and soda required may be determined by the simple formulae:

Lime required = .0052 (Mg + Alk) = .0052 (143 + 300) = 2.3 Lbs. per 1000 gallons 90% lime.

Soda Ash required = Non-carbonate hardness x .0098 = .37 x .0098 = .34 lbs. per 1000 gallons 95% Soda Ash.

A rapid method for the control of water softening depending on the use of potassium stearate has been proposed by Von. C. Blacher,

U. Koerber and J. Jacoby.* The following constituents are determined:

1. Alkalinity.
2. Total hardness.
3. Calcium hardness.
4. Sulphuric acid.
5. Total bases.

The reagents required are: $^N/_{10}$ HCl, $^N/_{10}$ $BaCl_2$ and $^N/_{10}$ potassium stearate. The potassiuti stearate solution is prepared by dissolving 28.4 grams pure stearic acid in 250 grams glycerine and 400 c.c. 90% alcohol, warmed gently. This is neutralized to phenolphthalein with alcoholic KOH and made up to a liter with 90% alcohol.

Alkalinity is determined by titrating 100 c.c. of the water with $^N/_{10}$ HCl using methyl orange as an indicator.

Total hardness is determined by acidifying 100 c.c. of water boiled to drive off CO_2. It is cooled and brought to the exact phenolphthalein neutral point. All or an aliquot portion is then titrated with potassium stearate.

Calcium hardness is determined by acidfying 100 c.c. to the methyl orange neutral point. Air is passed through to drive off CO_2. This is rinsed into a 110 c.c. flask. For the precipitation of magnesium 1:1 alcohol and KOH are added. The flask is placed on the steam bath until the precipitate has coagulated, then filtered warm and 100 c.c. of the filtrate withdrawn for the determination of calcium hardness. This is acidified and boiled down to 30 or 40 c.c. and titrated with potassium stearate.

Sulphuric acid is determined by acidifying 100 c.c. of the water and adding 5, 10, or 15 c.c. of $^N/_{10}$ $BaCl_2$ to the boiling solution and concentrating to 50 c.c. The precipitate is filtered off and the neutral point is fixed to phenolphthalein. The excess of $BaCl_2$ is determined by titrating with potassium stearate.

Total bases are determined by evaporating to dryness 100 c.c. of the water. A few drops of H_2SO_4 are added and the residue heated over a flame to drive off organic matter and excess H_2SO_4. Sulphate is then determined as above.

This method depends for the end-point on the formation of a lather and like the soap test it is not reliable. “Standard Methods”† has this to say about the soap method: “At best the soap method is not a precise test on account of the varying amounts of calcium and

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*Zeit. fur Angew. Chem., 1909, 22, 967.

†Journal Infectious Diseases Supp. May 1905, p. 157.

magnesium present in different waters. For hard waters especially in connection with processes for purification and softening, it is advised that this method be not used."

In Technical Methods of Chemical Analysis, Part II, p. 802, Lunge proposes the following special tests to determine the amounts of lime and sodium carbonate necessary for the treatment of water.

I. Clear lime water, previously standardized with $^{N}/_{5}$ HCl, using phenolphthalein as indicator, is added to 200 c.c. of the water under examination until the first coloration appears and remains for a short time. This test indicates the amount of lime which must be added.

2. The turbid liquid obtained according to (1) is filtered, the filtrate is treated with an excess of $^{N}/_{5}$ sodium carbonate solution and then titrated back with $^{N}/_{5}$ HCl. The difference between the amount of $^{N}/_{5}$ Na_2CO_3 and the amount of $^{N}/_{5}$ HCl used indicates the amount of soda which must be added.

P. Bilger* has modified the above method somewhat. He adds 30 c.c. of lime water to 100 c.c. of the sample and heats to boiling. When cool, the volume is made up to 200 c.c. with distilled water free from CO_2 and allowed to settle. 100 c.c. of the clear liquid is then withdrawn and titrated with $^{N}/_{10}$ HCl using phenolphthalein as indicator.

EXPERIMENTAL.

The following experimental work was undertaken for the purpose of testing the adaptability of the methods already outlined for the control of water softening, and to devise, if possible, new methods or to combine methods already in use so as to make a method which is at the same time rapid, accurate and complete.

For this purpose water from the city supply of Belleville, Illinois, was selected because it is a representative sample of a hard water requiring both lime and soda ash to soften it.

A complete mineral analysis of the water was first made according to the methods used in the laboratory of the Illinois Water Survey† and the following results were obtained.

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*Chem. Zeit. 33, p. 757.

†Bulletin, University of Illinois, State Water Survey Series, No. 4, page 35.

Ions	Parts per Million	Hypothetical Combinations	Parts per Million
Na	13.9	$NaNO_3$	.2
NH_4	.5	NaCl	13.2
Mg	34.6	Na_2SO_4	26.5
Ca	77.6	$MgSO_4$	44.8
$Fe_2O_3 + Al_2O_3$	4.9	$MgCO_3$	88.8
NO_3	.1	$CaCO_3$	193.7
Cl	8.0	$Fe_2O_3 + Al_2O_3$	4.9
SO_4	53.6	SiO_2	29.3
Residue on evaporation	410.		
Alkalinity	283.		401.2

The same water was analyzed by a slight modification of the rapid method suggested by Pfeifer and Wartha.*

Non-carbonate hardness—Place 200 c.c. of the water into a 500 c.c. Erlenmeyer flask, boil 15 minutes to expel CO_2. Add 25 c.c. $^N/_{20}$ soda reagent, a mixture of equal parts NaOH and Na_2CO_3, boil 10 minutes and filter into a 200 c.c. flask. In an aliquot portion titrate the excess of alkali with $^N/_{50}$ H_2SO_4 using methyl orange indicator. Make blank determination using distilled water.

The difference between the number of c.c. used for the blank and the number of c.c. used for the water is non-carbonate hardness in terms of $CaCO_3$.

If the water contains Na_2CO_3 the number of c.c. used for the blank determination will be less than that used for the water.

Magnesium—Neutralize carefuly 100 c.c. of the water (the portion in which the alkalinity was determined may be used) to methyl orange with $^N/_{50}$ H_2SO_4, in a 200 c.c. graduated flask and heat on a hot plate to expel CO_2. Add 25 (or 50 c.c.) of saturated lime water. Let stand on a water bath for about 15 minutes, to allow the precipitate to settle completely. Make up to about 5 c.c. above the mark, to allow for contraction, shake thoroughly, and allow to cool.

Determine the excess of lime water with $^N/_{50}$ H_2SO_4, and methyl orange indicator using an aliquot part of the supernatent liquid or of the filtrate after rejecting the first portion. At the same time make a determination using distilled water.

The difference between the number of c.c. used for the blank and the number of c.c. used for the water represents the amount of magnesium present in terms of calcium carbonate.

*Z. angew. Chem. 15, 193.

The following data were obtained by the above method:

	Parts per million. as $CaCO_3$.
Non-carbonate hardness	40.00
Total magnesium	136.00
Alkalinity	283.00

For the purpose of comparing the rapid method just outlined with the regular method, a number of samples were analyzed both by the gravimetric and by the rapid methods. The results appear in the following table:

TABLE II.

Lab. No. or source of sample	Gravimetric Method		Rapid Boiler Method	
	Magnesium Parts per million as $CaCO_3$	Non-carbonate hardness Parts per million as $CaCO_3$	Magnesium Parts per million as $CaCO_3$	Non-carbonate hardness Parts per million as $CaCO_3$
18754	162	-266	166	-233
19041	1015	2056	1016	2058
20445	111	-5	112	-10
20505	88	-65	84	-86
20283	143	37	136	42
Lena, raw	200	39	192	45
Lena, treated	78	-1	68	0
Mendota raw	70	-55	66	-48
Mendota, treated	——	-50	40	-48

The above results show that the determinations made by the rapid method agree favorably with the gravimetric determinations. Although there are slight differences, the method is accurate enough for the control of water softening.

Calculations may be made from the above data to determine the amount of chemicals required for treatment.

From the rapid analysis we have for lime:

Mg + Alk. = Lime required as $CaCO_3$
136 + 283 = 419
For soda ash
1.06 N. C. H. = Soda ash required as $Na_2 CO_3$
1.06 x 40 = 42

For the purpose of practically testing the above method of calculating the reagents required a series of sixteen one liter portions of Belleville water in sixteen two-liter glass stoppered bottles was treated with varying amounts of lime of known strength. The bottles were well shaken after the addition of lime and allowed to stand

TABLE III.

TREATMENT OF BELLEVILLE WATER WITH LIME.

No.	Milligrams of Lime Used	Alkalinity to Phenolphthalein Cor. for Vol. Pts. per million	Alkalinity to Methyl Orange Cor. for Vol. Pts. per million	Hardness Cor. for vol. Parts per million as $CaCO_3$	Ca Pts. per million	Mg Pts. per million
1	0	0	286	330	77.4	34.5
2	20	0	281	311	....	....
3	40	0	270	306	61.5	34.0
4	80	0	214	283	....	....
5	120	0	194	250	49.1	35.0
6	160	28	167	181	....	....
7	200	23	135	189	27.7	34.0
8	240	47	129	134	....	....
9	280	47	118	114	25.7	29.3
10	320	26	72	118	....	....
11	360	36	57	108	36.0	15.5
12	400	39	61	105	....	....
13	440	40	55	126	50.2	7.1
14	480	63	75	143	....	....
15	520	104	112	189	74.0	6.6
16	560	152	163	....	....	....
17	600	206	236	....	150.0	6.2

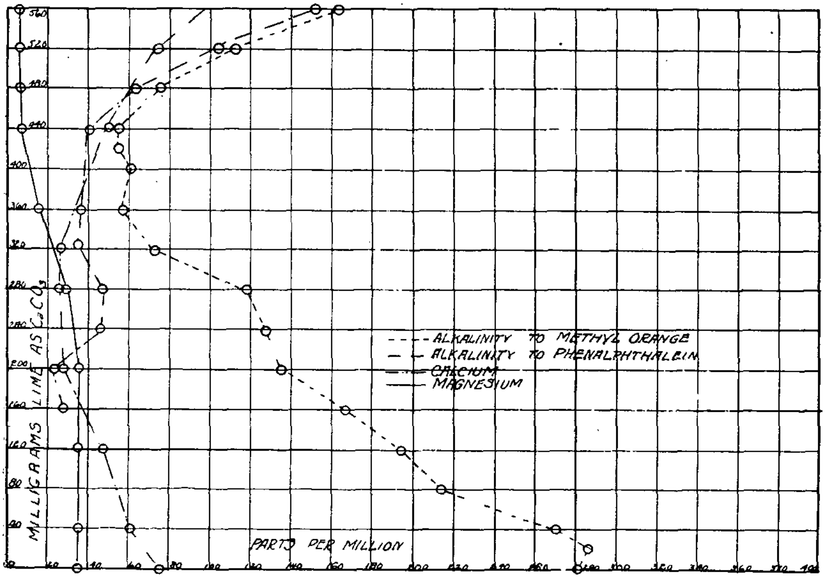

Plate I. Treatment of Belleville Water with Lime.

fourteen hours. They were then filtered and alkalinity to phenolphthalein and methyl orange was immediately determined. Calcium and magnesium were determined gravimetrically in 250 c.c. of the filtrate. The results appear in Table III and diagramatically in Plate I.

Another series of six one liter portions was used for the purpose of testing the method of calculating soda ash. To each of the two liter bottles, each containing one liter of water, was added varying amounts of sodium carbonate. After standing fourteen hours, they were filtered and the non-carbonate hardness determined as described above.

The following results were obtained:

TABLE IV.

TREATMENT OF BELLEVILLE WATER WITH Na_2CO_3

NO.	Milligrams Na_2CO_3	Non-carbonate Hardness Parts per million as $CaCO_3$
1	0	42.4
2	44	4.0
3	55	-4.0
4	66	-34.0
5	77	-47.0
6	88	-60.0

A third series was treated with the same amount of lime as in Series I, but 46 mg. of sodium carbonate were added to each bottle. The results are shown in Table V, and diagramatically in Plate II.

It will be noticed from these tables and diagrams that the practical results agree, within the limits of experimental error, with the calculation by the above formulae.

A further inspection of Plate I shows the following order of reactions: In all probability free CO_2 if present, is attacked first. Calcium bicarbonate is next attacked. This is shown by the simultaneous decrease in alkalinity to methyl orange and the calcium content while the magnesium content remains constant up to the point where 200 milligrams has been added. This is further substantiated by the analysis which shows that 194 milligrams of calcium carbonate are present. From this point up to 280 milligrams of lime, there is only a slight reduction in calcium and magnesium. However, when 320 milligrams of lime has been reached, alkalinity has been reduced to a minimum This is evidently the point where lime has reacted with calcium and magnesium present as bicarbonates, and is the best treatment where lime alone is used. From this point on, magnesium decreases and calcium increases showing that $MgSO_4$ is decomposed into insoluble $Mg(OH)_2$ and soluble $CaSO_4$.

TABLE V.

TREATMENT OF BELLEVILLE WATER WITH LIME AND SODA.

42 Milligrams Na_2CO_3 added to each liter

No.	Milligrams of Lime Used.	Alkalinity to Phenolphthalein Cor. for vol. c.c. N/50 H_2SO_4	Alkalinity to Methyl Orange. Cor. for vol. c.c. N/50 H_2SO_4	Ca Parts per million	Mg Parts per million
1	0	0	283	77.4	34.5
2	21	0	323	....	....
3	42	0	289	40.0	34.4
4	84	0	245	....	....
5	126	0	206	....	....
6	168	0	173	....	....
7	210	0	147	29.0	34.4
8	252	0	130	....	....
9	294	16	107	....	....
10	336	23	93	13.0	27.0
11	378	27	78	....	....
12	420	24	52	15.0	9.0
13	462	30	49	....	....
14	504	35	47	....	....
15	546	38	66	37.0	6.0

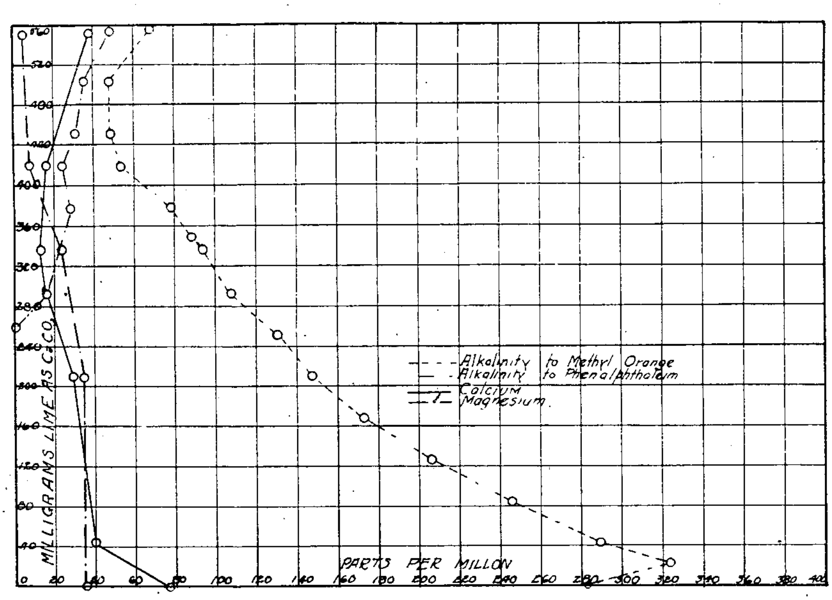

Plate II. Treatment of Belleville Water with Lime and Soda Ash.

A study of Plate II shows that the same order of reactions has taken place. The best treatment appears to be at the point where 420 milligrams has been added. This agrees very well with our formulae:

Mg + Alk. + CO_2 = lime required.

It was thought that the method proposed by Lunge and modified by Bilger as already described, would afford, with some slight modifications, a rational and accurate means for the determination of the amount of lime to be added to a water. A series of experiments was, therefore, carried out. The procedure was as follows:

200 c.c. of the water to be tested was measured into a 500 cc. Jena Erlenmeyer flask. 75 cc. of saturated lime water was immediately added and the volume boiled down to a little below 200 cc., cooled, filtered and made up to 200 cc. with distilled water free from CO_2. 50 cc. was withdrawn, and titrated with $^N/_{50}$ H_2SO_4 using methyl orange as indicator.

A modification of the Lunge-Bilger method was also tried. The modification consisted in adding Na_2CO_3 to the sample in quantity equivalent to the amount of non-carbonate hardness. Otherwise the procedure was as above. This method of procedure is an exact duplicate of the practical methods of water softening. Theoretically, therefore, it shows the amount of lime used up in reacting with sulphate of magnesium, salts of iron and aluminium, and free CO_2.

The strength of the lime water was obtained by running a blank determination similar to the sample, except that no Na_2CO_3 was added. By either method, lime required = 20 (Burette reading blank-Burette reading sample) when $^N/_{50}$ acid is used.

For the purpose of comparison, each sample was analyzed by the rapid boiler method and lime calculated by the formula.

Lime-required = Mg + Alk. + CO_2.

The following are some of the results:

TABLE NO. VI.

Method	Lab. No. 20734	Lab. No. 20741	Lab. No. 20746
Rapid Boiler	446	670	440
Lunge-Bilger	560	728	474
Modified Lunge-Bilger	576	720	460

In a number of other samples similar results were obtained. It will be noticed that the lime required, as determined by the use of excess of lime with or without Na_2CO_3, is greater than as determined by the rapid boiler method. To further test this method, artificial hard waters were made up as described below.

Solution A. To 20 liters of distilled water were added 4 grams $CaSO_4$, 10 grams $MgSO_4.7H_2O$ and 4.6 grams $CaCO_3$. On analysis this water showed:

	Amount found	Amount added
Mg as $CaCO_3$	188	196
Non-carbonate hardness as $CaCO_3$	332.	324.
Alkalinity as $CaCO_3$	230.	230.
Free CO_2 as $CaCO_3$	10.	10.

Method	Lime required
Rapid Boiler	428.
Lunge-Bilger	526.
Modified Lunge-Bilger	540.

Solution B. To 14 liters of distilled water were added 7.6 grams $MgSO_4.7H_2O$, and 3.8 grams $CaCO_3$. On analysis this water showed:

	Amount found	Amount added
Mg as $CaCO_3$	230.	220.
Non-carbonate hardness	200.	220.
Alkalinity	274.	274.
Free CO_2	0.	.0

Method	Lime required
Rapid Boiler	504.
Lunge-Bilger	560.
Modified. Lunge-Bilger	560.

Solution C. To 10 liters of distilled water was added the equivalent of 388 parts per million of lime which was brought into solution as $CaCO_3$ by means of a current of CO_2. On analysis this water showed:

	Amount found	Amount added
Mg	0	0
Non-carbonate hardness	0	0
Alkalinity	388.	388.
Free CO2	12.	13.

Method	Lime required.
Rapid Boiler	400.
Lunge-Bilger	450.

The above results show that the lime required as determined from the formula Mg + Alk. + CO_2 is considerably less than the amount shown by the use of excess of lime. Apparently this difference is independent of the nature of the calcium and magnesium salts present.

In order to ascertain whether the lime required, as determined by the rapid boiler method or by the use of an excess of lime, was the correct amount to add to a water to properly soften it, a series of five bottles each containing one liter of an artificially prepared hard water, was treated with Na_2CO_3 equivalent to the non-carbonate hardness, and lime varying according to the amounts indicated by the different methods of analysis.

This water at the time of treatment showed the following constituents:

Mg as $CaCO_3$	188.
Non-carbonate hardness as $CaCO_3$	330.
Alkalinity as $CaCO_3$	184.
Free CO_2 as $CaCO_3$	20.

Lime required by the different methods:

Method	Lime required as $CaCO_3$
Rapid Boiler	392.
Lunge-Bilger	492.
Modified Lunge-Bilger	492.

After standing fourteen hours, the water in this series, treated as described above, was filtered and alkalinity to phenolphthalein and to methyl orange was determined in the filtrate. The results obtained are recorded in the following table:

No.	Milligrams lime as $CaCO_3$	Alkalinity to phenolpthalein Parts per million as $CaCO_3$	Alkalinity to methyl orange Parts per million as $CaCO_3$
I	384	38	70
II	420	36	56
III	456	42	62
IV	492	50	72
V	528	73	93

This experiment shows that the best treatment is obtained when the lime required is calculated from the formula Mg + Alk. + CO_2.

That there is a discrepancy in the amounts of lime and soda ash required to give the best treatment as determined in the laboratory and in actual practice is well known. In the laboratory, calculations are made for reagents of standard strength. In actual practice, however, their strength may vary from time to time as they come from the dealers. Moreover, lime, whether in the form of oxide or hydrate, readily takes up CO_2 from the air and forms $CaCO_3$ which is valueless as a softening agent.

For the purpose of comparing the quantity of reagents required and the cost of treatment as determined in the laboratory with the amount used and the cost in actual practice, samples of raw and treated water from two treatment plants on the Illinois Central Railroad were secured. One set of samples was taken at Mendota, Illinois, and the other at Lena, Illinois.

Complete mineral analyses were made of these waters, and the results are tabulated below.

TABLE VII

Ions	Mendota		Lena		Hypothetical Combinations	Mendota		Lena	
	Raw	Treated	Raw	Treated		Raw	Treated	Raw	Treated
Na	30.3	29.0	9.2	31.1	$NaNO_3$	4.8	5.5	6.0	6.6
Mg	17.7	10.0	48.9	19.8	NaCl	8.3	8.3	19.3	26.4
Ca	53.4	12.2	107.6	3.0	$NaSO_4$	1.9	3.8	......	62.2
Fe_2O_3 Al_2O_3	1.2	.5	1.0	.3	$NaCO_3$	57.7	52.9	......	1.6
NO_3	3.5	4.0	4.4	4.8	$MgCl_2$	......	......	4.4	......
Cl	5.0	5.0	15.0	16.0	$MgSO_4$	......	......	46.4	......
SO_4	1.3	2.6	37.0	42.0	$MgCO_3$	61.3	34.6	133.0	68.6
SiO_2	10.5	8.6	13.3	1.7	$CaCO_3$	133.2	30.5	268.5	7.5
Bases ...	1.0	.6	1.3	.9	Fe_2O_3+Al_2O_3	1.2	.5	1.0	.3
					SiO_2	10.5	8.2	13.3	1.7
					Bases	10.0	.6	1.3	.9
					Total	280.9	144.9	493.2	175.8

For the Mendota water: Lbs. per 1000 gallons of 90% lime

Lime required = .00517(Mg + Alk)

" " = .00517(74 + 252)

No Na_2CO_3 is required.

Cost of treatment of 1000 gallons at $.003 per lb. of lime = 1.8 x .003 = $.0054.

For the Lena water: Lbs. per 1000 gallons of 90% lime

Lime required = .00517(203 + 388) = 3.0 lbs. per 1000 gallons of 90% purity.

Soda ash required = .0092 (N.C.H.)

" " " = .0092(43) = 0.4 lbs.

Cost of lime treatment per 1000 gallons = $.009

Cost of soda treatment per 1000 gallons at $.01 per lb. = .004

$.013

Mr. C. E. Thomas, General Foreman Waterworks, Illinois Central Railroad, reports* that at Mendota they use 2.8 lbs. of lime per

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*In a communication to Dr. E. Bartow, Director State Water Survey.

1000 gallons at a cost of \$.0106 per 1000 gallons for treatment. At Lena they use 3.12 pounds of lime per 1000 gallons and .56 pounds of soda ash per 1000 gallons at a cost of \$.0157 per 1000 gallons for treatment.

In the case nf either water the amount of reagents used and cost of treatment are greater in actual practice than that determined in the laboratory. This may be partly accounted for by the fact that the reagents used contain an excessive amount of impurities and also to the lack of proper control. We hope that further investigations along this line may be made.

If it is desired to know the class to which a water belongs, it can be ascertained within certain limits by calculation from the data as obtained. For example, if the non-carbonate hardness is less than total magnesium, we may say that part of the magnesium is present as a sulphate and the remainder as bicarbonte. If, on the other hand, the non-carbonate hardness is greater than total magnesium we know that part of the calcium and all of the magnesium is present as a sulphate. If the mineral acid hardness is negative, no sulphates of calcium or magnesium can be present. In making hypothetical combinations from the data of the rapid analysis chlorine is calculated to sodium chloride and the non-carbqnate hardness to sulphates of calcium and magnesium. That this is sometimes insufficient is apparent from the following analysis:

LABORATORY NO. 20582

Solids	398.	$NaNO_3$	83.
Alkalinity	94.	NaCl	16.
Chlorine	30.	$MgCl_2$	27.
Sulphate	140.	$MgSO_4$	91.
Nitrate	6.	$CaSO_4$	95.
Total Magnesium	104.	$CaCO_3$	94.
N. C. H.	174.		
			406.

If the non-carbonate hardness had consisted of sulphates of calcium and magnesium, the above would have been a fair water for boiler use, but as sulphates are not present in sufficient amounts to equal the non-carbonate hardness, $MgCl_2$ is present. This salt liberates HCl at boiler temperature and causes corrosion.

It is obvious from the above example that a knowledge of total SO_4, is essential in order to form an intelligent opinion as to the quality of a water. Some work was, therefore, done on the volumetric determiration of sulphates in water.

The first method tried was suggested by Dr. W. B. Holmes of the University of Illinois. In this method barium oxalate (BaC_2O_4) is added to the water. $BaSO_4$ is formed together with a corresponding amount of soluble oxalate which is determined by titration with standard $KMnO_4$ solution. This method was first tried on standard H_2SO_4 solution. The following procedure was carried out.

51 cc. $^N/_{50}\cdot H_2SO_4$ was run into a 200 cc. graduated flask, the volume made up to about 100 cc. About one gram $Ba_2C_2O_4$ was added and the soultion boiled for some time. The solution was made up to 200 c.c. and cooled. It was then filtered and 50 cc. withdrawn, sulphuric acid added, heated to boiling and titrated with $KMnO_4$ of such strength that 1 c.c. equaled 0.00365 SO_4. Blank tests were run at the same time and the number of cc. used were subtracted from the number of cc. required by the sample. With standard H_2SO_4 the following results were obtained:

	SO_4 present	SO_4 found
No. 1 51 cc. N/50 H2SO4..................	.049	.051
No. 11 51 cc. N/50 H2SO4	.049	.051

When samples of pure H_2SO_4 were used, good results were obtained, but when a water of known sulphate contents was tried very unsatisfactory results were obtained.

For the purpose of studying the interference four solutions were made up.

Solution I contained 1.8 grams NaCl in 1000 cc. distilled water.

Solution II contained 1.0 grams $MgCl_2$ in 1000 c.c. distilled water.

Solution III contained 10 grams $MgSO_4$ in 1000 c.c. distilled water.

Solution IV contained 0.41 grams $CaCO_3$ in 1000 c.c. distilled water.

The following table shows the results of this study of interference:

TABLE VIII.

No.	cc. N/50 H_2SO_4	cc. Sol. I	cc. Sol. II	cc. Sol. III	cc. Sol. IV	SO_4 present	SO_4 found
1	51	100	....	....	......	49	47
2	51	100	50	....	......	49	47
3	....	......	....	25	......	50	52
4	51	......	50	....	......	49	47
5	51	50	50	....	100	49	23
6	51	100	....	....	100	49	37

The above shows that there was little interference when NaCl, $MgCl_2$ or $MgSO_4$ was present, but the end-point was difficult to obtain as it was not sharp. The presence of $CaCO_3$ makes this method unreliable. It was thought that the necessity of completely removing calcium would render the method impractical, consequently it was abandoned.

A method* originally used for determination of sulphur in pyrites and described by F. Raschig† depends on the formation of insoluble benzidine sulphate which is filtered off and titrated with a standard alkali.

The solutions required are:

Benzidine solution.
One per cent hydroxyl-amine-hydrochloride solution.
Standard alkali solution.

The benzidine solution is made as follows:

8 grams benzidine is triturated with 8 cc. water, the pulp is brought with 150 cc. of water into a liter flask, 10 cc. concentrated HCl is added, and the whole made up to 200 cc. In a short time everything dissolves to a brown liquid, which is filtered if necessary. This is then made up to 4 liters, 150 cc. of this dilute solution is sufficient to precipitate .1 gram H_2SO_4.

Use an amount of water that will give about 20 mgs. of SO_4. Add 10 cc. of the 1% hydroxyl-amine hydrochloride solution and 100 cc. of the benzidine solution, let stand fifteen minutes, filter the precipitate rapidly by means of a suction filter, wash with 10 cc. of water. The precipitate is never allowed to become completely dry. Wash the precipitate and filter paper into the beaker in which the precipitation took place, heat to boiling and titrate with $^{N}/_{20}$ NaOH using phenolphthalein as indicator. The following results were obtained by this method:

Number	Gravimetric method SO_4 found in milligrams	Volumetric method SO_4 found in milligrams
N/50 H_2SO_4	24.4	24.0
18761	158.0	145.0
19041	1918.	1907.
19906	199.	190.
19928	125.	115.
20399	99.	93.
20400	218.	207.

The results show that this method is accurate enough for the purpose, and the fact that the time required to make one determination need not exceed thirty minutes makes this a very satisfactory method.

It is sometimes desirable to know approximately the amount of

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*Z. angew. Chern. 19, 331.

†The Chemical Engineer. Vol. IV. June 1906. p. 76.

alkalies present in a water. This may be accomplished by calculating all acids not required by Ca, Mg, (Fe) to Na.

In the foregoing operations we have a rapid, fairly accurate volumetric method for the determination of all the common constituents in a water. The whole procedure may be carried through in about one hour. The data thus obtained can be used to calculate the treatment required. Hypothetical combinations may also be made.

In the analytical methods used by the Illinois State Wate Survey* the ions are combined in the following order: Basic, Na, Mg, Ca; Acidic, NO_3, Cl, SO_4 and CO_3

For the purpose of testing a water after treatment to determine whether it has been properly treated or not it is usually sufficient to determine alkalinity to phenolphtalein and to methyl orange. If the phenolphthalein alkalinity is more than one-half the total alkalinity, hydroxides are present and the water has been over treated. If the phenolphthalein alkalinity is less than one-half the total alkalinity, the water has been undertreated. The best treatment will show the phenolphthalein alkalinity equal to one-half the total alkalinity.

A properly treated water should show no coloration on the addition of phenolphthalein to a sample of the water to which has been added a few crystals of $BaCl_2$. If a color appears the amount of hydroxide present may be determined by titrating with a standard HCl solution.

A water having permanent hardness should after treatment have the non-carbonate hardness equivalent to zero.

Different methods of analysis have been tested and methods of calculating the quantity of reagents required for softening have been tried, and the writers have formed opinions as follows:

Stabler's formula for calculating from ions can, for most cases, be simplified. Kimberley's method of analysis is unnecessarily long and the method of calculation complicated. In a magnesium water, the non-carbonate hardness does not necessarily contain $CaSO_4$, which is his contention.

The rapid method used in the Pittsburg Testing Laboratory does not take into account the fact that two equivalents of lime are necessary to precipitate $Mg(HCO_3)_2$. whereas only one is necessary in the case of Ca.

The potassium stearate method is impractical.

The method of analysis proposed by Pfeifer and Wartha is rapid and as to accuracy compares favorably with the gravimetric method.

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*University of Illinois Bulletin, State Water Survey Series No. 4, p. 38.

From the data thus obtained, calculations of reagents required can be made by means of a very simple formulae. The amount of lime required to treat a water determined by adding an excess of lime and titrating the excess gives high results.

A comparison between the quantity of reagents required and cost of treatment as determined in the laboratory and in actual practice shows that lower results are obtained in the laboratory.

The Benzidine method is a satisfactory and rapid method for the determination of sulphates in water.

In general, a rapid, complete and sufficiently accurate method is suggested for determining the constituents required in an analysis for control of water softening.

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NITRATE DESTRUCTION

TEST FOR A POLLUTED WATER‡

The chemical and bacteriological analyses performed in the laboratory of the Illinois State Water Survey to determine the purity of a water, take seventy-two hours. Confirmatory tests for the colon bacillus if made would require still more time. The length of time required is determined by the longest test and if a short test can be substituted for a long one it will be of advantage. The presumptive tests for *B. coli* in mixed cultures take from twenty-four to forty-eight hours. The nitrite destruction method which has been described in a previous bulletin* is proposed as an additional or substitute test for determining the presence of *B. coli* or other intestinal bacteria and may shorten the time which must lapse before an opinion upon the character of a water can be given.

Intestinal bacteria seem to be very active in destroying nitrites in the nitrite broth. If the time limit for the destruction of nitrites can be reduced to twenty-four hours, the test will be invaluable. It is simple and would confirm the other presumptive tests for *B. coli.*

A medium was prepared according to the method described by Sellards*. In sterilizing, however, ten pounds pressure for twenty minutes in an autoclave was used instead of the intermittent method. This nitrite medium was inoculated with one c. c. quantities of the waters.

The nitrite content of the incubated broth was determined by the sulphanilic acid method†. The absence of color in the tests shows that nitrites have been destroyed.

The nitrite medium was inoculated with samples of fifty-seven waters from different sources, mostly shallow dug wells, that were of questionable purity. These waters were also tested for gas formers.

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‡Abstract from thesis prepared by Frank Bachmann, under the direction Edward Bartow and submitted in partial fulfillment of the requirement for the degree of Bachelor of Science in Chemistry.

*Sellards, A. W. Uni. of Ill. Bul. Water Survey Series No. 7, P. 46.

†Standard Methods of Water Analysis.

The comparative results recorded at the end of forty-eight hours are as follows:

	Gas formers	$NaNO_2$ media
Positive	44	46
Negative	13	11
Indeterminate	0	0
		Per cent.
Agreements	47	82.45
Disagreements	10	17.54
Indeterminate	0	0
Total	57	

Dr. Sellards obtained sixty-nine per cent agreement on a series of one hundred and thirty-one waters, using the same kind of medium. The great difference in the percentages is probably due to the class of waters used. Three tests gave positive gas formers in forty-eight hours, but the nitrites were not destroyed until four days after inoculation. In three other tests, the nitrite test was positive, while the gas formers were absent in the 1 c. c. sample, but present in the 10 c. c. samples of the water. The destruction period in eleven samples was twenty-four hours, and in all of these, gas formers were present in 0.1 c.c. portions of the water.

In an endeavor to determine the best conditions for the reaction, the acidity of the media which would be most favorable for the destruction of nitrites by intestinal bacteria was next tested. Broths were prepared by dissolving in one liter of water six grams of Liebig's Beef Extract, ten grams of peptone (Witte's) and twenty grams of gelatine. 0.05% of $NaNO_2$ was added just before tubing the media. The broths were marked A, B, C, D, E, and H, and had a final reaction of neutral, +2%, +4%, +6%, —2%, —4% respectively. A plus (+) sign before a number signifies acid, while a minus (—) sign signifies per cent alkaline. These broths were inoculated with waters from different sources, with pure cultures and with mixed cultures. Table I shows the results. From the results obtained, it is evident that broths A and B give the best results. A neutral or 2 per cent acid reaction is, therefore, the most favorable reaction for the broths to possess. Further experiments were performed with these broths as shown in Table II.

The results are summarized as follows:

	Broth A Neutral	72 hours Broth B. +2% acid
Agreements	31	33
Disagreements	10	8

TABLE I.

NITRATE FERMENTATION TEST

Lab. No.	Source	GAS FORM-ERS	SOLUTION A Hours 24	A 48	A 72	B Hours 24	B 48	B 72	C Hours 24	C 48	C 72	D Hours 24	D 48	D 72	E Hours 24	E 48	E 72	F Hours 24	F 48	F 72
20084	River	+	—	+	+	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—
20085	River Filtered	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20086	Well 36' dug	+	+	+	+	—	+	+	—	—	—	—	—	—	—	—		—	—	—
20087	Well 160' drilled	—	—	+	+	—	—	+	—	—	—	—	—	—	—	+	+	—	—	—
20088	Well 48' dug	+	—	+	+	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—
20089	Well 38' bored	+	—	+	+	—	—	—	—	—	—	—	—	—	—	+	+	—	+	+
20090	Well 32' dug	+	—	—	+	—	—	—	—	—	—	—	—	—	—	+	+	—	—	—
20091	Well 175' drilled	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20092	Spring	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20093	Well 50' bored	—	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20094	Well 90' dug-bored	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20095	Well 24' dug	+	—	+	+	—	—	+	—	—	+	—	—	—	—	—	—	—	—	—
20096	Belleville P. Sta.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20097	Belleville Tap	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20098	Dug Well	+	—	+	+	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—
20099	Tap	+	—	+	+	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—
20100	Well 20' dug	+	+	+	+	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—
20101	Dug Well	+	—	+	+	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—
20102	Well 80' drilled	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20103	80' dug-bored Well	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20104	Well 18' dug	+	—	—	—	—	+	+	—	—	—	—	—	+	—	—	—	—	—	—
20105	Well 20' dug	+	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—
I	B. Prodigiosus		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
II	B. Subtilis		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
III	B. Mycoides		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
IV	B. Mcgatherium		—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—	—
V	B. Coli		+	+	+	+	+	+	+	+	+	—	—	—	—	—	+	—	—	—
VI	B. Vulgaris (Proteus)		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
VII	B. Proteus Vulgaris		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
VIII	Mixture of Bacteria		+	+	+	+	+	+	+	+	+		+	+	—	—	—	—	+	+

TABLE II.

Lab. No.	GAS FORMERS	NITRITE FERMENTATION TEST SOLUTION A Hours			B Hours		
		24	48	72	24	48	72
20111	—	—	—	—	—	—	—
20112	—	—	—	—	—	—	—
20113	+	—	+	+	+	+	+
20114	+	—	+	+	—	+	+
20115	+	—	+	+	—	—	+
20116	—	—	—	+	—	—	—
20120	+	+	+	+	+	+	+
20122	+	+	+	+	—	+	+
20123	+	+	+	+	—	—	—
20124	+	—	+	+	—	+	+
20125	+	—	—	—	—	—	—
20126	—	—	—	—	—	—	—
20127	—	—	+	+	—	+	+
20128	—	+	+	+	—	+	+
20129	+	+	+	+	—	+	+
20130	+	—	+	+	—	+	+
20131	+	+	+	+	—	+	+
20132	—	—	+	+	—	+	+
20133	+	—	+	+	—	+	+
20134	—	—	—	—	—	—	—
20135	—	—	—	+	—	—	—
20136	+	+	+	+	—	—	+
20137	—	—	+	+	+	+	+
20138	—	—	—	—	—	—	—
20139	+	—	+	+	—	+	+
20140	+	—	+	+	—	+	+
20141	+	—	+	+	—	+	+
20143	+	—	+	+	—	+	+
20144	—	—	—	—	—	—	—
20145	+	+	+	+	—	+	+
20146	—	—	—	—	—	—	—
20147	+	—	—	—	—	—	—
20148	+	+	+	+	+	+	+
20149	+	—	+	+	—	—	+
20150	+	—	+	+	—	—	+
20151	+	+	+	+	+	+	+
20152	+	+	+	+	+	+	+
20153	+	—	+	+	+	+	+
20154	+	+	+	+	+	+	+
20155	—	—	—	+	—	—	—
20156	+	—	—	—	—	—	—

Forty-one tests appear to be too few to enable us to draw conclusions as to the superiority of the neutral broth over the 2 per cent acid broth. However, we believe that either can be used to advantage.

The composition of the media plays an important part in favoring or inhibiting the growth of certain organisms. For instance, large amounts of peptone encourage the growth of many common *saplirophytes*, as well as the intestinal bacteria, while large amounts of gelatine without peptone inhibit the growth of all bacteria. Table III and

TABLE III.

NITRATE FERMENTATION TEST

SOLUTION

Lab. No.	Source	GAS FORM-ERS	O Hours 24	O Hours 48	O Hours 72	I Hours 24	I Hours 48	I Hours 72	II Hours 24	II Hours 48	II Hours 72	III Hours 24	III Hours 48	III Hours 72	IV Hours 24	IV Hours 48	IV Hours 72	V Hours 24	V Hours 48	V Hours 72
20300	Well 30’ dug	+	—	—	—	—	+	+	—	+	—	—	—	—	—	+	+	+	+	+
20301	Well 30’ dug	+	—	—	—	—	+	+	—	—	—	—	—	—	—	+	+	—	+	+
20302	Well 25’ dug	+	—	+	+	—	+	+	—	+	+	—	+	+	—	+	+	+	+	+
20303	Well 25’ dug	—	—	—	—	—	+	+	—	—	—	—	—	—	—	+	+	—	+	+
20304	Well 20’ dug	+	—	—	—	—	+	+	—	+	+	—	—	—	—	+	+	—	+	+
20305	Well 35’ dug	+	—	+	+	—	+	+	—	+	+	—	—	—	—	+	+	+	+	+
20306	Well 25’ dug	+	—	+	+	—	—	+	—	+	+	—	—	—	—	+	+	—	+	+
20307	Well 20’ dug	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+
20308	Wilmette Tap	+	—	+	+	—	+	+	—	+	+	—	—	—	—	+	+	—	+	+
20309	Wilmette Well	+	—	+	+	+	+	+	—	+	+	—	—	—	—	+	+	—	+	+
I	Mixture of Bacteria		—	—	+	—	—	+	—	+	+	—	—	—	+	+	+	+	+	+
II	B. Prodigiosus		—	—	—	—	—	+	—	—	+	—	—	—	—	—	—	—	—	—
III	B. Subtilis		—	—	—	+	+	+	—	+	+	—	—	—	—	+	+	—	+	+
IV	B. Mycoides		—	—	—	—	+	+	—	+	+	—	—	—	—	—	+	—	—	—
V	B. Megatherium		—	—	—	—	—	+	—	+	+	—	—	+	—	+	+	—	+	+
VI	B. Coli		—	—	—	—	+	+	—	+	+	—	—	—	+	+	+	+	+	+
VII	B. Vulgaris (Proteus)		—	—	—	—	—	+	+	+	+	—	—	—	—	—	—	—	—	—
VIII	B. Proteus Vulgaris		—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	+	+
IX	B. Cloaca		—	—	—	—	—	+	—	—	—	—	—	—	—	+	+	—	+	+
X	Sewage Streptococci		—	—	—	—	—	—	—	—	+	—	—	—	—	—	+	—	+	+

TABLE IV.

		NITRITE FERMENTATION TEST											
	SOLUTION	I				II				III			
		Hours				Hours				Hours			
No.	Source?	24	48	72	120	24	48	72	120	24	45	72	120
I	Mixture	—	—	—	—	—	—	—	—	—	—	—	—
II	B. Prodigiosus	—	—	—	—	—	—	—	—	—	—	—	—
III	B. Subtilis	—	—	—	—	—	—	—	—	—	—	—	—
IV	B. Mycoides	—	—	—	—	—	—	—	—	—	—	—	—
V	B. Megatherium	—	—	—	—	—	—	—	—	—	—	—	—
VI	B. Coli	—	—	—	—	—	—	—	—	—	—	—	—
VII	B. Vulgaris (Proteus)	—	—	—	—	—	—	—	—	—	—	—	—
VIII	B. Proteus (Vulgaris)	—	—	—	—	—	—	—	—	—	—	—	—
IX	B. Cloaca	—	—	—	—	—	—	—	—	—	—	—	—
X	Sewage Streptococci	—	—	—	—	—	—	—	—	—	—	—	—

IV show the results of the experiments from which we draw the above conclusion.

The media in the experiments recorded in Table III contained three grams beef extract and 1, 3, and 5% of peptone per liter. Solutions O, I, and II had a neutral reaction and contained 1, 3, and 5% of peptone respectively. Solutions III, IV, and V had a +2% reaction and contained 1, 3, and 5% peptone respectively. Even some of the common saphrophytes destroyed nitrites in these media.

Media marked I, II, and III in Table IV each contained 3 grams of beef extract and 1, 3, and 5% of gelatine per liter respectively. The reactions of the media were +2% and each contained 0.05% $NaNO_2$. Even *B. coli* did not destroy the nitrites in these media.

Apparently gelatine might be used to advantage as an inhibiting agent, while peptone acts in the opposite direction. There were considerable growths in all the broths whose action is shown in Table III, and practically no growths were visible in the broths whose action is shown in Table IV.

Because of the above results, media were prepared containing a smaller quantity of gelatine. The amount of peptone was thought. to be sufficient in quantity, and was not changed. The composition of the medium was as follows: 6 grams of beef extract per liter, 0.2% gelatine, 2% peptone, 0.05% sodium nitrite with a final reaction of +2% acid. The medium was filtered and tubed as previously described. *B. coli* emulsion was made and tenfold dilutions. prepared. A sample from the Bone Yard Creek (a polluted stream), was also diluted in the same manner. Comparative tests were made with these dilutions using the 0.2% gelatine broth and the 2% broth previously described. The results are shown in Table V.

The dilutions of the *B. coli* emulsion were apparently not carried far enough, for gas formers were present in the highest dilution. A destruction of nitrite was obtained in twenty-four hours in the

TABLE V.

c. c.	GAS FORM-ERS	NITRITE FERMENTATION TEST					
		0.2% Gelatine broth Hours			2% Gelatine broth Hours		
B. Coli Emulsion		24	48	72	24	48	72
1.0	+	+	+	+	+	+	+
0.1	+	+	+	+	—	+	+
0.001	+	+	+	+	—	+	+
0.0001	+	+	+	+	—	+	+
0.00001	+	+	+	+	—	—	+
0.000001	+	+	+	+	—	—	+
0.0000001	+	+	+	+	—	—	+
Bone Yard creek, c. c.							
1.0	+	+	+	+	+	+	+
0.1	+	+	+	+	—	—	+
0.01	+	+	+	+	—	—	+
0.001	—	—	+	+	—	—	—
0.0001	—	—	—	—	—	—	—
0.00001	—	—	—	—	—	—	—
0.000001	—	—	—	—	—	—	—

0.2% gelatine broth with both the dilutions of *B. coli* emulsion and Bone Yard Creek water; while the destruction time for the 2% gelatine broth was forty-eight hours.

The experiment was repeated twice with variable results, as is shown in Tables VI and VII. In Table VI, there is shown an agreement between the gas formers and the 2% gelatine broth in forty-eight hours when *B. coli* dilutions were used. There was disagreement, however, in the dilutions of water from the Bone Yard Creek. The 0.2% gelatine broth, however, showed agreement between the gas formers and nitrite removal in the tests of dilutions of water from the Bone Yard Creek, but did not show agreements with the

TABLE VI.

B. Coli Emulsion	GAS FORM-ERS	NITRITE FERMENTATION TEST					
		0.2% Gelatine broth Hours			2% Gelatine broth Hours		
c. c.		24	48	72	24	48	72
0.1	+	+	+	+	—	+	+
0.01	+	+	+	+	—	+	+
0.001	+	+	+	+	—	+	+
0.0001	—	+	+	+	—	—	—
0.00001	—	+	+	+	—	—	—
0.000001	—	+	+	+	—	—	—
0.0000001	—	—	—	—	—	—	—
0.00000001	—	—	—	—	—	—	—
0.000000001	—	—	—	—	—	—	—
Bone Yard creek, c. c.							
0.1	+	+	+	+	—	—	—
0.01	—	—	—	—	—	—	—
0.001	—	—	—	—	—	—	—
0.0001	—	—	—	—	—	—	—
0.00001	—	—	—	—	—	—	—

INCUBATION 38-39°

TABLE VII.

B. Coli Emulsion c. c.	GAS FORM-ERS	NITRITE FERMENTATION TEST					
		0.2% Gelatine broth Hours			2% Gelatine broth Hours		
		24	48	72	24	48	72
0.1	+	+	+	+	—	+	+
0.01	+	—	+	+	—	—	+
0.001	+	—	+	+	—	—	+
0.0001	+	—	+	+	—	—	+
0.00001	—	—	—	—	—	—	—
0.000001	—	—	—	—	—	—	—
0.0000001	—	—	—	—	—	—	—
0.00000001	—	—	—	—	—	—	—
0.000000001	—	—	—	—	—	—	—
Bone Yard creek, c. c.							
0.1	+	+	+	+	—	—	—
0.01	—	—	—	—	—	—	—
0.001	—	—	—	—	—	—	—
0.0001	—	—	—	—	—	—	—

INCUBATION 35-39°

dilutions of *B. coli.* These comparative tests gave us the impression that the 0.2% gelatine broth was not only more delicate than the 2% gelatine broth, but more delicate than the dextrose broth test, which was used in determining the presence of gas formers. A repetition of this experiment was made, as shown in Table VII. The results differ from those shown on Table VI in that the nitrites did not disappear so quickly. The reason for this is attributed to the difference in the incubation temperature. The latter was incubated at 35-37° C, while the former was at 38-39° C. The temperature of the incubator was brought to 38-39° C. A series of tests was made using 0.2% gelatine broth in order to obtain, if possible, a check on the results with the broth of the composition shown

TABLE VIII.

B. Coli Emulsion c. c.	GAS FORM-ERS	NITRITE FERMENTATION TEST		
		0.2% Gelatine broth Hours		
		24	48	72
0.1	+	+	+	+
0.01	+	+	+	+
0.001	+	+	+	+
0.0001	+	—	+	+
0.00001	+	—	+	+
0.000001	—	—	—	—
0.0000001	—	—	—	—
0.00000001	—	—	—	—
0.000000001	—	—	—	—
Bone Yard creek, c. c.				
0.1	+	+	+	+
0.01	+	—	—	—
0.001	—	—	—	—
0.0001	—	—	—	—

in Table VI. The results of this experiment are shown in Table VIII. The higher dilutions of *B. coli,* instead of giving positive results in twenty-four hours to correspond with the gas formers, required forty-eight hours for the destruction of nitrite in the broth.

In an attempt to reduce the time required for the nitrite removal, two batches of broth were made containing 0.2% gelatine, 2% peptone, 6 grams of beef extract per liter, and a final reaction of +1.5%. To one of the broths there was added 0.05% sodium nitrite, and to the other 0.02% sodium nitrite. These broths were inoculated with dilutions of *B. coli* and water from the Bone Yard Creek. The results of the experiment and of a repetition were not satisfactory. The fault seemed to lie in the composition of the media. We do not think that the change in nitrite content, or the change of the reaction from +2% to +1.5% was the cause. The temperature of the incubations was from 38°-40°C. Better results were obtained as is shown later in Table X.

A medium with a lower nitrite content was inoculated with pure cultures. The composition of the medium was as follows: 6 grams of beef extract per liter, 2% peptone, 0.2% gelatine, 0.005% sodium nitrite, and a final reaction of +2%. The results are shown in.

TABLE. IX.

NITRITE FERMENTATION TEST

No.	1st series	FERMENTATION GLUCOSE	Destruction of Nitrite Hours		
			24	48	72
I	B. Proteus Vulgarus	12%	—	—	—
II	B. Coli	40%	+	+	+
III	B. Mycoides (Bacterium)	—	—	—	—
IV	B. Megatherium	—	—	—	—
V	B. Cloaca	97%	—	+	+
VI	B. Prodigiosus	—	—	—	—
VII	Sewage Streptococci	—	—	—	—
VIII	B. Subtilis	—	—	—	—
IX	B. Coli	30%	+	+	+
	2nd Series				
I	B. Proteus Vulgarus	10%	—	—	—
II	B. Coli	35%	+	+	+
III	B. Mycoides (Bacterium)	—	—	—	—
IV	B. Megatherium	—	—	—	—
V	B. Cloaca	85%	+	+	+
VI	B. Prodigiosus	—	—	—	—
VII	Sewage Streptococci	—	—	—	—
VIII	B. Subtilis	—	—	—	—
IX	B. Coli	40%	+	+	+

Table IX. The only bacteria used which destroyed nitrites were *B. coli* and *B. cloaca* Two cultures of *B. coli* from different laboratories were used in this series of tests. No effort was made to differentiate the characteristics of these organisms. *B. cloaca* was not as active as *B. coli* in destroying nitrites in the medium as will be observed in the first series, Table IX. Destruction of nitrites occurred in twenty-four hours.

Dilutions of *B. coli* emulsions and Bone Yard Creek water were next prepared and inoculated in the medium. The results are recorded in Table X. The destruction of nitrite was accomplished in twenty-four hours in those samples in which gas formers were present. Destruction of nitrite was complete in 48 hours in the 0.01 Bone Yard sample, but no gas formers were present. It was also noticed that this sample had a thick growth. It is possible that gas formers were present in very small numbers, and that they were over-grown by other bacteria present, and that the nitrite medium was more favorable to the gas formers than to the other bacteria present.

TABLE X.

	GAS FORM. ERS	NITRITE FtiRMENTATION TEST		
		Hours		
B. Coli Emulsion c. c.		24	45	72
.1	+	+	+	+
.01	+	+	+	+
.001	+	+	+	+
.0001	+	+	+	+
.00001	+	+	+	+
.000001	+	+	+	+
.0000001	—	—	—	—
Bone Yard creek, c.c.				
. 1	+	+	+	+
.01	—	—	+	+
.001	—	—	—	—
.0001	—	—	—	—

This medium was next used in testing several waters, some of

TABLE XI.

Lab. No.	GAS FORMERS	NITRITE FERMENTATION TEST			
20990	—	—	—	—	—
20991	—	—	—	—	—
20992	+	+	+	+	+
20993	—	—	—	—	—
20994	—	—	—	—	—
20995	—	—	—	—	—
20996	—	—	—	—	—
20997	—	—	—	—	—
20998	—	—	+	+	+
20999	—	—	+	+	+
21000	—	—	+	+	+
21001	—	—	—	—	—
21002	—	—	—	—	—
21003	—	—	—	—	—
21004	+	+	+	+	+
21005	—	—	—	—	—
21006	—	—	—	—	—
21007	+	+	+	+	+
21008	+	+	+	+	+

good and others of questionable character. The results are shown in Table XI. Positive tests for the nitrite destruction which were obtained in twenty-four hours agreed with the gas formers. Samples 20,998, 20,999, and 21,000 gave positive nitrite tests in forty-eight hours.

In summarizing the work, the following conclusions may be drawn.

The reaction of the media which appears to be most suitable to gas formers, and which has given satisfactory results in the removal of nitrites, is +2 per cent (acid).

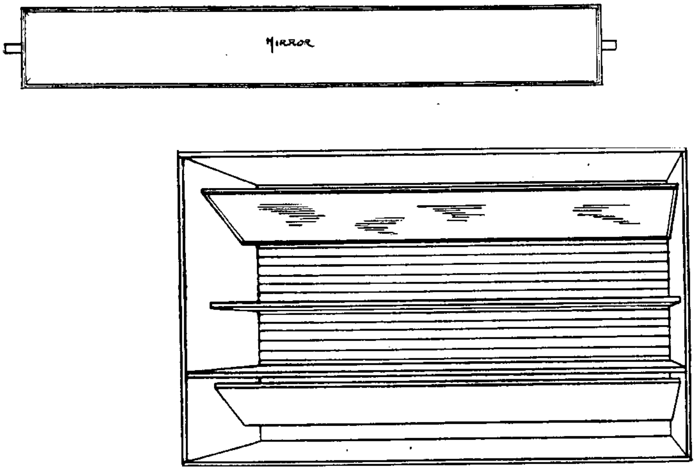
Peptone can be used to advantage in increasing the nitrite destroying power of bacteria while gelatin can be used in producing the opposite effect.

The time required for the nitrite fermentation test is 24 hours when the medium described on Page .123 is used.

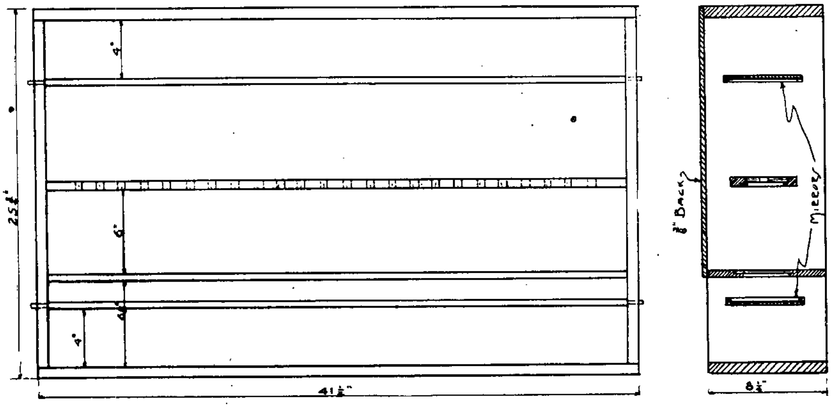
A CONVENIENT CAMERA FOR COLOR COMPARISONS IN NESSLER TUBES.

At various times we have been asked for information in regard to the camera in our laboratory used in comparing colors of solutions in Nessler tubes.

The camera as shown in the accompanying sketch, consists es-



PERSPECTIVE AND PLAN OF MIRROR.



SECTIONAL VIEWS. FRONT VIEW. END VIEW.

sentially of a wooden box 41 ½" x 25 ½" x 8 ¼". In this box there are two parallel shelves ½" thick (see sectional views), the lower the full width of the box and 6 ½" from the bottom, the upper 4 ½" wide and 6" higher. The shelves have corresponding holes 1" in diameter and 1 ½" center to center. A strip of glass is placed on the lower shelf so as to permit light to pass through the holes while at the same time supporting the Nessler tubes.

Above the upper shelf and 4" from inside of top of box, and below the lower shelf and 4" from inside of bottom of box there are mounted mirrors which can be rotated around an axis. The mirrors are mounted on a base 40" x 5 ½" and must not be made wider or they will not rotate properly. The glass is held in place by a ¾" moulding.

The camera is placed in a north window, the light being more constant there. The light is admitted into the camera through the back of the box below the lower shelf which as shown in the sketch is not inclosed. The lower mirror is adjusted so as to reflect the light directly upward through the Nessler tubes supported on the glass plate on the lower shelf. The upper mirror is adjusted so that the image of the tubes and the color of each is reflected in the mirror. After the camera has been thus adjusted, the colors may be compared conveniently by looking in the upper mirror. If desired the front below the lower shelf may be tightly closed and a movable door may be used to protect the upper part from dust. The woodwork is painted black to decrease interference from reflected light. The apparatus as thus described is suitable for Nessler tubes 10" high and has a capacity of 27 tubes. The length can of course be varied as occasion demands.

ADDITIONAL FARM WATER SUPPLIES.

Several series of analyses of farm well waters were reported in a former paper.* Since that time we have made a few collections of series of samples from other parts of the state.

The previous collections were made northwest of Champaign, in Champaign County, from near Centralia, in Marion county; from east of Elgin, most of the samples having been taken from Cook county; from northeast of Kankakee, in Kankakee county, and from north of Cairo, in Alexander county. Additional collections and analyses have now been made from Gibson, Ford county, Kewanee, Henry county, Tolono, Champaign county, and Southeast of Urbana, Champaign county.

The source and characteristics of the water used at these places on the farms follow:

GIBSON.

No. 1 (18801) is a 22-foot well walled with brick. A privy at a distance of 150 feet is the only source of possible pollution that could be seen. Our analysis indicates that surface water enters the well, and although no intestinal bacteria were found, such a well might become polluted very easily. At the time our analysis was made, the water was safe for drinking.

No. 2 (18802) is a 100-foot driven well cased to bottom with iron pipe. The well is located 10 feet from a feed lot, while there is a stable 100 feet away. The water is excellent for drinking purposes, and is also very satisfactory for domestic use as its hardness is not excessive.

No. 3 (18803) is a 65-foot driven well very similar to No. 1. The sanitary condition of the water is very good, and although there is a slight turbidity the water is perfectly safe for drinking.

No. 4 (18804) is another drilled well 100 feet deep, cased with iron pipe. The data obtained from the analysis of this water indicate that it is free from contamination and consequently a safe water.

No. 5 (18805) is a flowing spring situated in a feed lot. The water is free from contamination and is excellent for domestic use, as its hardness is comparatively low.

No. 6 (18806) is 100-foot driven well cased with iron pipe.

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*University of Illinois Bul. W. S. Series, No. 7. P. 78.

The water has few bacteria and although its turbidity perhaps makes it unattractive, it is never the less perfectly safe for drinking. The water is rather hard for domestic use.

No. 7 (18807) is another 100-foot driven well very similar to the preceeding in character. What may be said of the former water may also be said of this well.

No. 8 (18808) is a 100-foot driven well which yields a safe water for drinking purposes. The high turbidity renders the water wattractive in appearance. Otherwise there could be little objection to its use.

No. 9 (15809) is an 85-foot driven well. No bacterial examination was made of the water. The chemical data and the examination of the surroundings however make evident the fact that the water is perfectly safe.

Of the nine waters examined from this Section, eight were found to be in very good condition, while one was shown to be contaminated with surface water. This latter sample was from a dug well, while all the others were from deeper driven wells. With conditions as at Gibson driven, drilled or bored wells are possible and should be used.

KEWANEE.

No. 1 (18662) is a 59-foot well dug 39 feet and drilled 20 feet. It is walled with brick as far as dug while the drilled portion is cased with iron pipe. A cesspool is located 100 feet distant but drainage is away from the well. The analysis of the water shows that it is safe for drinking purposes, but would be rather a hard water for laundry purposes.

No. 2 (18663) is a 60-foot dug well walled with brick. A feed lot is situated nearby with drainage away from the well. The bacteriological examination indicates that the water is safe, although the chemical data show that there is undoubtedly some entrance of surface water into the well.

No. 3 (18664) is a dug well 40-feet deep, walled with brick. This water is very satisfactory both for drinking purposes and for domestic use:

No. 4 (18665) is a dug well 30-feet deep. The data indicate that the water is not all that could be desired, and surface water probably enters this well. The casing and cover might be arranged so that a better water could be obtained.

No. 5 (18666) is a 40-foot dug well walled with brick. There are possible sources of contamination within a radius of 100 feet. The chemical analysis showed marked evidences of pollution, and the test for gas formers indicates the presence of intestinal bacteria. This water could not be used with safety for drinking.

No. 6 (18667) is a well 57-feet deep, dug 30 feet and walled with brick, while the remaining 27 feet are drilled and cased with iron pipe. There was a stable within 25 feet of the well. The water is excellent from a sanitary standpoint, no disease germs being present. The water contains a large amount of mineral matter, and on account of its hardness not very suitable for domestic uses.

No. 7 (15668) is a 30-foot well. The sample for bacteriological examination was broken in transit so that only the information obtained from chemical analysis is available. This indicates an unsatisfactory water especially for laundry use, as the high mineral content and alkalinity show that the water is very hard. Without the aid of the bacteriological examination it would be unwise to express a definite opinion as to the safety for drinking purposes, but the other data give grounds for suspicion.

No. 8 (18669) is a 40-foot dug well walled with brick. The surroundings were in good sanitary condition, the nearest source of pollution being 200 feet. The analysis however was unfavorable, both the chemical and bacteriological data showing that surface water was evidently entering this well. At the time the examination was made the water was probably safe for drinking purposes, but such a supply would easily become contaminated without warning. The water is also rather hard for domestic use.

No. 9 (18670) is a 32-foot well similar to No. 1 except that it is walled with stone. There is a privy 50 feet away and a stable at a distance of 100 feet. Although the water is hard, it is safe for drinking.

No. 10 (18671) is a 60-foot dug well. Although the water is hard and would give trouble for laundry purposes, it is safe for drinking.

This series of ten samples from Kewanee were collected and analyzed by our representative in December, 1908. Nearly all were from dug wells. Six were found to be in good condition, while the remainder were evidently contaminated by entrance of contaminated surface water. Driven, drilled or bored wells are evidently little used. This is probably due to the character of the strata. Great care should be taken to keep the surface about the wells free from contamination. The upper part of the casing should be water proofed and the cover should be tight. When a well is dug and then bored deeper, water from the dug part of the well should be shut out by extending the inner casing to the surface.

SAMPLES FROM GIBSON CITY, COLLECTED FEBRUARY 8, 1909.

Laboratory No.	Appearance			Total Solids	Chlorine	Oxygen Consumed	Nitrogen as			Nitrates	Alkalinity	Bacteria per c.c.	Gas Formers				Depth	Remarks
							Ammonia											
	Turbidity	Color	Odor				Free	Aluminoid	Nitrites				10 cc.	1.0 cc.	0.1 cc.	Indol		
18801	0	5	0	307	10.5	1.6	.042	.058	.012	1.908	227	4,000	1?	2—	2—	2—	22 ft dug	Poor
18802	5	20	0	341	3.6	1.7	.080	.080	.004	.400	281	20	1—	2—	2—	2—	100 ft driven	Good
18803	10	35	0	324	2.0	1.0	.320	.040	.004	.160	324	14	1—	2—	2—	2—	65 ft driven	Good
18804	10	20	0	377	3.0	1.2	.144	.048	.005	.200	341	280	1—	2—	2—	2—	100 ft driven	Good
18805	0	5	0	275	4.0	0.5	.056	.056	.000	.240	215	20	1—	2—	2—	2—	Spring	Good
18806	10	40	0	360	3.5	1.0	.448	.032	.006	.120	349	50	1—	2—	2—	2—	100 ft driven	Good
18807	3	30	0	326	3.5	2.2	.800	.064	.007	.153	201	90	1—	2—	2—	—	100 ft driven	Good
18808	10	60	0	328	3.0	2.3	1.000	.064	.007	.193	322	140	1 +	2—	2—	+	100 ft driven	Good
18809	3	60	0	328	2.0	2.2	1.000	.088	.008	.272	314	....	....	....	....	....	85 ft driven	Good

SAMPLES FROM KEWANEE, HENRY COUNTY, COLLECTED DECEMBER 28, 1908.

Laboratory No.	Turbidity	Color	Odor	Total Solids	Chlorine	Oxygen Consumed	Free	Aluminoid	Nitrites	Nitrates	Alkalinity	Bacteria per c.c.	10 cc.	1.0 cc.	0.1 cc.	Indol	Depth	Remarks
18662	2	10	0	833	86	2.4	.016	.080	.002	3.698	452	370	1—	2—	2—	—	59 ft dug and drilled	Good
18663	0	5	0	596	73	0.6	.024	.056	.003	6.400	446	230	1?	2—	2—	—	60 ft dug	Good
18664	0	10	0	478	65	0.9	.024	.080	.001	.720	285	610	1—	1—1?	2—	—	40 ft dug	Good
18665	5	10	0	665	48	1.1	.016	.096	.002	12.000	389	152	1—	2 +	1—1+	—	30 ft dug	Poor
18666	3	10	Vegetable	713	100	1.4	.032	.128	.012	29.988	316	770	1 +	2 +	1+1—	—	40 ft dug	Poor
18667	8 0	20	0	1164	43	3.3	.480	.176	.002	.480	626	55	1—	2—	2—	—	57 ft dug and drilled	Good
18668	2	10	0	1970	276	1.8	.056	.144	.007	5.993	480	....	....	....	....	....	30 ft dug	Poor
18669	3	15	0	999	126	0.7	.016	.160	.003	20.000	343	260	1?	1—1+	1—1+	—	40 ft dug	Poor
18670	5	25	0	548	43	2.0	.048	.152	.004	1.000	492	66	1—	2—	2—	+	32 ft dug	Good
18671	4	20	Vegetable	648	34	.9	.048	.056	.002	.560	434	400	1—	2—	2—	—	60 ft dug	Good

TOLONO.

No. 1 (18692) is a bored well 140 feet deep and cased with iron pipe. It is located in Sec. 22, T. 18 N, R 8 E. There is a feed lot adjacent to the well, a stable at a distance of 50 feet and a privy 150 feet away. The water is safe for drinking, but the turbidity which developes on standing, the high color and the hardness would give trouble when used for other purposes.

No. 2 (18693) is a 150-foot bored well very similar to No. 1 in Sec. 22, T 18 N, R 8 E. The water is safe for drinking, but the results of the chemical analysis show that the water has undesirable characteristics exactly like No. I.

No. 3 (18694) is a 25-foot dug well walled with brick, located in in Sec. 27, T 18 N, R 8 E. There is a privy 100 feet away, and other sanitary wastes at greater distances. Both the sanitary and bacterilogical examination of the water indicate that surface water is entering the well. No intestinal bacteria are present so that the water might be used with safety for drinking at the time of analysis

No. 4 (18695) is a 90-foot bored well in Sec. 28, T 18 N, R 8 E. The well is cased with iron pipe. It is situated in a feed lot, and a stable, and privy are within 100 feet. The analysis indicates that the water is safe for drinking. However the turbidity, color and hardness make it unsatisfactory for other uses.

No. 5 (18696) is a dug well, 25 feet deep, and walled with brick. It is in Sec. 28, T 18 N, R 8 E. The chemical data show that surface water probably enters the well. No disease germs are present however, and the water could be used with safety. This water is comparatively soft and would be excellent for laundry use.

No. 6 (18697) is a 127-foot drilled well in Sec. 21, T 18 N, R 8 E. The bacterial analysis shows that the water is excellent from a sanitary standpoint. It has however other qualities, such as turbidity which developes on standing, high color and high ammonia which make it undesirable for general use. Such qualities are characteristic of the deep wells of Champaign County.

No. 7 (18698) is a 25-foot dug well in Sec. 23, T 18 N, R 8 E. Both the chemical and bacteriological examination show that surface water is evidently entering this well. Intestinal bacteria are also present so that the water could hardly be considered safe for drinking.

No. 8 (18699) is a 120-foot bored well on the same farm as the previous well. The water is safe for drinking purposes but is very hard. The mineral matter consists almost wholly of carbonates of calcium, magnesium and sodium.

No. 9 (18700) is a bored well, 137 feet deep located in Sec. 25, T 18 N, R 8 E. Bacteriologically the water is excellent. The mineral content differs from the other deep wells of the section in that it is higher in chlorine and lower in ammonia. The water is excellent for drinking purposes.

No. 10 (18701) is a 140-foot bored well. No sources of contamination are near, and both the chemical and bacteriological examination show that the water is in excellent condition.

Ten well waters from Tolono were examined, some from dug and some from drilled or bored wells. Most of the wells were in good condition. In the deep wells, the color, the high turbidity which developes on standing, and the high ammonia show some of the characteristics of the deep well waters of this section of the state. Most of these waters contain considerable amounts of iron, which becomes oxidized and separates out upon standing, causing turbidity of the water. The water is colorless when first drawn. The water may be clarified by aeration and sedimentation or filtration or more quickly by treatment with lime.

URBANA.

No. 1 (17269) is a 165-foot driven well cased with iron pipe. The mineral content of the water differs from others in this section in that the residue, chlorine and nitrates are very high. The water is very low in bacteria, and would be safe for drinking.

No. 2 (17270) is a dug well 29 feet deep on the same farm as No. 1. Both the chemical and bacteriological data show that the water is safe for drinking purposes.

No. 3 (17271) is a 160-foot drilled well. The color and turbidity of the water are somewhat objectional, but otherwise the water is very satisfactory.

No. 4 (17273) is a 46-foot driven well. There is a stable 20 feet away with no other possible sources of contamination. The water is in excellent condition.

No. 5 (17274) is a 25-foot bored well. A privy and a stable are within 75 feet of well. The latter is cased to the bottom with iron pipe. The sanitary condition of the water is good, and it is safe for drinking purposes.

No. 6 (17275) is a 50-foot well, dug and driven. It is cased with iron pipe. There is a privy 50 feet away and a dumping ground for household wastes at a like distance. The analysis indicates that the water is of doubtful purity, for surface water is evidently entering the well. This might be stopped by repairing the casing.

No. 7 (17276) is a 30-foot dug well walled with brick. The analysis shows contamination and this water should not be used for drinking unless previously boiled. Intestinal bacteria are shown to be present.

The above seven samples were collected on April 2, 1908 from farms near Urbana. Most of these wells were in good condition, although two were contaminated, one seriously. No. 17269 is interesting in that it differs from most deep wells of this section in mineral content. The water is highly mineralized and contains large amounts of chlorides and nitrates, which are not usually found in such quantities in this vicinity. This series shows that the deep wells unless highly mineralized, and the driven or bored wells are much to be preferred to the dug wells.

SAMPLES FROM TOLONO, COLLECTED JANUARY 4, 1909.

	Appearance						Nitrogen as						Gas Formers					
							Ammonia											
Laboratory No.	Turbidity	Color	Odor	Total Solids	Chlorine	Oxygen Consumed	Free	Albuminoid	Nitrites	Nitrates	Alkalinity	Bacteria per c.c.	10 cc.	1.0 cc.	0.1 cc.	Indol	Depths	Remarks
18692	250	40	0	658	4	6.8	2.480	.224	.001	.240	566	120	1—	2—	2—	—	140 ft. bored	Good
18693	200	50	0	717	5	8.1	4.000	.264	.000	.240	665	....	....	....	....	....	150 ft. bored	Good
18694	0	10	0	411	33	1.6	.024	.084	.012	9.588	236	1100	1—	2—	2—	+	25 ft. due	Poor
18695	100	55	0	698	7	7.5	1.160	.304	.001	.160	636	520	1—	2—	2—	—	90 ft. bored	Good
18696	0	5	0	260	10	.9	.024	.064	.001	15.000	153	360	1—	2—	2—	—	25 ft. dug	Good
18697	300	50	0	880	5	12.6	8.800	.448	.001	.240	756	5	1—	2—	2—	—	127 ft. bored	Good
18698	0	5	0	777	108	1.0	.040	.080	.000	12.800	248	320	1 ?	1+1?	1—1?	—	25 ft. dug	Good
18699	300	70	0	1049	6	15.6	32.000	.688	.001	.160	1014	800	1—	2—	2—	—	120 ft. bored	Good
18700	0	35	0	362	17	3.3	.264	.128	.000	.160	300	14	1—	2—	2—	—	137 ft. bored	Good
18701	30	60	0	667	8	8.7	6.400	.360	.001	.280	585	140	1—	2—	2—	—	140 ft. bored	Good
SAMPLES FROM URBANA, CHAMPAIGN COUNTY, COLLECTED APRIL 2, 1908.																		
17269	0	0	0	1419	335	3.2	.064	.120	.002	50.00	240	8	1—	2—	2—	—	165 ft. driven	Good
17270	20	6	0	364	3	4.2	.590	.080	.000	.360	332	700	1—	2—	2—	+	29 ft. dug	Good
17271	50	10	0	379	3	3.1	.528	.072	.000	.160	348	50	1—	2—	2—	—	160 ft. drilled	Good
17273	5	0	0	429	16	1.3	.320	.040	.007	.910	280	50	1—	2—	2—	—	46 ft. driven	Good
17274	10	0	0	346	5	.4	.040	.048	.000	.200	246	30	1—	2—	2—	—	25 ft. bored	Good
17275	0	0	0	597	58	1.3	.048	.096	.005	20.00	212	560	1 +	2—	2—	+	50 ft. dug and driven	Poor
17276	5	0	0	775	110	2.6	.064	.082	.036	27.96	156	650	1 +	2 +	1 + 1 —	+	30 ft. dug	Poor

A WATER WORKS LABORATORY.

It is a contention of the State Water Survey that every water supply should be under some kind of chemical and bacteriological control, and that a careful supervision be kept of the sanitary quality of the water furnished. Water taken from deep wells need be examined only occasionally and the special laboratory is not essential. Water taken from surface sources such as rivers, lakes or reservoirs is subject to variation and should therefore be carefully watched. We are glad to report that there is a growing demand among the operators of the water purification works in Illinois for careful control of the treatment of water and for a closer supervision of the sanitary quality of the water. At the suggestion of the State Water Survey, there have already been established at several water works in the state small laboratories, equipped for making the simple tests. The physical and chemical tests made include turbidity, color, alkalinity, free chlorine. The bacteriological tests made include the number of bacteria and the fermentation test.

By means of these few tests and a proper interpretation of the results obtained, a water purification plant may be operated to much better advantage.

The following list of apparatus and chemicals is submitted in the hope that it may prove of service to water works officials who are considering the establishment of a small laboratory. The list in capitals contains the minimum amount of apparatus necessary for making the tests given above. It may be extended as occasion demands, for example, if the operator wishes to make his own media or if he desires to make up his own reagents and to make other quantitative tests. The additional apparatus is shown in ordinary type, or if more of a certain kind is desirable it is indicated by figures in parenthesis.

The Catalog Number refers to the Catalog of Sargent & Co. but the apparatus may be obtained from other dealers.

APPARATUS.

NO.		CATALOG NUMBER
1	Balance	320
1	Harvard trip scale	420
1	HAND SCALE, BEST QUALITY HORN PAN, LENGTH OF BEAM 6"	454
1	Balance cover	462
1	Set of weights, 50 grams down to 1 milligram	478
1	SET WEIGHTS, 50 GRAMS DOWN TO 1 MILLIGRAM	480
2	Battery jars, 8"x6"	572
2	NESTS BEAKERS, NO. 0 TO 4 GRIFFIN'S FORM LIP	582
12	2 LITER GLASS STOPPERED BOTTLES	682
12	1 liter glass stoppered bottles	682

12 ½ liter glass stoppered bottles	682
24 (36) BOTTLES, 4 OZ. SALT MOUTH MUSHROOM STOPPER, FLINT GLASS	692
2 DROPPING BOTTLES, 2 OZ.	732
1 Wash bottle, complete, 1 liter capacity	790
3. (4) BURETTES GEISSLER'S WITH STRAIGHT STOPCOCK, CAP. 50 c.c. GRADUATED TO 1/10 c.c.	892
1 Automatic burette	916
1 Bunsen burner*	972
2 BUNSEN BURNERS*	1006
1 Bunsen burner*	1024
1 Fletcher burner No. 2*	1056
2 CASSEROLES, 65 M.M. DIAMETER	1164
2 Casseroles, 80 m.m. diameter	1164
1 Clamp	1260
12 NESSLER TUBES WITHOUT LIP, U. OF I. STYLE	1348
2 (4) CYLINDERS GRADUATED WITH LIP, DOUBLE GRADUATION, CAPACITY 1000 c.c.	1560
2 Graduated cylinders, 50 c.c.	1562
2 EVAPORATING DISHES, CAP. 210 c.c., OUTSIDE DIAMETER 11 CM.	1650
100 (150) SMITH TUBES, U. OF ILL. SIZE AND SHAPE	1774
100 Filter papers, 24 cm.	1826
100 FILTER PAPERS, 11 CM. NO. 597	1828
100 FILTER PAPERS, 15 CM. NO. 597	1828
1 Flask, 1000 c.c. capacity	1886
10 ERLENMEYER FLASKS, CAPACITY 175 c.c.	1890
2 Funnels, 20 cm. diameter	1995
2 GRADUATED FLASKS, 1000 c.c.	1954
2 GRADUATED FLASKS, 500 c.c.	1954
2 GRADUATED FLASKS, 100 c.c.	1954
2 FUNNELS, DIAMETER 2 ½"	1992
2 FUNNELS, DIAMETER 4"	1992
2 Funnels, 20 cm. diameter	1995
1 lb. Glass tubing assorted 5-10 mm. outside diameter	2338
2 ALCHOHOL LAMPS, 8 OZ. CAPACITY§	2688
1 MICROSCOPE, FOR COUNTING	2734
1 MORTAR AND PESTLE, DEEP FORM ALL PORCELAIN, No. 2 DIAMETER 12 cm.	2916
6 PENCILS FOR WRITING ON GLASS	3108
2 PIPETTES 100 c.c.	3138
2 PIPETTES, 50 c.c.	3138
2 PIPETTES, 25 c.c.	3138
2 Pipettes, 5 c.c.	3138

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*If gas is available.

§If gas is not available.

24 PIPETTES, 10 cc. GRADUATED MOST ACCURATELY	3144
24 PIPETTES, 1 c.c. MOHR'S GRADUATED TO 1/10 c.c.	3146
6 in. Platinum wire, No. 27 guage	3252
3 ft. Rubber tubing, 3/16" diameter	3454
6 ft. Rubber tubing, 1/4" diameter	3454
12 ft. RUBBER TUBING, 5/16" diameter	3462
2 Rings, 5" diameter	3424
1 Support, medium	3696
1 BURETTE STAND	3724
2 (4) THERMOMETERS, 360°C	3820
2 THERMOMETERS, MAXIMUM AND MINIMUM, SIX'S	3882
1 Pair of crucible tongs	3902
2 TRIPODS, IRON WITH ROUND TOP	3984
2 Tubes, 25 cm. in length	4046
1 Waterbath, Victor Meyer	4140
2 WIRE GAUZE, ASBESTOS CENTER, 6"	4174
1 COUNTING APPARATUS	6046
1 Extra counting plate	6048
36 (60) Petri DISHES, 100 mm. DIAMETER	6052
3 PETRI DISH BOXES	6058
1 ARNOLD STERLIZER NO. 625	6400
2 WIRE BASKETS	6414
1 Test tube filling device	6418
200 (300) SPECIMEN TUBES, 5 ½" x ½" INT. DIAMETER ROUND BOTTOM.	

APPARATUS TO BE MADE OR OBTAINED BY SPECIAL PURCHASE.

2 THERMOSTATS AND REGULATOR HEATING COILS.**
Obtain from Wm. J. Smith, Electrician, University of Illinois.
1 ICE BOX AND 20° INCUBATOR OR SPECIAL INCUBATOR AND ICE BOX.**
1 INCUBATOR, 37 ½° C. OR
Small refrigerator to be heated by electricity**.
1 OVEN FOR STERLIZING
Oven used on gas or gasoline stoves.
20 FERMENTATION TUBE RACKS
to be made. See University of Illinois. Bul. State Water Survey Series No. 6, p. 31.
1 DOUBLE OATMEAL BOILER
4 PIPETTE STERILIZING BOXES, TO BE MADE
100 GUMMED LABELS
5 lbs. COTTON
1 qt. DENATURED ALCOHOL§
6 TOWELS

**If electricity is available.

§If gas is not available.

1	TURBIDIMETER
1	GASOLINE OR OIL STOVE§
1	Jewel gas stove, 2 burners*

NO.	CHEMICALS.
2	OZ. SOLUTION PHENOLPHTHALEIN
2	OZ. SOLUTION METHYL ORANGE
1000	c.c. N/50 SULPHURIC ACID
½	lb. MERCKS SOLUBLE STARCH
1000	c.c. N/10 ARSENIOUS ACID SOLUTION
500	c.c. N/10 IODINE SOLUTION
50	G. POTASSIUM IODIDE, c. p.
1	lb. ACETIC ACID, c. p. 30%
4	oz. Merck's purified litmus extract
2	gms. Erythrosine
1	lb. Chloroform, Merk's
2	oz. Sodium thiosulphate, chemically pure, dry
1	lb. Sodium hydroxide, purified from alcohol
1	lb. Potassium hydroxide purified in sticks
2	.lbs. Potassium bichromate
1	lb. Hydrochloric acid
1000	c.c. Sulphuric acid, normal
1	lb. Sodium carbonate, chemically pure anhydrous
4	lbs. Gelatine, gold label
2	lbs. Agar-agar
1	lb. Peptone
1	lb. Schuchardt's grape sugar
1	lb. Lactose
1	pt. Alcohol, ethyl 95%
2	oz. Extract of beef
1	gm. Potassium platinic chloride
1	oz. Cobalt chloride.

The above lists might be further increased by the addition of apparatus and chemicals for the determination of residue on evaporation, nitrates, nitrites, amonia and for microscopical examination. We do not publish a list at this time as these tests will be attempted only by experts, who will have their own ideas concerning the materials needed.

The apparatus and chemicals in capitals can be obtained for approximately $200.00 the additional materials (including balance $50.00) will cost about $125.00. Laboratory tables and furniture may be made to suit the requirements of the operators. They are often included in the contract for the plant.

The survey will be glad to receive criticisms of this list and will incorporate corrections in a revised list to be published later.

SUGGESTED DISPOSAL OF DRAINAGE AT TOLONO.*

Letters were recently received by the State Water Survey concerning the use of a deep well for drainage at Tolono. As many water supplies in the State are obtained from wells similar in character to the water-works at Tolono, the letters are given in full, together with the replies to them.

TOLONO, ILLINOIS, November 16, 1908.

Dear Doctor:

What effect, if any, upon the purity of our Tolono public water supply would be caused by sinking a well to the sands of the drift—about 130 to 140 feet below the surface—and turning into it surface water, especially drainage from a cellar?

As you know, conditions here are very similar, to those at Champaign geologically, and our water comes from the depth indicated above.

Would a charcoal filter or any other form of filter on such a drainage well save us from a contaminated water supply?

Should such a well with filter attachment be permitted?

Any information you may give us on this subject will be thankfully received.

Thanking you, I am

Very truly yours,
(Signed) JOHN MARTEN,

Health Officer.

URBANA, ILLINOIS, November 16, 1908.

Dr. John Marten, Health Officer, Tolono, Illinois:

Dear, Doctor—Your letter of November 16th is received. It is my opinion that you cannot turn surface drainage into a water bearing stratum, such as you have at Tolono, without danger of injuring the water supply. I should say that such a method of disposing of drainage should not be permitted.

There will be no opportunity for bacteria to become oxidized, and they would sooner or later reach the wells from which the water is drawn. You can better afford to ditch to drain the cellar or to dispose of waste than to run any risk of injuring the water supply.

Very truly yours,
(Signed) EDWARD BARTOW,
Director State Water Survey.

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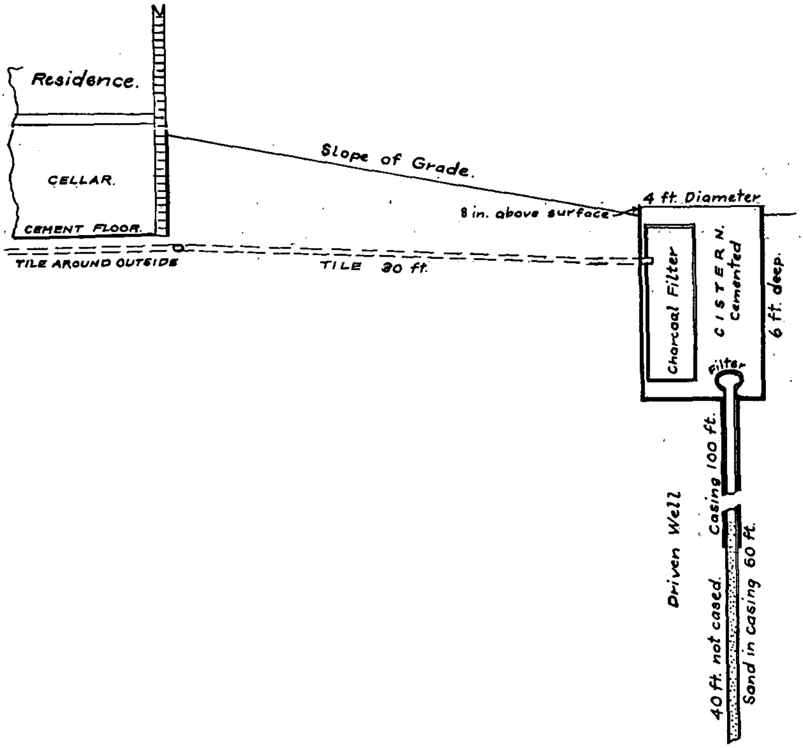
*Proc. Ill. Water Supply Assn. 1909, 160.

TOLONO, ILLINOIS, December 15, 1908.

Mr. Edward Bartow, Director State Water Survey, Urbana, Illinois:

Dear Sir—I am enclosing a sketch of drainage plan I am constructing. (See below.) First, I put down a well about thirty feet from residence, at foot of grade; same is 140 feet deep, 100 feet of which is cased with two-inch iron casing; no screen was put in, and sand has risen about 60 feet in same. My residence is nearly new; when building I put a tile around outside of wall six inches below wall; have all cellar bottom cemented. My grade slopes some two feet in 30 feet away from wall all around house. I made a cistern around my well six feet deep and four feet in diameter, bricked up and cemented tight to keep out all surface water except that which enters tile drain after soaking through several feet of earth. There is no sewage connected with this. The drain is simply to carry off any water which may have a tendency to enter cellar during wet season. At mouth of tile I placed a removable box filled with charcoal, and



all water must filter through this before entering the well. I also placed a filter covering mouth of well.

Will you kindly study cut enclosed and advise if this drainage as arranged and for purposes I drain would contaminate the water supply of our village which have wells several blocks from my residence, said wells being between 140 and 150 feet deep.

Thanking you for an early and favorable reply, I am

Respectfully yours,
(Signed) A. H. EDWARDS.

URBANA, ILLINOIS, December 16, 1908.

Mr. A. H. Edwards, Tolono, Illinois:

Dear Sir—Your letter of December 15, enclosing sketch of drainage plan is received. . . . The latter part of your letter would indicate that you do not use this well for your own drinking purposes, but simply as an outlet for the drainage. If this is the fact it would seem to me better to dispose of the drainage in some other way than using the well. *You* may be very careful to prevent sewage from entering this well at this time, but others later may not be so careful, and if you allow drainage to enter the water-bearing strata through a well there is no reason why others nearer the village water works should be deprived of the same privilege.

If I have not answered your questions fully let me know and I will try again.

Very truly yours,
(Signed) EDWARD BARTOW,
Director State Water Survey.

The matter was considered at the January and February meetings of the Tolono City Council. The council at the first meeting was divided as to the proper procedure. Letters were read from Dr. J. A. Egan, Secretary of the Illinois State Board of Health, and from Dr. J. N. Hurty, Secretary of the Indiana State Board of Health. Both in considering the scheme gave an opinion that it would not injure the water supply. The Director of the State Water Survey was present and expressed the opinions given in the letters, namely, that such a method of disposal should not be permitted. It seemed possible that the well in question properly cared for could not injure the Tolono water supply, and final action was postponed. At the February meeting Dr. Westervelt, of the State Board of Health, and the Director of the State Water Survey condemned the proposition on the ground that it was dangerous to run any risk of allowing pollution to enter the water-bearing stratum. While the builder of the cistern might use every precaution to prevent access of pollution, the property might pass into other hands and sanitary sewage might enter.

There was also the probability that others would desire to use the same means of disposing of drainage or sanitary sewage. In the course of the discussion the fact was brought out that there were already two wells of this kind in operation. It was, therefore, the principle and not the individual case that was condemned.

Because of these opinions of the representatives of the State Board of Health and the State Water Survey, and after Mr. Edwards had himself admitted that the council would have good grounds for condemning the scheme, the Tolono City Council declared such wells to be a nusiance. An ordinance was then passed forbidding the use of such wells and placing a fine at not less than $50 and not more than $150 for each offense.

Thus far no parallel case has been found yet there is data concerning underground flow. Dr. Frank E. Adams* mentions the under ground currents connecting wells, and states that pollution from a cesspool has been found to travel over 100 feet through the soil. Where the water is pumped from a deep well like the one at Tolono, water would undoubtedly be drawn to it from a great distance.

Mr. Quince Walling† reports that after salt water was allowed to escape into the water-bearing stratum from which the Muncie, Ind., supply was obtained, the chlorine increased from 40 parts per million, normal to as high as 150 parts per million, and that it became necessary to seek another source of water supply.

Even though such a well as described above were used for some years as a drain and the neighboring water supply was unaffected, it would not be definitely proven that the latter would not be contaminated at a later date.

The reading of this paper led to the following discussion by members of the Illinois Water Supply Association.

Mr. Cobb: I would like to ask how they dispose of sewage at Tolono.

Dr. Bartow: They have no sewerage system. They have simply cesspools. Tolono is in a flat country, so drainage is difficult.

Mr. Cobb: I wonder if the water from the ordinary cesspool would not work down to the water strata.

Dr. Bartow: No. There is an impervious stratum above the water-bearing stratum. I have thought that if sanitary sewage were allowed to flow into a well of this kind it would very soon become stopped up, yet I feel that such a thing should not be allowed.

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*Ohio Sanitary Bulletin, 12, 147.

†Conference of Municipal and Private Owned Water Plants of Indiana with the State Board of Health, page 38.

Chairman: It seems to me that the most prominent thing is, first, its impracticability, and the next is that while probably this particular installation would not have caused any trouble, it certainly was a good thing to stop it, for the sake of precedent.

Mr. Cobb: What is the theoretical fact about the water-bearing strata of this country? Where does the water come from?

Dr. Bartow: The water supply here and at Tolono have the same source. Tolono is about nine miles from here. Evidently it must come from some distance, possibly from the edges of the drift area.

Prof. Talbot: Evidently in this case the purpose of the construction was to devise means for obtaining a fall or difference in level, for in the flat country the difference of level is too small to give a satisfactory outlet with a very long drain. It seems to me that it is a little more serious than the discussion would indicate. I recall that before Champaign had a sewerage system a man in charge of matters came to me with a proposition to construct a deep well about one-half mile west of here and this side of the Illinois Central tracks, to receive the sanitary sewage of the city. In the first place, such a well would not have been able to take care of the sewage. His idea was that if we can get so much water but of the ground we should be able to put in as much as we take out. With the depth available in the case there would not have been much trouble in operation if it were not for the fact that the solid matter would soon have clogged it up. But there would still be a chance for seepage that would be harmful, not only because the sanitary sewage would get in, but because of the surface drainage which would get through. In the case of our drift wells here we have, it is believed by some, a great advantage in the presence of the layer of clay which acts as a filter if the water comes from the surface in the neighborhood and passes through the clay into the sand. After we go through 30 to 40 feet we come to a layer of fine sand. The upper portion of the sand is not water bearing. At Tolono they would be piercing the clay stratum and would be taking the sewage down into a stratum which would not allow purification. It is different from the condition cited by Mr. Cobb of a layer not saturated with water. It seems to me that the action taken by the council in preventing the use of such a method was a very wise one, and it would be detrimental to the water works interests of the State to permit such methods to be employed.

Mr. Birdsall: Not long ago I noticed that in a report of the United States Geological Survey they described wells which had been driven in Michigan for the purpose of draining shallow ponds and lakes which they could not get rid of in any other way.

Mr. Wheeler: I want to ask whether a citizen who is restrained from disposing of his water in some such a way as that could not compel the public to provide some other way. It would seem to be a fair question.

Mr. Parkin: I don't think that that would work except in Wisconsin. In Illinois the courts would tell him as they have told him out West. (Mr. Parkin then told a story in which a man settled on a stream out West, in which there was a limited supply of water. Another man came and settled on the same stream but above him, thus depriving him of some of the water. He brought the matter before a justice and was told that the only thing he could do was to move above the other man—that he "was unfortunately located.") The same might apply to this man in question. (Laughter.)

Since this paper was published an article entitled "Drainage by Wells" by M. L. Fuller, has appeared in Water Supply Paper No. 258 of the United States Geological Survey. Mr. Fuller discusses the condition of drainage by wells, the effectiveness of wells sunk in different materials, the location, construction and capacity of drainage wells, the causes of their failure and the pollution of ground water by such wells. He makes the following recommendations:

1. The emptying of sewage into drainage wells is very dangerous and should be avoided.

2. The drainage of industrial wastes into borings is objectionable if not dangerous, and the practice is to be condemned.

3. The drainage of cellars into wells is objectionable in towns where near-by wells must draw on the ground water into which the cellar waters are carried. In the country the practice is not objectionable if the water is carried through a tight casing to a bed lower than that which supplies the local water wells or to a higher bed if the water wells are tightly cased through this bed and through a thickness of imprevious material sufficient to prevent any possibility of contamination.

4. The drainage of most ponds and swamps into wells is unobjectionable, for they are far from houses and from wells that supply drinking water. The movement of ground water is normally away from rather than toward the houses, the addition from the pond serving, at the worst, to back up rather than to reverse the movement. Moreover, water does not spread far underground. On the whole the drilling of wells for draining swamps and ponds should be encouraged, but the usefulness of the wells is limited to ponds covering a few acres and to basins not exceeding in extent 75 acres.

Mr. Fuller's recommendations concerning drainage in towns agree in every respect with recommendations made by the Water Survey.

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