THESIS

A SANITARY SURVEY OF THE GRAND RIVER

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1915

The Grand River
Water – Pollution
Water – Analysis

This thesis was contributed by

Mr. A. H. Jewell

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A Sanitary Survey

of

The Grand River

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By

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THESIS

INTRODUCTION.

As the result of a large number of human beings being concentrated upon a small area, the fundamental needs of individual life must be met by new means. Special measures must be adopted for getting food from a wide radius into the center where so much of it is to be consumed. The spread of epidemics which always threaten crowded communities must be guarded against; and the waste products which accompany all living processes must be removed.

The magnitude and importance of these questions have been such that the State and Federal supervision are necessary, resulting in Food and Dairy Commissions, and Boards of Health.

This last task, the removal of the city's wastes, is one of the most difficult which confronts a modern municipality. From every large city there pours out a river of waste material which polutes streams, harbors, and sea shores, spoiling what should be the chief pleasure spots of the city and damaging property values, if it does not actually threaten human life and health.

The simplest solution of the problem, where it is permissible, and the one most frequently employed in this country, is to discharge the sewage directly into some flowing stream, or large body of fresh water, the ocean, or one of its estuaries. This is called "disposal by dilution". So far as cheapness is concerned this stands easily first among the methods of disposal, since it requires the purchase of no land and needs no care to regulate its working.

It is usually efficient also in removing the sewage beyond the limits of the area contributing to its volume. Looked at in a less selfish way, and considering the good of the State and country as well as of the locality sewered, other and adverse arguments present themselves in some cases. Although the sewage is removed to a distance from the contributing territory, it may be deposited in proximity to other communities, on banks or shores, or retained by dams, thus creating a nuisance; or may render unfit for drinking, household, or manufacturing purposes, water which would otherwise be so used.

There are undoubtedly conditions under which disposal by dilution is much less objectionable than any other available method. And in considering this it must be borne in mind that the liquid must ultimately be discharged into some stream or body of water; the question being, therefore, to what extent, if at all, must it be purified or modified. Under what conditions and to what extent a water receiving sewage will purify itself is a question which has received less attention than have methods of treating sewage, although it is much the most common method of disposal.

In discussing the problem of pollution of waterways many widely diverse opinions are expressed. There are those on one hand who speak of absolute prevention of pollution as though it were feasible to effect, while the opposite view is held by some, that the streams should receive the unrestricted discharge of sewage from urban communities. Between these two extremes lies the logical position held by students of the problem whose professional training and experience compels attention. This latter position is held by sanitarians and sanitary engineers in general, and consists in control of pollution, using the streams wherever possible without detriment to the public health. The pollution of rivers, streams and lakes within a State may be controlled by State laws. The problem of the control of great inter-state and international lakes and rivers is not so simple.

The State of Michigan has a law known as the Water and Sewage law, for the purpose of establishing and maintaining a certain degree of supervisory control over public water supplies and over the discharge of sewage into the waters of the State, this control being exercised through the medium of the State Board of Health. In brief, the law outlines the duties of both the Board and the municipality, making certain restrictions on the Board's power, and provisions for the review and enforcement of the orders of the Board by any court of chancery or other court having jurisdiction. The main restriction being that no power is granted "to prevent any municipality now disposing of its sewage into any river, from continuing so to do". On first sight this seems to be repugnant to the general spirit of the law, but if construed literally and strictly, does not appear to be inconsistent with the idea of rendering the sewage innocuous previous to its final disposition in a river.

All doubt or fear of such a situation was cast aside when the Michigan Supreme Court handed down the decision in the Grand Rapids stream pollution case, May 28th, 1913.

"This was a proceeding in equity to declare and to abate and restrain a public nuisance clamed to result from the discharge of sewage and night soil from the city of Grand Rapids into Grand River. The decision declares that the acts complained of do create a public nuisance below the city, and that the continuation or creation of that nuisance may properly be restrained by injunction, and that the Attorney General is a proper complainant."

"This decision is based upon the doctrine of riparian ownership, and not primarily upon considerations of public health such as form the broad foundation of the Water and Sewage law. The right of the city, as a riparian proprietor, to make reasonable use of the waters of the river is clearly affirmed; but the right of the city to use the water of the river for the purpose of carrying away the sewage in an unreasonable manner, or in such a way as to destroy the usefulness of the river to lower riparian proprietors or to impair their rights or to unreasonably increase their burdens, is as clearly defined." Thus the question of what is reasonable or unreasonable use of a stream is a question of fact, to be determined as other facts are determined.

In order that these facts may be determined, it is necessary to make a thorough investigation and study of the stream in question. Such investigations and studies have been termed "Sanitary Surveys."

With the increasing population (and corresponding increase in amount of waste materials) of Lansing, questions arise as to the effect or result of disposal of her wastes by dilution in the Grand River. It was with this idea that "A Sanitary Survey of the Grand River" was started.

Such surveys are usually carried on by the State Board of Health or special commissions, in co-operation with municipal boards of health, and should cover at least a year's examination. Thus it evident that owing to the lack of time, apparatus, and assistants, this survey is only preliminary and shows what may be done in the future.

The writer wishes to express his sincere thanks for the many helpful suggestions and co-operation given by Professor E.D.Rich and Mr. H.G.McGee of the Michigan State Board of Health, Professor A.J.Clark of the Chemistry department of the Michigan Agricultural College, and Miss Zae Northrop of the Bacteriological department of the Michigan Agricultural College.

TREATMENT.

The object therefore, of this survey is to determine as far as possible (1) whether or not there is a local nuisance, (2) the effect of this pollution on the stream, and to what extent the stream is able to purify itself.

In order that these determinations might be made in the short time allotted, only a few of the many methods were used. It is evident that all results would depend on the discharge of the stream, therefore the first problem was to gage the river. With the discharge determined, the next problem is to make the necessary examinations. These could be Physical, Chemical, Microscopical, and Bacteriological if the necessary apparatus, time and assistance were available, but as these were limited, only the following were considered. Under "Chemical" it was decided that Dissolved Oxygen would probably be the best adapted to the problem under consideration. Under "Bacteriological" it was decided that Total Counts on Litmus Lactos Agar and Presumptive Tests for B. Coli would show the condition of the stream and the self purification effect the best.

With the above problems solved the next step would be in the form of a conclusion, embracing those results and all available data, together with the necessary assumptions.

All work of taking samples was done with a canoe, covering as much territory as possible during the day and camping out along the bank at night. Much bad weather was encountered which made the work very disagreeable at times and made accuracy more difficult.

DISCHARGE.

One of the United States Geological Survey gaging stations is located at the Seymour Street Bridge at North Lansing. Daily readings are taken with a chain gage suspended from the west end of the bridge, and are recorded upon the daily reports of Weather Bureau of the U.S. Department of Agriculture. With the aid of a ratimg table of this station it would be an easy matter to determine the discharge on any particular day. The last rating table on record was made in 1905. If any change in the bed of the stream had taken place it is evident that the cross sectional area would change and hence of the discharge for any particular gage height. Therefore it was decided to survey and plot the cross section with reference to the chain gage. This was done by means of a level and level rod. The elevation of zero on the gage being known, the elevation of the line of sight could be found from sighting on the gage. The rod was extended and a weight tied at the base, and a long pole fastened near the top. This was let down at five foot intervals along the west edge of the bridge, and the rod reading taken. The cross section was then plotted together with the gage. Then with the use of a planimeter the area at any gage height could be determined very readily.

A small Price Current Meter was used in determining the velocity of the stream. It was decided to take readings at the middle of ten foot sections and six tenths of the depth of the water below the surface. These depths were easily obtained from the cross sectional drawing.

As time was very limited the purpose of these gagings was simply to check up the present discharge with that given by the table for 1905. On the following pages will be found this table and the results of the writer's gaging. The points check close enough for the end in view, and since the readings on which the table was based, were made with a large Price Meter, they are probably more reliable, and hence the rating table could be used in the survey.

Gaging made April 8, 1915, by A. H. Jewell on Grand River at N. Lansing, Gage Height in feet, 3.0; Meter No. HWC2; Total Area, 550 Sq. Ft., Mean Velocity, 1.27; Discharge, 697.

Distance from Initial Point	Depth	Observations for Gage Reading 3.0			Velocity Computations		Area of Section with Planimeter	Discharge of Section
		Depth of Observation	Time in Seconds	Revolutions	R. P. S.	Velocity per Sec.		
5	0	0	0	0	0	0	0	0
15	0.9	0.5	98.6	20	.20	.52	7.6	4.0
25	1.9	1.0	58.0	30	.52	1.26	18.7	23.6
35	2.8	1.6	57.8	27	.47	1.14	26.5	30.2
45	2.9	1.7	60.4	30	.50	1.22	28.4	34.7
55	3.1	1.8	59.0	33	.56	1.36	31.0	42.2
65	3.2	2.2	61.0	40	.66	1.58	36.9	58.4
75	4.2	2.4	64.0	40	.63	1.52	41.5	63.0
85	4.0	2.3	58.0	40	.69	1.67	38.9	65.0
91	3.3	1.9	64.4	40	.62	1.50	7.4	11.1
106	3.8	2.2	120.0	16	.13	.35	30.1	10.5
115	3.8	2.2	59.8	30	.50	1.22	40.1	49.0
125	4.3	2.5	60.6	40	.66	1.59	41.5	66.0
135	3.9	2.3	64.0	36	.56	1.36	40.1	54.5
145	4.3	2.5	64.0	34	.53	1.30	41.5	54.0
155	4.0	2.3	65.0	32	.49	1.20	38.9	46.8
165	3.3	1.9	68.0	35	.51	1.25	33.7	42.2
175	2.7	1.5	67.6	30	.44	1.09	27.7	30.2
185	2.2	1.3	97.6	22	.23	.58	20.6	12.0
191	0.4	0.2	--	--	--	--	--	--
							Computed	697.4
							U. S. G. S. Rating Table	716.0

Gaging amde April 22, 1915, by A. H. Jewell on Grand River at N. Lansing, Mich., Gage Height in Feet: Beginning 2.8; End 3.0; Mean 2.9; Meter No., HWC2; Total Area, 535 Sq. Ft.; Mean Velocity, 1.30; Discharge, 687.

Distance from Initial Point.	Depth.	Observations for Gage Reading 2.9			Velocity Computations		Area of Section with Planimeter.	Discharge of Section.
		Depth of Observation.	Time in Seconds.	Revolutions.	R. P. S.	Velocity per Sec.		
5	0	0	--	--	--	--	--	--
15	0.8	0.5	107	25	.23	.60	6.5	3.9
25	1.8	1.0	50	29	.59	1.44	17.6	25.4
35	2.7	1.6	100	36	.36	.89	25.4	22.6
45	2.8	1.7	52	25	.48	1.17	27.3	32.0
55	3.0	1.8	55	30	.55	1.34	29.9	40.2
65	3.6	2.2	55	32	.58	1.41	35.8	50.5
75	4.1	2.4	59	36	.61	1.48	40.4	59.8
85	3.9	2.3	57	43	.75	1.90	37.8	68.0
91	3.2	1.9	61	40	.65	1.57	7.2	11.2
106	3.7	2.2	110	15	.14	.38	29.3	11.1
115	3.7	2.2	72	39	.54	1.32	39.0	51.5
125	4.2	2.5	55	32	.58	1.41	40.4	57.0
135	3.8	2.3	59	31	.52	1.27	39.0	49.5
145	4.2	2.5	60.4	33	.55	1.34	40.4	54.2
155	3.9	2.3	56.2	29	.52	1.27	37.8	48.0
165	3.2	1.9	58	32	.55	1.34	32.6	43.7
175	2.6	1.5	60	30	.50	1.22	26.6	32.5
185	2.1	1.3	60.6	20	.33	.83	19.5	16.2
191	0.3	0.2	--	--	--	--	--	--

Computed 687.3

U. S. G. S. Rating Table 672.0

UNITED STATES GEOLOGICAL SURVEY.

Station rating table for Grand River at North Lansing, Mich., from January 1 to December 31, 1905.

Gage Height	Discharge	Gage Height.	Discharge
Feet	Sec-ft.	Feet.	Sec-ft.
1.50	167	5.10	1820
1.60	194	5.20	1880
1.70	222	5.30	1940
1.80	251	5.40	2000
1.90	281	5.50	2065
2.00	313	5.60	2130
2.10	347	5.70	2195
2.20	383	5.80	2265
2.30	421	5.90	2335
2.4	461	6.00	2405
2.50	502	6.10	2485
	544	6.20	2565
2.60	544	6.30	2645
2.70	586	6.40	2730
2.80	629	6.50	2815
2.90	672	6.60	2900
3.00	716	6.70	2990
3.10	761	6.80	3080
3.20	807	6.90	3170
3.30	854	7.00	3260
3.40	902	7.20	3445
3.50	950	7.40	3665
3.60	999	7.60	3830
3.70	1049	7.80	4030
3.80	1099	8.00	4240
3.90	1149	8.20	4455
4.00	1200	8.40	4675
4.10	1255	8.60	4900
4.20	1310	8.80	5130
4.30	1365	9.00	5370
4.40	1420	9.20	5610
4.50	1475	9.40	5870
4.60	1530	9.60	6130
4.70	1585	9.80	6400
4.80	1640	10.00	6680
4.90	1700		
5.00	1760		

CHEMICAL EXAMINATION.

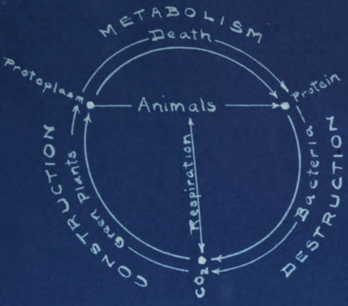
Let us first glance at the diagram of cycles for carbon, nitrogen and sulphur. We are particularly interested in that part known as "Destruction". In every case we find that it is a process of oxidation or burning up, aided by the action of bacteria. That is, changing unstable, putrefying, organic matter to stable compounds. In order to do this the organic matter must have oxygen, which it takes out of the water. As long as there is sufficient dilution the required amount of oxygen can be furnished, but as soon as the available oxygen is exhausted, putrefactive changes will take place. In other words, it is simply a question of a balance between the available oxygen of the stream and the oxygen which the organic matter will require.

Thus if we could measure the amount of available or dissolved oxygen in a sample of water, we could get a relative idea of the condition of the stream. It was decided to use the Winkler Method for Dissolved Oxygen as recommended in "Standard Methods of Water Analysis" published by the American Public Health Association, which is as follows:-

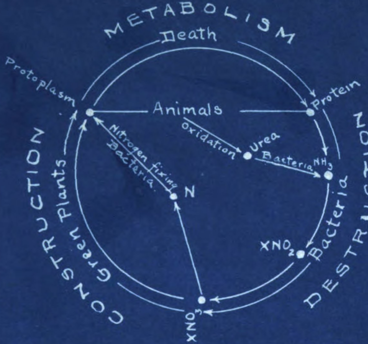
Winkler Method reagents. - 1. Manganous sulphate solution: Dissolve 48 grams of manganous sulphate in 100 c.c. of distilled water.

2. Solution of sodium hydrate and potassium iodide: Dissolve 360 grams of sodium hydrate and 100 grams of potassium iodide in one liter of distilled water.

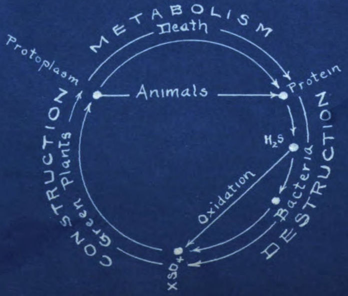
3. Sulphuric acid. Specific gravity 1.4 (dilution 1:1).



CARBON CYCLE



NITROGEN CYCLE



SULPHUR CYCLE

4. Sodium thiosulphate solution. Dissolve 6.2 grams of chemically pure recrystallized sodium thiosulphate in one liter of distilled water. This gives a $\frac{N}{40}$ solution each c.c. of which is equivalent to 0.2 mg. of oxygen or 0.1395 c.c. of oxygen at 0° C. and 760 mm. pressure. Inasmuch as this solution is not permanent it should be standardized occasionally against an $\frac{N}{40}$ solution of potassium bichromate as described in almost any work on volumetric analysis. The keeping qualities of the thiosulphate solution are improved by adding to each liter 5 c.c. of chloroform and 1.5 grams of ammonium carbonate before making up to the prescribed volume.

5. Starch solution. Mix a small amount of clean starch with cold water until it becomes a thin paste, stir this into 150 to 200 times its weight of boiling water. Boil for a few minutes, then sterilize. It may be preserved by adding a few drops of chloroform.

Collection of the sample. - The sample shall be collected with extreme care in order to avoid entrainment or absorption of any oxygen from the atmosphere. The sample bottle shall be preferably a glass-stoppered bottle with a narrow neck and which holds at least 250 c.c. The exact capacity of the bottle shall be determined and for convenient reference this may be scratched upon the glass with a diamond.

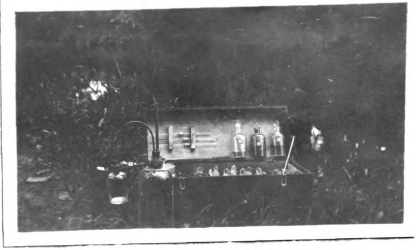
If a sample is to be collected from a tap the water shall be made to enter the bottle through a glass or rubber tube which reaches to the bottom of the bottle, the water being allowed to overflow for several minutes, after which the glass stopper is carefully replaced so that no bubble of air is caught beneath it.

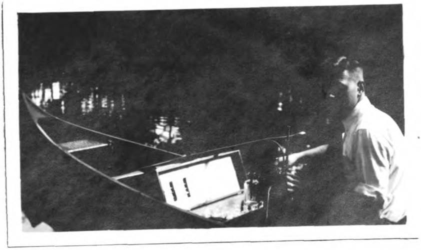
If the sample is to be collected from the surface of a pond or tank two bottles shall be used, the ordinary sample and a second bottle of four times the capacity. Both bottles shall be provided with temporary stoppers of double perforation and in both cases a glass tube shall extend through one hole of the stopper to the bottom of the bottle and a short glass tube shall enter the other hole of the stopper but not project into the bottle. The short tube of the sample bottle shall be connected with the long tube of the larger bottle. In collecting the sample the sample bottle shall be immersed in the water and suction applied to the short tube of the large bottl and enough water drawn through the hole to fill the large bottle. In this way the water in the smaller bottle will be changed several times and a fair sample secured.

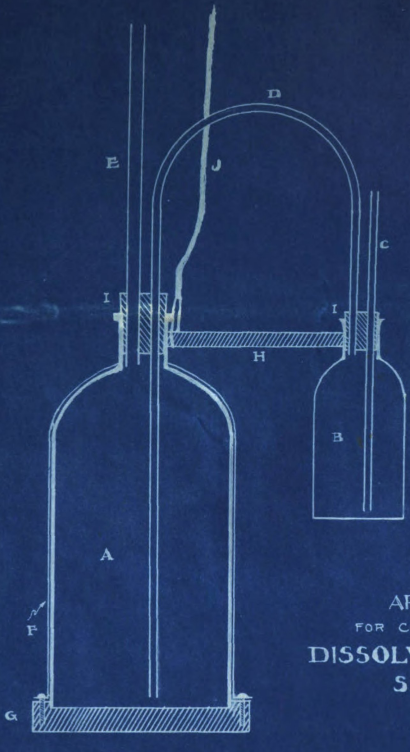
If the sample is to be taken at a depth below the surface both bottles may be connected, lowered to the desired depth, and if the smaller bottle is placed beneath the larger one the water will enter the small bottle and pass from that into the larger bottle, the air escaping from the short tube of the large bottle. As soon as the small bottle has been filled remove the temporary stopper and insert the permanent glass stopper using care not to entrain any bubbles of air.

Procedure. - Remove the stopper from the bottle and add approximately two c.c. of the manganous sulphate solution and two c.c. of the sodium-hydrate potassium iodide solution delivering both of these solutions beneath the surface of the liquid by means of a pipette. Replace the stopper and mix the

DISSOLVED OXYGEN FIELD APPARATUS







APPARATUS
FOR COLLECTION OF
DISSOLVED OXYGEN SAMPLES

MADE BY

Albert H. Jewell.

Scale 3/8" = 1"

A = Large bottle holding two liters.
B = Small "dissolved oxygen" bottle holding 250-300 c.c.
C = Small brass tube
D = Small brass tube
E = Larger brass tube.
F = Sheet metal strap over neck of bottle.
G = Cast iron base, for weighting down.
H = Metal clamp to support B
I = Two holed rubber stoppers.
J = Heavy chord.

contents of the bottle by shaking. Allow the percipitate to settle. Remove the stopper, add 2 c.c. of sulphuric acid and mix thoroughly. Up to this point the procedure shall be carried on in the field but after the sulphuric acid has been added and the stopper replaced there has been no further change and the rest of the operation may be conducted at leisure. For accurate work there are a number of corrections necessary to be made, but in actual practice it is seldom necessary to take them into account as they are ordinarily much less than the errors of sampling. Rinse the contents of the bottle into a flask, titrate with $\frac{N}{40}$ solution of sodium thiosulphate using a few c.c. of the starch solution towards the end of titration. Do not add the starch until the color has become a faint yellow; titrate until the blue color disappears. If nitrites be present, correction must be made.

Calculation of results. - The standard method of expressing results shall be by parts per million of oxygen by weight.

It is sometimes convenient to know the number of c.c. of the gas per liter at 0° C. temperature and 760 mm. pressure and also to know the percentage which the amount of gas present is of the maximum amount capable of being dissolved by distilled water at the same temperature and pressure. All three methods of calculation are therefore here given.

$$\text{Oxygen in parts per million} = \frac{0.0002\ N \times 1,000,000}{V} = \frac{200\ N}{V}$$

$$\text{Oxygen in c.c. per liter} = \frac{0.1395\ N \times 1,000}{V} = \frac{139.5\ N}{V}$$

$$\text{Oxygen in \% of saturation} = \frac{200\ N \times 100}{V \times O} = \frac{20,000\ N}{V \times O}$$

Where N = number of c.c. of $\frac{N}{40}$ thiosulphate solution.

V = capacity of the bottle in c.c. less the volume of the manganous sulphate and potassium iodide solution added (i.e., less 4 c.c.).

O = the amount of oxygen in parts per million in water saturated at the same temperature and pressure. See Table

TABLE SHOWING THE AMOUNT OF DISSOLVED OXYGEN AT MEAN SEA LEVEL AND AT 810 FT. ELEVATION WHEN SATURATED AT DIFFERENT TEMPERATURES.

Temperature Degrees C.	Oxygen at Sea Level ppM. by Weight.	Oxygen at 810 Ft. Elev. ppM. by Weight.
0	14.70	14.26
1	14.28	13.85
2	13.88	13.46
3	13.50	13.09
4	13.14	12.74
5	12.80	12.42
6	12.47	12.10
7	12.16	11.80
8	11.86	11.50
9	11.58	11.23
10	11.31	10.97
11	11.05	10.72
12	10.80	10.48
13	10.57	10.25
14	10.35	10.04
15	10.14	9.84
16	9.94	9.64
17	9.75	9.46
18	9.56	9.27
19	9.37	9.09
20	9.19	8.91
21	9.01	8.74
22	8.84	8.57
23	8.67	8.41
24	8.51	8.25
25	8.35	8.10
26	8.19	7.94
27	8.03	7.79
28	7.88	7.64
29	7.74	7.51

DISSOLVED OXYGEN TEST FROM LANSING TO IONIA, APRIL 30th TO MAY 2nd 1915. DISCHARGE 222 SEC. FT.

Sample taken at	Temp. Degrees C.	V.	N.	O.	O_2 in ppm.	O_2 in cc per liter	O_2 in % Sat.
F	15	285	7.50	9.84	5.27	3.68	53.6
G	15	233	6.45	9.84	5.54	3.86	56.4
H	15	296	13.80	9.84	9.34	6.52	95.0
I	15	230	11.20	9.84	9.73	6.78	99.0
J	15	291	8.50	9.84	5.83	4.07	59.3
K	13	282	10/20	10.27	7.28	5.08	71.0
L	13	275	10.70	10.27	7.79	5.43	76.0
M	13	283	12.00	10.27	8.46	5.90	82.3
N	13	216	11.20	10.27	10.38	7.23	101.0
O	15	263	16.20	9.84	12.32	8.60	125.5
P	15	281	20.90	9.84	14.87	10.38	151.0
Q	15	276	19.00	9.84	13.75	9.60	139.9
R	15	284	19.40	9.84	13.65	9.53	138.8
S	15	234	14.60	9.84	12.48	8.70	127.0
T	13	287	16.30	10.27	11.35	7.92	110.5
U	13	285	16.00	10.27	11.23	7.83	109.5
V	17	280	14.40	9.50	10.28	7.17	108.3
W	19	300	14.40	9.13	9.60	6.70	105.2
X	17	286	15.40	9.50	10.78	7.53	112.5
Y	18	287	12.50	9.30	8.72	6.10	93.8

Where N = number of c.c. of $\frac{N}{40}$ thiosulphate solution.

V = capacity of the bottle in c.c. less the volume of the manganous sulphate and potassium iodide solution added (i.e., less 4 c.c.).

O = amount of oxygen in parts per million in water saturated at the same temperature and pressure. See Table

DISSOLVED OXYGEN TESTS ABOVE LANSING

MAY 14th 1915 — DISCHARGE 250 SEC. FT.

Sample taken at	Temp. Degrees C.	V.	N.	O.	O_2 in ppm.	O_2 in cc. per liter	O_2 in % Sat.
A	19	285	14.90	9.09	10.50	7.34	115.7
B	18.5	233	13.20	9.18	11.32	7.90	123.5
B_1	18	296	15.85	9.27	10.73	7.49	116.0
C	17	230	12.30	9.46	10.70	7.46	113.0
C_1	17	291	14.45	9.46	9.95	6.95	105.0
D	18	282	10.20	9.27	7.23	5.05	78.0
D_1	17	275	12.70	9.46	9.25	6.45	98.0
E	17	283	13.15	9.46	9.30	6.50	98.4

DISSOLVED OXYGEN TESTS FROM LANSING TO PORTLAND

MAY 17th TO 20th 1915 — DISCHARGE 250 SEC. FT.

Sample taken at	Temp. Degrees C.	V.	N.	O.	O_2 in ppm.	O_2 in cc. per liter	O_2 in % Sat.
F	14.5	280	9.45	9.95	6.75	4.72	68.0
G	13.0	263	9.95	10.27	7.57	5.28	73.[illegible]
H	11.5	281	10.95	10.62	7.80	5.45	73.4
I	12.5	276	11.40	10.38	8.27	5.78	79.7
J	12.0	284	8.45	10.50	5.95	4.15	56.7
K	14.5	234	10.00	9.95	8.55	5.97	86.0
L	13.0	287	17.70	10.27	12.30	8.58	119.5
M	12.5	285	11.80	10.38	8.28	5.78	79.8
N	11.5	280	12.00	10.62	8.55	5.97	80.5
O	11.5	232	11.85	10.62	10.20	7.12	96.2
P	12.5	300	12.85	10.38	8.56	5.98	82.4
Q	13	286	13.75	10.27	9.63	6.72	93.7
R	13	287	13.55	10.27	9.45	6.60	91.7

Where N = number of c.c. of $\frac{N}{40}$ thiosulphate solution.

V = capacity of the bottle in c.c. less the volume of the manganous sulphate and potassium iodide solution added (i.e., less 4 c.c.).

O = amount of oxygen in parts per million in water saturated at the same temperature and pressure. See Table

BACTERIOLOGICAL EXAMINATION.

In considering this phase of the work many difficulties presented themselves. The samples should be examined within six hours of the time of taking. It would be impossible to collect very many samples, pack them in ice, and get back to the laboratory within six hours, especially at any distance from Lansing. It was, therefore, decided to take such apparatus and media as could be used in the field.

The tests decided upon included total count and red colonies on litmus lactose agar, and presumptive tests for B. Coli using litmus lactos bile. The preparation of media was according to "Standard Methods of Water Analysis".

Litmus Lactose Agar.

1. Boil 10 or 15 g. thread agar in 500 c.c. water for half an hour amd make up weight up to 500 g. or digest for 15 minutes in the antoclave. Let this cool to about 60° C.

2. Infuse 500 g. lean meat 24 hours with 500 c.c. water (distilled) in refrigerator.

3. Make up any loss by evaporation.

4. Strain infusion through cotton flannel.

5. Weigh filtered infusion.

6. Add two per cent of Witte's peptone.

7. Warm on water bath, stirring till peptone is dissolved and not allow the temperature to rise above 60° C.

8. To 500 g. of the meat infusion add 500 g.c. of the three percent agar, keeping the temperature below 60° C.

9. Titrate, after boiling one minute, to expel carbonic acid.

BACTERIOLOGICAL FIELD APPARATUS

10. Adjust reaction to neutral by adding normal hydrochloric acid or sodium hydrate as required, using Phenolphthalein as an indicator.

11. Heat over boiling water (or steam) bath for 40 minutes.

12. Restore loss by evaporation.

13. Readjust to normal, if necessary, and boil 5 minutes over free flame, constantly stirring.

14. Make up loss by evaporation.

15. Filter through absorbent cotton and cotton flannel, passing the filtrate through the filter until clear.

16. Titrate and record the final reaction.

17. Add one percent of lactose and one percent of azolitmin solution.

18. Tube, using 10 c.c. of medium in each tube.

19. Sterilize 15 minutes in the antoclave at 120°, or for 30 minutes in streaming steam on three successive days.

20. Store in the ice chest in a moist atmosphere to prevent evaporation.

Litmus Lactose Bile.

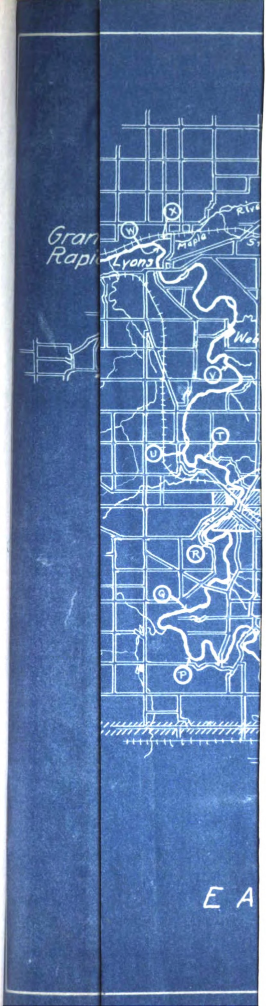
This medium consists of sterilized, undiluted fresh ox gall (or a ten per cent solution of dry fresh ox gall) to which has been added one per cent of peptone and one percent of lactose.

Sample		Total colonies on Agar	Red colonies on Litmus Lactose Agar	Gas in Litmus Lactose Bile	Acid in Litmus Lactose Bile
F	1.0	2000		+	+
	0.1	2500	1000	+	+
G	1.0	3000		+	+
	0.1	2500	100	+	+
H	1.0	1600	5	+	+
	0.1	1750		+	+
I	1.0	300		+	+
	0.1	450	70	+	+
J	1.0	700	2	+	+
	0.1	1000	130	+	+
K	1.0	700		+	+
	0.1	500		+	+
L	1.0	600		+	+
	0.1	500		+	+
M	1.0	150		+	+
	0.1	250		+	+
N	1.0	200		+	+
	0.1	500		+	+
O	1.0	250		+	+
	0.1	400		+	+
P	1.0	400		+	+
	0.1	400		+	+
Q	1.0	60		+	+
	0.1	80		+	+
R	1.0	100		+	+
	0.1	120		+	+

Bacteriological Tests from Lansing to Portland, May 17 - 20, 1915.

Discharge 250 sec. ft.


~ SPRING
to May 20th, 1915
ON AGAR.
Rocks
P
Q
SCALE


Gran
Rapi
Lyons
Maple
X
W
V
T
U
R
Q
P
E A

D = dilution required to prevent nuisance

DISCUSSION.

In solving the first problem, (1), whether or not, there is a local nuisance, use is made of the tentative standard for dissolved oxygen in New York harbor established by the New York Metropolitan Sewerage Commission. There must be at least 3 c.c. of dissolved oxygen gas per liter of water.

Since 1 c.c. of oxygen weighs 1.434 milligrams.

3 c.c. of oxygen weighs 4.302 "

1 p.p. M = 1 milligram per liter

or the N.Y.M.S.C. standard = 4.302 p.p. M.

The water in the New York harbor is considered as containing 60 % of sea water (chlorine in sea water = 18,000 p.p. M.) and 40 % of fresh water. Using 15° C., the temperature found in the worst case of dissolved oxygen at station F on April 30, 1915, and referring to table 12, page 62 of Standards Methods of Water Analysis we can find the amount of oxygen at saturation.

18,000 p.p.M x 60 % = 10,800 p.p.M. of chlorine.

10,800 p.p.M at 15° C. = 9.06 p.p.M.D. O. at saturation.

4.302 ÷ 9.06 = 47.4 % of saturation allowable.

Comparing our worst case which was 53.6 % we find that it is within the allowable limit.

Considering the question from the standpoint of dilution of sewage required to prevent nuisance, use of the formula as found on page 782 of the American C. E. Hand Book is made.

$$D = \frac{x}{s} = \frac{fm}{o} = \frac{M}{o}$$

D = dilution required to prevent nuisance.

x = volume of water.

s = volume of sewage.

o = amount of dissolved oxygen in the water.

m = the result of the "oxygen consumed" test in p.p.M.

f = factor = 4 for 5 minute test.

If the water is considered as having 100 % saturation then $o = 9.84$ at 15° C. Assuming the volume of sewage = 100 gallons per capita daily, then for an average city sewage the amount of oxygen consumed as shown by the 5 minute test is 58 p.p.M. or $M = 232$.

$$D = \frac{x}{s} = \frac{232}{9.84} = 23.5$$

Lansing has a population of about 38,000, pf which about 30,000 are connected with the sewers. East Lansing and the College have a combined population of probably about 5,000 most of which are connected with the sewers. This makes a total of 35,000 people or 3,500,000 gallons per day.

3,500,000 gallons per day = 5.35 cu.ft. per second.

Substituting in $D = \frac{x}{s}$ we have $23.5 = \frac{x}{5.35}$

$x = 126$ sec. ft.

The rating table gives 167 sec. ft. for a gage height of 1.5 feet, which is about the lowest that the water ever gets as shown by the records of the U.S. Department of Agriculture.

If we were to figure a worse condition, say a temperature of 26° C. and the water only 70 % saturation, then $o = 7.94$

and $$D = \frac{x}{s} = \frac{232}{7.94} = 29.2$$

$$29.2 = \frac{x}{5.35}, \text{ or } x = 156 \text{ sec. ft.}$$

Even in this case there would be enough dilution, although it would be approaching the limit.

In the case of the Chicago Drainage Canal, Rudolph Hering provided for at least 3.33 cu. ft. per second of water for the dilution of the sewage of each 1,000 persons. X. H. Goodnough places the limits for Massachusetts conditions between 3.5 and 6 cu. ft. per second. Rafter used 4 cu. ft. per second for certain New York conditions.

Using the different factors in this case we would have

6 x 35 = 210 sec. ft.

5 x 35 = 175 " "

4 x 35 = 140 " "

3.33 x 35 = 117 sec. ft.

Using the average of these, we find there is plenty of flow as long as the gage remains at or above 1.5. If it drops below this there is likely to be trouble.

If any trouble at all is caused, it will probably be during the month of July, August, and September, when the temperature is the highest and the discharge is the least. Therefore results obtained in April and May of a normal year would not give the worst conditions. This spring has been an unusually dry one as is shown by the accompanying Monthly Meteorological Summaries. There are on record only two years when the rainfall for March and April has been below that for this year. That was in 1875 and in 1895, and now in 1915 we have another dry spring. There seems to be a coincidence of 20 years apart. The average reading of the gage for April 1915 was 2.6 feet, while the average for the last 9 years is 4.3 feet. The aver-

Form No. 1030 Met'l.

U. S. Department of Agriculture
WEATHER BUREAU
CHARLES F. MARVIN, Chief.

MONTHLY METEOROLOGICAL SUMMARY

LANSING, MICHIGAN — APRIL, 1915

Date	Temp. Highest	Temp. Lowest	Temp. Mean	Precipitation (in inches.)	Character of day	Percentage of possible sunshine	This month since 1864: Year	Mean Temp.	Total Precip.
1..	42	29	36	0	Cloudy	50	1864	45.9	3.80
2..	39	27	33	0	Cloudy	28	1865	47.4	2.32
3..	44	21	32	0	Pt.cldy	70	1866	48.9	1.40
4..	49	22	36	0.05	Pt.cldy	71	1867	48.2	2.19
5..	53	38	46	0.03	Cloudy	0	1868	43.7	1.83
6..	61	34	48	0.04	Pt.cldy	84	1869	45.7	3.42
7..	60	35	48	0	Pt.cldy	92	1870	50.4	2.02
8..	63	34	48	0	Pt.cldy	100	1871	49.8	2.97
9..	67	45	56	0.17	Cloudy	21	1872	47.4	1.26
10..	57	43	50	0.19	Cloudy	11	1873	43.2	3.88
11..	55	35	45	0.43	Cloudy	38	1874	36.9	1.67
12..	38	29	34	0	Cloudy	0	1875	41.1	0.61
13..	54	25	40	0	Clear	100	1876	44.2	2.08
14..	59	30	44	0	Clear	100	1877	46.2	4.14
15..	62	30	46	0	Pt.cldy	75	1878	50.6	3.76
16..	50	33	42	0.04	Cloudy	24	1879	44.8	1.25
17..	63	28	46	0	Clear	100	1880	45.9	7.06
18..	70	38	54	0	Cloudy	81	1881	45.6	1.73
19..	80	53	66	0	Cloudy	80	1882	44.7	1.88
20..	72	44	58	0	Clear	97	1883	43.5	1.90
21..	61	41	51	0	Cloudy	68	1884	43.7	1.95
22..	70	48	59	0.03	Pt.cldy	59	1885	43.6	2.47
23..	83	56	70	0	Pt.cldy	88	1886	50.2	1.99
24..	87	60	74	0	Clear	98	1887	45.4	0.90
25..	86	62	74	0	Clear	100	1888	44.0	1.15
26..	88	59	74	0	Pt.cldy	78	1889	46.6	2.02
27..	83	60	72	0	Pt.cldy	66	1890	47.2	3.20
28..	78	56	67	0	Clear	96	1891	47.4	1.74
29..	66	47	56	0	Pt.cldy	71	1892	44.5	2.04
30..	49	41	45	0.02	Cloudy	1	1893	43.5	4.81
31..	..	..	..	....	....	...	1894	48.4	2.76
							1895	48.6	0.67
							1896	52.6	2.77
							1897	44.6	2.74
							1898	43.6	2.12
							1899	49.8	1.23
							1900	47.4	2.00
							1901	46.4	2.16
							1902	44.6	1.70
							1903	43.0	4.40
							1904	39.4	0.50
							1905	44.6	1.49
							1906	46.6	2.43
							1907	37.8	2.81
							1908	44.6	2.15
							1909	42.8	5.96
							1910	49.2	2.48
							1911	44.3	2.11
							1912	45.6	3.12
							1913	45.9	3.10
							1914	44.7	2.90
							1915	51.6	1.00

Mean highest temp...... 63.0
Mean lowest temp...... 40.1
Mean temp. for month.. 51.6
Total precip. for month 1.00

WEATHER

Number days clear........ 7
Partly cloudy........... 11
Cloudy 12
With 0.01 or more of precipitation......... 9

SUNSHINE

Number hours sunshine 262.2
Possible hours sunshine 402.5
Percentage of possible.. 65

SUMMARY

BAROMETER

Mean...... 30.06 inches.
Highest... 30.54 inches.
Date......... 13th.
Lowest.... 29.64 inches.
Date......... 11th.

TEMPERATURE

Highest, 88, on 26th.
Lowest, 21, on 3rd.
Greatest daily range, 35, on 17th.
Least daily range, 8, on 30th.
Normal for month, 45.6°
Excess or deficiency this month, +6.0°.
Accumulated excess or deficiency since Jan. 1st, +264°: average daily, same period, +2.2°
Highest in 30 years, 88°, lowest, 10°.

PRECIPITATION

Total amount, 1.00; normal, 2.54; excess or deficiency this month, −1.54; since Jan. 1st, −3.49.
Greatest amount in any 24 hours, 0.43 on 11th.
Total snowfall, 0.0 in.

WIND

Prevailing Dir., S W.
Total movement, 4,667 miles; av. hourly vel., 6.5 miles.
Max. vel., 28, on 11th.

DATES OF—

Auroras 0
Dense fog............ 0
Hail................... 11
Sleet.................. 0
Thunderstorms 9 11 27
Halos: solar 4 8 15 18
lunar.............. 0
Frost: killing... 15 17
heavy 0
light............... 0
(Frosts recorded after April 15th.)

DEWEY A. SEELEY,
LOCAL FORECASTER.

Form No. 1030 Met'l.

U. S. Department of Agriculture
WEATHER BUREAU
CHARLES F. MARVIN, Chief.

MONTHLY METEOROLOGICAL SUMMARY

LANSING, MICHIGAN — MAY, 1915

Date	Temp. Highest	Temp. Lowest	Temp. Mean	Precipitation (in inches.)	Character of day	Percentage of possible sunshine	This month since 1864: Year	Mean Temp.	Total Precip.
1..	57	40	48	0	Cloudy	29	1864	60.2	2.87
2..	66	39	52	0	Cloudy	73	1865	57.6	1.77
3..	49	45	47	0.17	Cloudy	0	1866	55.0	3.48
4..	47	41	44	0.29	Cloudy	1	1867	61.1	3.80
5..	58	42	50	0	Cloudy	54	1868	59.1	2.80
6..	68	41	54	0.06	Pt.Cldy	64	1869	56.0	2.05
7..	64	48	56	0.30	Pt.Cldy	44	1870	64.3	1.16
8..	63	43	53	0.23	Pt.Cldy	46	1871	61.4	1.97
9..	54	35	44	0	Cloudy	33	1872	58.5	3.72
10..	66	30	48	0	Clear	100	1873	56.9	3.05
11..	73	40	56	0	Clear	100	1874	59.6	1.77
12..	80	46	63	0	Clear	90	1875	60.8	4.46
13..	67	46	56	0	Cloudy	60	1876	58.0	4.13
14..	67	39	53	0	Pt.Cldy	84	1877	58.2	2.23
15..	63	38	50	0.20	Cloudy	29	1878	54.6	3.44
16..	54	38	46	0.50	Cloudy	3	1879	58.8	2.45
17..	53	33	43	0	Cloudy	24	1880	64.3	5.59
18..	50	33	42	0.07	Cloudy	28	1881	65.2	2.11
19..	61	31	46	0	Clear	99	1882	52.7	4.04
20..	52	42	47	0.07	Cloudy	0	1883	52.8	5.66
21..	76	49	62	0.11	Clear	62	1884	56.9	3.95
22..	57	48	52	0	Cloudy	28	1885	55.8	2.30
23..	68	40	54	0	Pt.Cldy	68	1886	58.1	2.67
24..	66	52	59	0.02	Cloudy	41	1887	64.3	2.42
25..	68	52	60	0.49	Cloudy	31	1888	53.7	3.66
26..	58	34	46	0	Cloudy	51	1889	57.4	3.61
27..	60	30	45	0	Cloudy	68	1890	53.7	4.98
28..	63	41	52	0.16	Cloudy	5	1891	55.7	1.63
29..	60	45	52	0.07	Cloudy	5	1892	54.5	5.92
30..	70	40	55	0	Clear	100	1893	54.4	2.86
31..	74	40	57	0	Clear	91	1894	56.9	4.83
							1895	61.8	2.06
							1896	66.5	3.14
							1897	55.8	3.29
							1898	56.5	2.15
							1899	58.8	3.59
							1900	58.8	4.17
							1901	55.2	2.42
							1902	58.4	4.92
							1903	59.5	2.63
							1904	57.4	2.40
							1905	56.7	5.17
							1906	56.6	3.05
							1907	51.2	2.22
							1908	59.6	5.59
							1909	55.8	2.44
							1910	51.5	4.13
							1911	63.5	2.67
							1912	57.6	6.57
							1913	56.2	2.22
							1914	58.6	4.66
							1915	51.5	2.74

Mean highest temp...... 62.3
Mean lowest temp...... 40.7
Mean temp. for month.. 51.5
Total precip. for month 2.74

WEATHER

Number days clear........ 7
Partly cloudy........... 5
Cloudy 19
With 0.01 or more of precipitation........ 14

SUNSHINE

Number hours sunshine 222.2
Possible hours sunshine 454.7
Percentage of possible.. 49

BAROMETER

Mean............ 29.93 inches.
Highest, 30.33 inches, on 27th.
Lowest, 29.38 inches, on 11th.

SUMMARY

TEMPERATURE

Highest, 80°, on 12th.
Lowest, 30°, on 27th.
Greatest daily range, 36°, on 10th.
Least daily range, 4°, on 3rd.
Normal for month, 57.1°
Excess or deficiency this month, −5.6°.
Accumulated excess or deficiency since Jan. 1st, +87°: average daily, same period, +0.6°
Highest in 30 years, 95°, lowest, 17°.

PRECIPITATION
(in inches)

Total amount, 2.74; normal, 3.58; excess or deficiency this month, −0.84; since Jan. 1st, −4.33.
Greatest amount in any 24 hour period, 0.70, on 15th & 16th.
Total snowfall, 0.4 in.

WIND

Prevailing Dir., N E.
Total movement, 4,671 miles; average hourly velocity, 6.3 miles.
Maximum velocity, 30, from the S W, on 21st.

DATES OF—

Auroras.............. 0
Dense fog........... 0
Hail.................. 0
Sleet.................. 0
Thunderstorms 8, 15, 21
Halos: solar.... 26, 27
lunar.............. 0
Frost: killing....... 0
heavy 10, 19, 27
light.............. 17

DEWEY A. SEELEY,
LOCAL FORECASTER.

age reading of the gage for May 1915 was 1.9 feet while the average for the last 5 years is 3.8 feet showing the lack of flow from the normal.

In solving the other problem, (2) the effect of this pollution on the stream, and to what extent the stream is able to purify itself, no exact standards can be used. The results of the dissolved oxygen tests show a general increase in dissolved oxygen as the river continues on its way, after being laden heavily at Lansing. The total counts of bacteria show very nicely the manner in which the purification takes place. The presumptive tests for B. Coli show that the water is not safe to use for drinking purposes, even down as far as Portland without treatment. Better results would have been obtained if greater dilutions had been used in testing. These tests simply give a preliminary idea of what could be done.

Some of the results on dissolved oxygen show over 100 % saturation. This at first may look erroneous, but on further consideration it looks very probable that these results might be obtained. This is due to several reasons, the water above these stations had been running over a shallow stony bed full of rocks and had absorbed considerable oxygen from the air until it was close to 100 % saturated, then if there were growing plants, which give out oxygen into the water, more might be given out than could be diffused and liberated at the surface. Therefore any consideration of the question should involve a study of plankton forms and also of the detached growths on the shores of the river.

CONCLUSION.

From what observations and determinations I have been able to make, I would say that the present method of disposal of sewage by dilution at Lansing is satisfactory.

The stream is an ideal one for that purposeas it contains stretches of rapid shallow water, separated by pools of back water. The former allowing absorption of oxygen from the atmosphere, killing of bacteria by sunlight, and thorough mixing of the organic matter with the water and oxygen. The latter allowing chemical and bacterial action, together with sedimentation.

There is no danger of polluting the water supplies of cities or towns below Lansing as they all obtain their supplies from wells, with the exception of Grand Rapids, which has a modern rapid sand filter.

Many complaints are made by farmers between Lansing and Grand Ledge about the condition of the water and banks of the stream. In warm weather offensive odors are given off and the better class of fish have left for purer water. Many dead fish are to be seen in this locality. The bottom of the stream in many places looks somewhat like a sludge bed. One point which arises is there danger to the cattle or live stock along the river from drinking the water or wading throughit? As we get on down below Grand Ledge the water becomes much swifter and better and before arriving in Portland you pass through good fishing grounds where bass may be caught. The presence of those fish shows to some extent the purification that must have taken place in the water.

Below Portland we find several large power dams which hold the river back, making it appear more like a lake. General appearance and condition seemed to increase and good fishing abounds. No complaints are heard from the inhabitants of this district about the condition of the water.

After completing the examination in the field the attention of the writer was called to the report of the Committee at Havana meeting of 1911 in regard to dissolved oxygen which is as follows:- "It has been shown by Adeny and Letts (5th Report of the Royal Commission on Sewage Disposal) that the Winkler method gives unreliable results when it is applied to polluted waters. containing nitrites or considerable organic matter. The former causes high results because of the liberation of iodine by oxides of nitrogen in acid solution, and the latter causes low results by its reduction of iodine. These discrepancies are especially marked in tests of harbor waters polluted by sewage. Consequently your committee recommends, pending investigation, that when polluted waters are analyzed for dissolved oxygen, that corrections by means of a blank be made of that the Levy method be used. One good modification of the latter is that used by the Metropolitan Sewerage Commission of New York (Report for 1910, page 401)."

Dissolved Oxygen Method used in New York

Harbor Method.

(Modification of Levy method, see Mason, page 110.)

Solutions.

Standard Fe SO_4 -- 144 gr. (Kahlbaum's crystalized sulphate) and

15 c.c. conc. H_2SO_4 all diluted to 3 liters.

Standard Na_2CO_3 -- 200 gr. in 1 liter of water.

Standard H_2SO_4 a- dilution, one part acid and one part water.

Standard potassium permanganate -- 25.4 gr. in water diluting to 4.5 liters. Standardized against especially prepared Mohz's salt, one c.c. = 1 c.c. oxygen.

Bottles.

500 c.c. recommended but 250 - 300 c.c. O.K.

Operation.

Fill the bottle with the sample under proper conditions. Remove the stopper add 6 c.c. of Fe SO_4 to the bottom, then 5 c.c. Na_2CO_3 at the top. Set the stopper in and shake. Then remove the stopper and add 10 c.c. H_2SO_4 solution. This sets the sample and dissolves the percipitate allowing the titration to proceed with potassium permanganate.

Run a blank using the same water and the same procoedure only omitting the addition of the Na_2CO_3 which gives an alkaline reaction, and allows the D.O. to work. The number of c.c. of potassium permanganate used in this blank determination, minus the number used in the first or sample test, gives the number of c.c. of dissolved oxygen in the sample. Put the result in terms of c.c. of oxygen per liter.

It is therefore evident that this method should be used in any future consideration of this question.