MOHLMAN

The Relation of Dissolved Oxygen to the Stability of Sewage

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THE RELATION OF DISSOLVED OXYGEN TO THE STABILITY OF SEWAGE

BY

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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INDEX.

THE RELATION OF DISSOLVED OXYGEN TO THE STABILITY OF SEWAGE.

At the present time a sewage analysis comprises the same general determinations as a water analysis, with several important additions. These additional determinations promise in time to supplant some of the routine chemical determinations, and are being studied and improved from day to day.

The results of a sewage analysis must be interpreted from various standpoints. There is the chemical property of composition, the physical property of concentration, and the biological property of condition. In considering sewage treatment, each of these characteristics is important, but at present most attention is being paid to determinations best showing the last property, that of condition. The tendency is towards the elimination of as many determinations as possible which simply show composition, and the adoption of more accurate determinations of condition.

HISTORICAL AND THEORETICAL.

Decomposition of sewage is a biological process, hence tests for expressing the condition of a sewage have been of rather recent proposal. Putrescibility is caused by the presence and growth of bacteria and micro-organisms in a medium which can supply food for their growth. This food consists of

organic matter, and the old sewage analysis showed the extent of biological activity by empirical determinations expressing some part of the carbon and nitrogen in organic combination. The value of oxygen concentration was also recognized, as it was known that objectionable conditions did not obtain until the decomposition became anaerobic; that is, that putrescibility meant absence of oxygen. The determinations showing oxygen concentration are nitrites, nitrates, and free dissolved oxygen. The great importance of the dissolved oxygen in preventing nuisance has been emphasized in the last decade.

Adeney[1] states that the most important change which occurs in an unpolluted water when mixed with sewage, is the more or less rapid absorption of its dissolved oxygen. He claims that the absorption is effected in three ways: 1. By dilution. 2. By oxidation of directly oxidizable substances. 3. By oxidation of organic substances, indirectly. The last action may be further sub-divided into-

(a) Carbon oxidizable substances

(b) Nitrogen fermentable substances and ammonium compounds.

It is evident that all of these actions can be duplicated in the laboratory by mixing sewage with a definite amount of aerated water and keeping the mixture either under anaerobic conditions in sealed bottles, or exposed to the air, with determinations of dissolved oxygen at intervals. The former method has been used more frequently than the latter, and

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1. Fifth Report, Royal Sewage Commission, 1908, p. 11.

is known as the "incubator test".

This test originated in England. Frankland[1] was probably the first to apply the test. He claimed that "if water contaminated with organic matter be excluded from the air in a stoppered bottle, the gradual diminution of the dissolved oxygen indicates exactly the progress of the oxidation of the organic matter." He used mixtures of 5% London sewage and aerated water in sealed bottles, and determined dissolved oxygen every day for seven days. He concluded that the oxidation of the organic matter proceeded with extreme slowness.

Incubation tests of surface waters were made by A. Gerardin[2]. He simply determined loss of dissolved oxygen in surface waters kept in sealed bottles for 10-14 days.

In 1884 Dupre[3] stated that when sewage polluted water was kept for 10 days out of contact with the air, a more or less complete absorption of the dissolved oxygen would take place, and that by a determination of the dissolved oxygen before and after incubation an idea might be obtained regarding the amount of organic matter present.

The methylene blue test was devised by Spitta in 1901, and improved by Spitta and Weldert in 1906.

Phelps[4] has studied this test and it has been found by Phelps and Winslow[5] that the time of decoloration of methylene

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1. First Report, River Pollution Commission of 1868, p. 20.
2. Compt. Rendus, 1875, p. 989.
3. Report of Local Government Board, (1884) p. 208
4. Public Health, 1906, p. 1.
5. Jour. Infect. Dis. Suppl. 3, 1907, p 1.

blue coincides with the disappearance of the total available oxygen consisting of the free, nitrate and nitrite oxygen, the oxygen disappearing in the order given. This test has been used more in American than the dissolved oxygen test.

In England Adeney[1] used the incubator test with determinations of dissolved oxygen in 1895. M'Gowan called it the "aëration method". Adeney has studied the test very carefully, and his results are expressed in the reports of the Royal Sewage Commission.

In 1900 Spitta[2] published two very exhaustive articles on the self-purification of streams and in regard to oxygen consumption, stated that the oxygen consumption was a measure of oxidizable substances, and that the hourly consumption varied with different bacteria.

Pleiszner[3] states that in polluted waters, the hourly oxygen requirement diminishes. He expresses results of the incubator test as "milligrams of oxygen per hour" from the beginning of the test.

Müller[4] has studied oxygen consumption, and claims that the course of oxygen withdrawal is not uniform, and is best shown by frequent determinations, with expression of results as "milligrams of oxygen per hour" between determinations.

In the Fifth Report of the Royal Sewage Commission,

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1. Trans. Royal Dublin Society, 5, pt 11, 1895.
2. Archiv. of Hyg. 1900, p. 215.
3. Arb. a. d. Kaiserl. Gesund. 1910, 34, 230.
4. Arb. a. d. Kais. Gesund., 1912, 38, 294.

1908, the dissolved oxygen consumption was made a test for the degree of purification of sewage, and suggested limits of oxygen consumption were given. These limits considered the rate of oxygen consumption as well as the amount; they stated that after being filtered, the effluent should not absorb more than 5.0 p.p.m. dissolved oxygen in 24 hours, 10.0 p.p.m. in 48 hours, and 15.0 p.p.m. in 5 days. The loss was to be obtained by multiplying loss in a given sample by the dilution.

The technique and interpretation of the test is given by Fowler.[1] He used a dilution of 1-10, and determined dissolved oxygen after 24 and 48 hours.

In 1911 Hoover[2] reported analyses of a year's work at the Columbus Sewage Works, giving results in terms of "oxygen consumed" from $KMnO_4$, using the five-minute boiling test, with periodic addition of permanganate, and also in terms of "dissolved oxygen consumed" by the undiluted sample. He claimed a practically constant ratio between the two determinations for each class of sewage, raw, septic and filtered; the dilutions to be used for the incubator test were determined from the $KMnO_4$ test so that a loss of about 5.0 p.p.m. dissolved oxygen occurs in 24 hours. The proper dilution is made, the mixture shaken, and siphoned into bottles; dissolved oxygen is determined in one at once; the other is sealed with paraffine and incubated at 37° for 24 hours. The loss of dissolved oxygen is multiplied by the dilution. The average monthly dilutions used were--crude sewage 1:23, septic sewage, 1:17, filter

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1. Sewage Works Analysis, 1902, p.82.
2. Eng. News, 1911, p. 311.

effluent, 1:4. The respective values of dissolved oxygen consumed by the undiluted sample were 118, 85, and 25.5 The ratios of permanganate value to dissolved oxygen value were, respectively, 1:2.40, 1:2.66, and 1:1.34.

In another paper by Hoover[1] the "biologic oxygen consumed" test is discussed, and its desirability explained. Hoover was the only man in charge of a sewage treatment plant using this test as a routine test. As a necessity for a test of sprinkling filter effluents, he pointed out that "from one-half to two-thirds of the available oxygen in our sprinkling filter effluents comes from the nitrates and nitrites and this oxygen will not be brought into service until at least 80% of the dissolved oxygen has been consumed; consequently unless a fairly complete deoxygenation of the water of a stream is permissible, the nitrites and nitrates as sources of oxygen should not be considered."

Phelps has investigated the test and although in procedure and technique he uses the general method proposed by Fowler and the Royal Sewage Commission, he has sought to devise a more convenient and more accurate method of reporting results. This is proposed in connection with his work on New York Harbor.[2] He states-"Considering the reaction taking place between the organic matter of the sewage and the oxygen dissolved in the water the following relation should hold:

$$\frac{d.O.}{dt.} = KOC,$$

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1. Sewage Works Analysis, 1902, p. 82.
2. Black and Phelps, M. I. T. Bulletin VII, 1911.

in which O is the amount of oxygen present in unit volume, C the amount of organic matter oxidizable, t the time allowed for the reaction to proceed, and K a constant determined by the character of the organic matter and in turn defining the oxidizability of that organic matter. Integrating,

$$\log \frac{O'}{O} = KCt,$$

O' being the initial and O the final amount of oxygen present, expressed in parts per million, C the concentration of sewage in per cent by volume, t the time in hours, and K the "reaction constant." K depends upon the character of the sewage matter and the concentration of that material in the sewage and is independent of the extent of dilution or character of diluting water".

The value of this formula, if accurate, is apparent. "A value of K = .0030 would indicate a sewage which in 25% admixture with water would reduce the oxygen content of the mixture 50% in four hours. Similarly, for K = .0020, the reduction in a 25% admixture in four hours would be 37.5%, and with K = .0015, 28.5%." This formula simplifies calculations in disposing of sewage in streams or harbors, and deserves study to prove its reliability.

The formula is derived from the mono-molecular law which governs certain chemical reactions. The governing conditions of such reactions are, that only two moleculer species shall be involved, and that one shall be in such an excess that its concentration is not changed appreciably during the course

of the reaction. Reactions which follow this law are (1) the inversion of sugar by acids, (2) the reduction of $KMnO_4$ by a large excess of oxalic acid, (3) the conversion of meta-phosphoric acid to phosphoric acid ($HPO_3 + H_2O = H_3PO_4$), (4) the saponification of methyl acetate by water ($CH_3COOC_2H_5 + H_2O = CH_3COOH + C_2H_5OH$). In each of these reactions the concentration of one molecular species is not appreciably changed; in (1) the acid, in (2) the oxalic acid, and in (3) and (4) the H_2O do not change appreciably.

Certain biological phenomena are also thought to follow this reaction. The commonest example is disinfection or killing of bacteria. H. Chick[1] showed that phenol and other disinfectants killed bacteria in accordance with this law, the number dying in any period being proportional to the number alive at the beginning of that period.

In this biological reaction also, the conditions must be such that the concentration of the phenol, or whatever disinfecting agent is used, must not change appreciably.

However, in integrating the differential when applied to sewage, the assumption that the concentration of organic matter remains constant during the test is only approximately true, as was pointed out by Lederer[2], and later admitted by Phelps[3]. He states that it is necessary in each case to employ a dilution approximately equivalent to that which will maintain in practice, when considering disposal of sewage in a

1. Journal of Hygiene, 1908, p. 92.
2. Jour. Am. Pub. Health Assoc., Feb. 1912, p. 99.
3. Am. Jour. Pub. Health, June, 1913, p. 527.

stream or harbor.

It is evident that both biological and chemical reactions are taking place in a putrefying sewage. Clark[1] experimented with septic sewage to determine if the absorption of oxygen was due to the oxidation or saturation of gases. He sterilized sewage by heat, driving out the volatile gases, and found no quick oxygen absorption; when sterilized with mercuric acetate, retaining the gases, a quick absorption of oxygen was noted. He concluded that the rapid absorption of oxygen was either due to oxidation of gases or else to oxidation of organic matter that sterilizing by heat had so changed that it was not easily oxidized.

However, Müller[2] claims that bacterial growth is essential for oxygen consumption in sewage. He claims that if in two parallel experiments in one a given bacterial count is reached by a quick growth of a few bacteria, in the other the number remains constant, the oxygen consumption will be much greater in the first case. He states, however, that in natural waters the bacterial oxygen consumption is strongly influenced by oxidation processes purely chemical.

Dr. Rideal[3] tested water, sewage and boiled sewage for oxygen consumption under aerobic conditions, and found no oxygen consumption in the boiled sewage, concluding that bacteria are essential for dissolved oxygen consumption.

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1. M.S.B. of H., Report, 1900, p. 389
2. Arb. Kais. Gesundh., 1912, p. 294.
3. Analyst, 1901, p. 201

It is difficult to say just how much of the oxygen consumption is due to purely chemical action and how much is due to bacterial action; however, it seems to have been established that a rapid increase of bacteria causes a corresponding rapid reduction of dissolved oxygen, and it is probable that biological factors influence the consumption to a greater extent than chemical factors.

By study of various dilutions of sewages of various ages, a better understanding of the course of the reaction may be gained. This work was planned to study the effect of various concentrations in an effort to standardize some method of determining the oxygen-consuming power of a sewage.

The test as used at the Hygienic Laboratory in Washington is made in 24 hours, using such dilutions as will leave a residual oxygen content of 20% the original amount in this time.

As before stated, the English test requires 10 days. The Eighth Report of the Royal Sewage Commission recommends an oxygen consumption of between 30% and 60% as being the best.

A committee of the American Public Health Association is also studying this test; Dr. Arthur Lederer is chairman of this committee, and some of the work outlined by him is included in this investigation.

EXPERIMENTAL.

The experimental work has consisted of incubation tests with various dilutions and various putrescible liquids.

The temperature used has been 20°C. This is generally recognized as the most desirable temperature, although 37° has been used by Hoover and others. 20° is the temperature nearer actual conditions in streams, and the bacterial flora at 20° is not similar to that at 37°. The use of the higher temperature would necessitate the making of the dilutions at 37°, as otherwise much oxygen must be lost by the decreased solubility at 37°, if the dilutions were made at room temperature.

The first tests were made on an artificial medium. This was prepared by making a .05% solution of peptone in distilled water; it was seeded with 1 cc. of a broth culture of B. coli, and allowed to stand one day until anaerobic. It was then mixed with distilled water which had been saturated with oxygen at 20° by bubbling air through it at that temperature. The mixing was done in a glass cylinder in the following manner: the aerated water was siphoned into it from a large vessel full of water. At the same time a certain quantity of the putrescible mixture was introduced below the surface of the water, and aerated water added to bring the mixture up to a definite volume. The mixture was stirred with a wire spiral, and siphoned into glass-stoppered bottles of about 250 cc.

capacity. Dissolved oxygen was determined immediately in one bottle by the Winkler method;[1] the remaining bottles were placed in the 20° incubator.

In this run dilutions of 25% and 50% putrescible solution were used, and the maximum time of the experiment was 24 hours. Glass-stoppered bottles were found to be satisfactory, and no appreciable leakage or ingress of air was noted. The results are tabulated in Table I. In this table the amount consumed in a given time divided by the dilution gives the amount consumed by the undiluted sewage in that time. Phelp's coefficient is calculated from the formula log. $\frac{O}{O'} = KCt$, as explained before.

This table shows that,(1) The rate and amount of oxygen absorbed decreases considerably as the solution becomes septic, and this decrease is not indicated to a proportional extent by the other chemical determinations. (2) Phelp's factor is higher in the more concentrated mixtures, and in general increases with higher oxygen absorption. (3) The amount consumed in a given time is less in the more concentrated solutions.

Table II shows the tabulated results of a similar experiment using .05 and .10% peptone solutions, two days old. Higher dilutions, 25% and 10% were used. As before, the values of K are quite variable, increase with higher absorption ,and are generally higher in the more concentrated mixtures.

In these determinations, the Levy[2] method of determin-

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1. Berichte d. Chem. Gesell., 21, 283.
2. Mason, Exam. of Water, p. 84.

TABLE I.

Comparison of data on putrescible solutions.

.05% peptone, 25% mixture
Oxygen demand

T	DO	2 days old DO used #3	#3 ÷ diln.	%	K	T	DO	3 days old DO used #3	#3 ÷ diln	%	K	T	DO	6 days old DO used #3	#3 ÷ diln.	%	K
0.	5.78	---	---	--	----	0.	6.10	---	-----	--	-----	0	6.24	----	----	--	-----
.5	5.36	.42	1.68	7	.0026	.5	6.06	.04	.16	1	.0002	.5	6.10	.14	.56	2	.0008
1.	----	---	---	--	----	1.	6.04	.06	.24	1	.0002	1.	6.00	.24	.96	4	.0007
2	4.94	.84	3.36	14	.0014	2.	5.80	.30	1.20	5	.0004	2.	5.96	.28	1.12	5	.0004
3.5	4.42	1.36	5.44	23	.0013	3.5	5.40	.70	2.80	11	.0006	4.	5.74	.50	2.00	8	.0003
5.	3.96	1.82	7.28	31	.0013	5.	4.88	1.22	4.88	20	.0008	8.5	5.30	.94	3.76	15	.0003
7.	3.92	1.86	7.44	--	----	23.	2.54	3.56	14.24	58	.0007	24.	4.16	2.08	8.32	34	.0003

.05% peptone, 50% mixture
Oxygen demand

T	DO	DO used #3	#3 ÷ diln.	%	K	T	DO	DO used #3	#3 ÷ diln	%	K	T	DO	DO used #3	#3 ÷ diln.	%	K
0.	3.66	----	----	--	-----	0.	4.06	----	-----	--	-----	0.	4.20	----	----	--	------
.5	3.52	.14	.28	4	.0013	.5	4.00	.06	.12	1	.0003	.5	4.10	.10	.20	2	.0004
1.	3.10	.56	1.12	15	.0029	1.	3.88	.18	.36	4	.0004	1.	4.00	.20	.40	5	.0004
2.	2.14	1.52	3.04	41	.0046	2.	3.46	.60	1.20	15	.0007	2.	3.80	.40	.80	9	.0004
3.5	1.60	2.06	4.12	56	.0041	3.5	2.90	1.16	2.32	29	.0008	3.	3.60	.60	1.20	14	.0004
5.	0.00	3.66	7.32	100	----	5.	1.92	2.14	4.28	53	.0013	8.5	2.74	1.46	2.92	35	.0004

	2 days old	3 days old	6 days old
Oxygen Cons.	129.60	130.40	114.00
N as free ammonia	1.70	3.36	4.80
N as nitrates	.64	.68	.68
Total Org. Nitrogen	72.00	72.00	68.00

T=Time in hours. DO=Dissolved oxygen. %=per cent used. K=Phelp's coefficient.

TABLE II.

Comparison of data on putrescible solutions.

Oxygen demand.

.05% peptone, 25% mixture.

T	D.O.	D.O. used	D.O. used ÷ diln.	%	K
0	6.64	----	-----	---	-----
.5	6.52	.12	.48	2	.0006
1.	6.48	.16	.64	2	.0004
2.	6.44	.20	.80	3	.0003
6.	5.38	1.26	5.04	19	.0006
8.	4.50	2.14	8.56	32	.0008
10.	.54	6.10	24.40	92	.0043

.05% peptone, 50% mixture.

T	D.O.	D.O. used	D.O. used ÷ diln.	%	K
0	5.30	----	-----	---	-----
.5	5.20	.10	.20	2	.0003
1.	5.08	.22	.44	4	.0004
2.	4.76	.54	1.08	10	.0005
4.	3.78	1.52	3.04	30	.0007
7.	2.14	3.16	6.32	60	.0011
9.	.30	5.00	10.00	94	.0027
10.	.00	5.30	10.60	100	-----

.10% peptone, 25% mixture.

T	D.O.	D.O. used	D.O. used ÷ diln.	%	K
0	5.90	----	-----	---	-----
.5	5.86	.04	.16	1	.0002
1.	5.80	.10	.40	2	.0003
5.	4.80	1.10	4.40	75	.0007
22.	.60	5.30	21.20	90	.0017

.10% peptone, 50% mixture.

T	D.O.	D.O. used	D.O. used ÷ diln.	%	K
0	4.50	-----	-----	---	-----
1.	4.22	.28	.56	6	.0006
7.5	2.24	2.26	4.52	50	.0008
9.5	.54	3.96	7.92	88	.0019

Note:-All solutions two days old.

ing dissolved oxygen was tried, but was discarded because of the difficulty of obtaining an accurate end point when titrating with permanganate. The Winkler method was used during the whole investigation, and gave satisfactory results; the interfering factors in using the Winkler method are, (1) the catalytic effect of nitrites which liberate iodine according to the formula H-O-N=O + H-I = H_2O + N=O + I; the reaction is catalytic, the N=O taking up oxygen from the air to form nitrous acid again. This effect is noticeable by a return of the blue color; no trouble was encountered in any of the work in this respect. The other objection to the Winkler method is the reduction of iodine by organic matter, as claimed by Hefelmann and Barth.[1] Hale and Melia[2] claim that the iodine is not reduced below amounts that could be accounted for by experimental error.

To determine if the values for dissolved oxygen would be low in the more concentrated solutions of organic matter an experiment was performed using sewage and aerated distilled water. After being titrated, half of the remaining solution containing free iodine was placed in an uncovered beaker, and the other half in glass-stoppered bottles, filled full. The results are tabulated in Table III.

The results show a slight reduction of iodine in closed bottles increasing in proportion to the amount of organic matter present, but not nearly as great as occurs when the

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1. Chem. Ztg. 13, 1337.
2. Jour. Ind. and Eng. Chem., Dec. 1913, 987.

TABLE III.

Reduction of iodine by organic matter.

% sewage	0; aerated water	25%	50%	75%	100%
Dissolved oxygen	8.08	5.16	2.41	0.53	0.00
Dissolved oxygen, closed bottles, 1 wk.	8.00	4.40	1.54	0.30	0.00
Loss	.08	.76	.87	.23	.00
% Loss	1.	15.	36.	43.	----
Dissolved oxygen in open beakers.	Faded in 1 week	0.00 in 2 days	0.00 in 1 day	0.00 in .5 day	----

solution is exposed to the air. This effect was noted in all titrations; the first 100 cc. removed from the bottles nearly always showed slightly higher values than the next 100 cc. It seems, therefore, that reduction of iodine does occur to an appreciable extent when the acidified iodine solution is exposed to the air; the reduction in inappreciable when the acid solution is kept in full, stoppered bottles.

The next experiments were made on raw Champaign sewage. The rate of consumption was expressed by calculating the consumption per hour, and the amount consumed by the undiluted sewage obtained by dividing this by the dilution; the rate was also expressed by Phelp's coefficient. The results are expressed in Table IV and by Curve I, and show that the amount consumed and the rate of consumption increase with increasing dilution. The rate of consumption is greatest between 6 and 24 hours. Phelp's coefficient remains fairly constant when the % reduction is between 30 and 75%, as shown graphically by the symmetry of the curves for 3%, 4%, and 5% dilutions. The values are higher when the consumption is higher than 75%, and lower when the consumption is below 30%. The values of the hourly rate are also more concordant in these dilutions.

Next tests were made upon raw and septic sewage from the Urbana septic tank and raw sewage from Champaign. This work was done in conjunction with the work of the Committee on Biologic Oxygen Consumed, of the American Public Health Association; Dr. Lederer is chairman of the committee.

TABLE IV.

CHAMPAIGN SEWAGE.

10% mixture.

Time Hours	D.O. P.P.M.	Loss P.P.M.	% loss	Loss ÷ diln.	Loss per hr.	Loss per hr ÷ diln	K
0	7.46	----	----	-----	----	----	------
6	6.94	.52	6	5.2	.086	.86	.00052
24	.20	7.26	97	72.6	.302	3.02	.00654
48	.00	----	----	-----	----	----	------

7% mixture.

0	7.70	----	----	-----	----	----	------
6	7.50	.20	3	2.9	.036	.51	.00027
24	1.52	6.18	80	88.3	.257	3.67	.00419
48	.00	----	----	-----	----	----	------

5% mixture.

0	8.00	----	----	----	----	------	------
6	7.90	.10	1	2.0	.016	.32	.00018
24	3.54	4.46	56	89.2	.186	3.72	.00295
48	.94	7.06	88	141.2	.147	2.94	.00387

4% mixture.

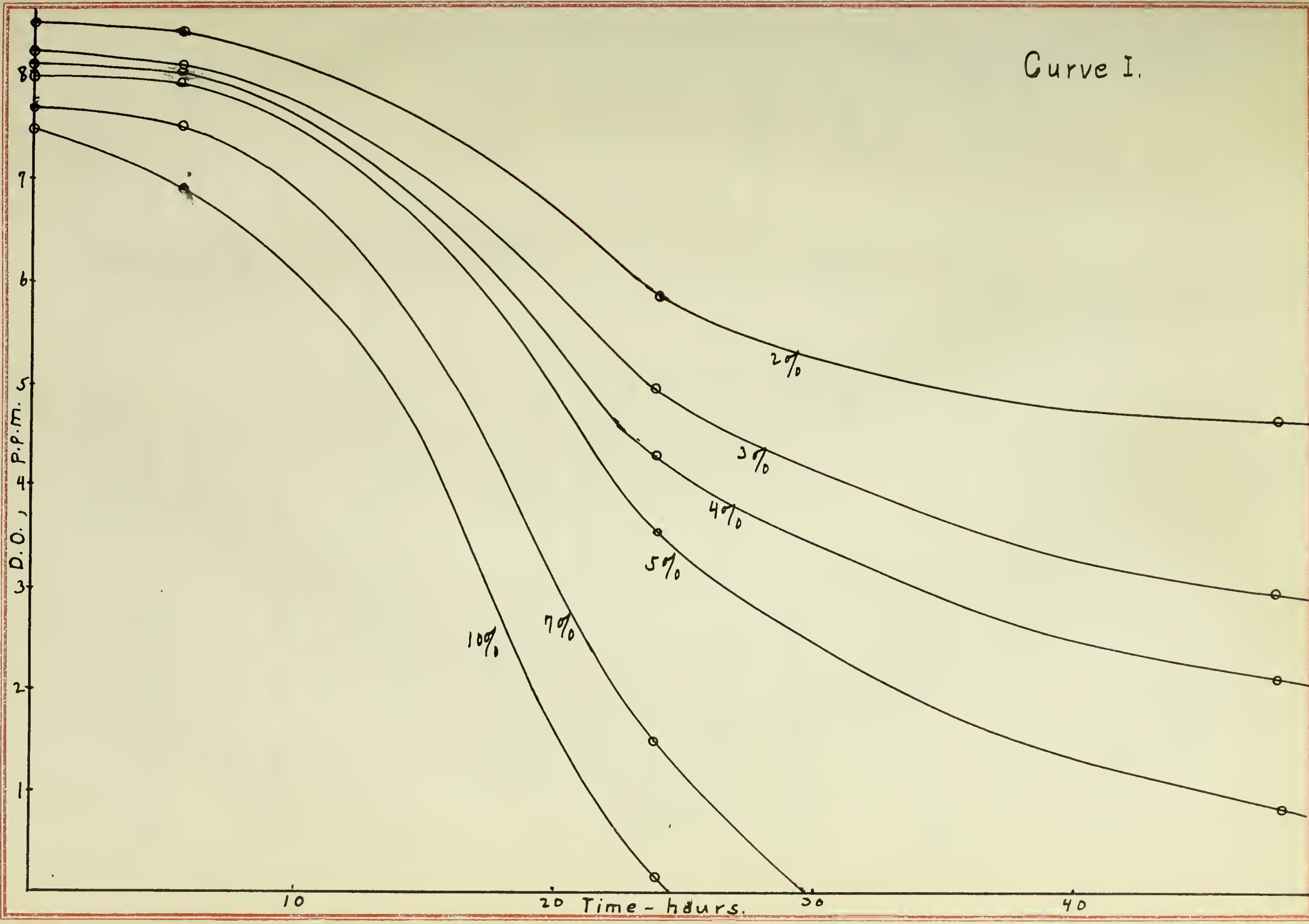
0	8.14	----	----	----	----	-----	------
6	8.00	.14	1	3.5	.023	.57	.00031
24	4.28	3.86	47	96.5	.161	4.02	.00290
48	2.16	5.98	74	149.5	.124	3.10	.00300

3% mixture.

0	8.20	----	----	----	----	----	------
6	8.04	.16	2	5.3	.026	.86	.00047
24	5.00	3.20	39	106.6	.133	4.43	.00298
48	2.94	5.26	64	175.3	.110	3.66	.00309

2% mixture.

0	8.40	----	----	----	----	----	------
6	8.34	.06	1	3.0	.010	.50	.00026
24	5.92	2.48	30	124.0	.103	5.15	.00316
48	4.62	3.78	45	189.0	.078	3.90	.00270



Curve I.
D.O., P.P.M.
1
2
3
4
5
6
7
8
10
20
30
40
Time - hours.
2%
3%
4%
5%
7%
10%

The procedure was the same as before, except that higher dilutions were used and incubation was for 10 days, with daily determinations of dissolved oxygen. This test necessitated the use of a tighter stopper than the glass stoppers. There the incubator varied about 3°C. Several methods of preventing entrance of air have been used.

Jackson and Horton[1] devised a bulb pipette, consisting of a perforated rubber cork, through which is passed a glass tube topped by a small rubber bulb.

Winkler[2] describes a complicated cover of celluloid or aluminium for the top of the bottle.

Buswell[3] uses a U shaped capillary tube, the free end of which extends to the bottom of a small test-tube. An S-shaped capillary has been used, one end of which may be exposed to the air with little oxygen reaching the solution.

The bulb pipette was used in this work, selected as being least cumbersome; the S-shaped capillaries probably are even less troublesome.

Three dilutions were used on the raw sewage, two on the septic. The suspended solids were allowed to settle out, and the supernatant liquid used, in order to obtain more uniform mixtures and to approximate natural conditions. The analyese of the sewages are given in Table V. The results are summarized in Tables XVII and XVIII.

The most apparent conclusion is that even after ten

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1. Jour. Ind. Eng. Chem. 1909, p. 328.
2. Cent.fur angew. Chem. 1912, p. 1563.

TABLE V.

Analyses of raw and septic sewages, Urbana tank.

	Raw	Septic	Raw	Septic	Raw	Septic	Raw	Septic
Table No.	VI	VII	VIII	IX	X	XI	XII	XIII
Laboratory No.	27430	27431	27441	27442	27472	27473	27497	27498
Turbidity	60	50	230	125	---	---	---	---
Color	50	40	60	55	40	55	40	45
Residue	787	715	845	711	798	702	1103	727
Chlorine	---	---	44	44	46	43	48	50
Oxygen Consumed	34.0	35.2	38.0	29.6	42.0	34.4	57.6	40.0
Nitrogen as Free Ammonia	17.2	24.0	30.0	25.6	27.2	12.8	33.6	33.6
Albuminoid Ammonia	4.80	3.52	4.40	2.40	6.00	4.00	6.60	3.44
Nitrites	.480	.480	.500	.510	.400	.400	.000	.000
Nitrates	4.000	.480	1.640	2.400	1.000	1.000	.880	.520
Alkalinity	----	-----	476.	430.	436.	436.	456.	452.

TABLE VI.

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source...Raw Urbana Sewage........ Date and time of

Dissolved Oxygen...0.00... collection.11:30 a.m. April 21,1914

Per Cent Sewage in Mixture..5..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Phelps coeff. K
0	8.10	----	----	162.	----	----
1	5.52	2.58	32		52	.00139
2	3.66	4.44	55		89	.00144
3	2.00	6.10	75		102	.00168
4	1.28	6.82	84		116	.00167
5	----	----	--		---	------
6	----	----	--		---	------
7	.94	7.16	88		143	.00111
8	.34	7.76	96		155	.00143
9	.00	8.10	100		162	------
10						
					Average	.00145

Per Cent Sewage in Mixture..3...

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Phelps coeff. K
0	8.45	----	----	282.	---	------
1	6.10	2.35	28		78	.00196
2	5.04	3.41	40		114	.00156
3	3.96	4.49	53		150	.00152
4	3.14	5.31	63		177	.00149
5	2.88	5.57	66		186	.00130
6	----	----	---		---	------
7	2.30	6.15	73		205	.00110
8	1.80	6.65	79		222	.00117
9	1.74	6.71	80		224	.00106
10	1.68	6.77	81		226	.00097
					Average	.00135

Per Cent. Sewage in Mixture 2...

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Phelps coeff. K
0	8.58	----	---	429	---	------
1	6.82	1.76	20		88	.00207
2	6.46	2.12	25		106	.00128
3	4.60	3.98	46		199	.00188
4	----	----	---		---	------
5	3.86	4.72	55		236	.00144
6	3.34	5.24	61		262	.00142
7	2.52	6.06	71		303	.00158
8	2.40	6.18	72		309	.00144
9	2.36	6.22	73		311	.00130
10	2.30	6.28	73		314	.00119
					Average	.00151

TABLE VII.

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source. Urbana Septic Tank Effluent

Dissolved Oxygen... 0.00

Date and time of collection 11:30 a.m. April 21,1914

Per Cent Sewage in Mixture... 3

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Velocity coeff. K
0	8.28	----	----	276	----	------
1	6.54	1.74	21		58	.00142
2	4.06	4.22	51		141	.00215
3	3.72	4.56	55		152	.00161
4	3.34	4.94	60		165	.00136
5	2.64	5.64	68		188	.00137
6	2.20	6.08	73		203	.00133
7	1.80	6.48	78		216	.00131
8	1.36	6.92	83		231	.00136
9	1.30	6.98	84		233	.00124
10	1.20	7.08	85		239	.00116
					Average	.00143

Per Cent Sewage in Mixture... 2

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Velocity coeff. K
0	8.18	----	---	409	---	------
1	7.04	1.14	14		57	.00135
2	5.64	2.54	31		127	.00168
3	5.04	3.14	38		157	.00146
4	4.26	3.92	48		196	.00147
5	3.46	4.72	57		236	.00155
6	3.06	5.12	63		256	.00148
7	2.70	5.48	67		274	.00143
8	2.40	5.78	70		289	.00139
9	2.18	6.00	73		300	.00133
10	2.06	6.12	75		306	.00125
					Average	.00144

Per Cent. Sewage in Mixture....

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Velocity coeff. K
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

TABLE VIII

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source. Raw Urbana Sewage .... Date and time of collection. 11:00 a.m. April 25,1914.

Dissolved Oxygen.. 0.00

Per Cent Sewage in Mixture. 5

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Velocity coeff. K
0	7.38	----	----	148	---	------
1	4.48	2.90	39		58	.00180
2	2.42	4.96	67		99	.00202
3	1.16	6.22	84		122	.00223
4	.74	6.64	90		135	.00208
5	.40	6.98	94		139	.00211
6	.14	7.24	98		145	.00239
7	.00	7.38	100		148	------
8						
9						
10						
					Average	.00210

Per Cent Sewage in Mixture. 2

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Velocity coeff. K
0	7.44	----	---	372	---	------
1	6.64	.80	10		40	.00103
2	5.74	1.70	23		85	.00117
3	4.98	2.46	33		123	.00121
4	4.56	2.88	38		144	.00110
5	4.04	3.40	45		170	.00112
6	3.46	3.98	53		199	.00115
7	2.97	4.47	60		223	.00118
8	2.63	4.81	64		240	.00118
9	2.35	5.09	68		254	.00115
10	2.24	5.20	70		260	.00108
					Average	.00114

Per Cent. Sewage in Mixture. 1

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Velocity coeff. K
0	7.80	----	---	780	---	------
1	6.76	1.04	13		104	.00259
2	6.52	1.28	16		128	.00162
3	6.34	1.46	19		146	.00125
4	6.08	1.72	22		172	.00112
5	5.90	1.90	24		190	.00101
6	5.00	2.80	36		280	.00134
7	4.60	3.20	41		320	.00136
8	4.36	3.44	44		344	.00131
9	3.92	3.88	50		388	.00138
10	----	----	--		---	------
					Average	.00144

TABLE IX.

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source. Urbana Septic Tank Effluent

Date and Time of collection. 11:00 a.m. April 25,1914

Dissolved Oxygen. 0.00

Per Cent Sewage in Mixture. 3

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per liter sewage	Value const. K
0	7.90	----	--	263	---	------
1	6.26	1.64	21		55	.00140
2	5.66	2.24	28		78	.00100
3	5.24	2.66	34		89	.00082
4	4.70	3.20	40		107	.00078
5	3.92	3.98	50		133	.00084
6	----	----	--		---	------
7	3.08	4.82	61		161	.00081
8	3.02	4.88	62		163	.00073
9	3.00	4.90	62		163	------
10	----	----	--		---	------
					Average	.00091

Per Cent Sewage in Mixture. 1

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per liter sewage	Value const. K
0	8.08	----	--	808	---	------
1	7.30	.78	10		78	.00184
2	6.86	1.22	15		122	.00148
3	6.56	1.52	19		152	.00125
4	6.22	1.86	23		186	.00118
5	5.70	2.38	30		238	.00126
6	5.20	2.88	36		288	.00132
7	4.82	3.26	40		326	.00134
8	4.56	3.52	44		352	.00129
9	4.32	3.76	47		376	.00126
10	----	----	--		---	------
					Average	.00136

Per Cent. Sewage in Mixture...

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per liter sewage	Value const. K
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

TABLE X.

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source..Raw Urbana Sewage.......... Date and time of

Dissolved Oxygen.0.00..... collection.11:00 a.m. April 30,1914

Per Cent Sewage in Mixture..4..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Velocity coeff. K
0	8.46	----	----	211	--	------
1	5.80	2.66	31		76	.00170
2	3.88	4.58	54		114	.00176
3	2.10	6.36	75		159	.00210
4	1.50	6.96	82		174	.00197
5	1.21	7.25	85		181	.00175
6	.95	7.51	89		188	.00165
7	.68	7.78	92		194	.00163
8	.00	8.46	100		211	------
9						
10						
					Average	.00179

Per Cent Sewage in Mixture..2..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Velocity coeff. K
0	8.60	----	----	430	--	------
1	7.10	1.50	17		75	.00173
2	6.56	2.04	24		102	.00122
3	5.38	3.22	37		161	.00141
4	5.10	3.50	41		175	.00117
5	4.44	4.16	48		208	.00119
6	4.10	4.50	52		225	.00111
7	3.48	5.12	60		256	.00116
8	3.16	5.44	63		272	.00113
9	2.96	5.64	66		282	.00107
10	2.84	5.76	67		288	.00100
					Average	.00122

Per Cent. Sewage in Mixture..1..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Velocity coeff. K
0	8.56	----	---	856	---	------
1	7.84	.72	8		72	.00160
2	7.32	1.24	14		124	.00141
3	6.90	1.66	19		166	.00130
4	6.34	2.22	26		222	.00135
5	5.87	2.69	31		269	.00136
6	5.34	3.22	37		322	.00142
7	4.85	3.71	43		371	.00147
8	4.40	4.16	48		416	.00150
9	4.18	4.38	51		438	.00144
10	3.88	4.68	55		468	.00143
					Average	.00143

TABLE XI.

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source. Urbana Septic Tank Effluent   Date and time of collection. 11:00 a.m. April 30,1914

Dissolved Oxygen. 0.00

Per Cent Sewage in Mixture. 3

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per litre sewage	Phelps coeff. K
0	8.28	----	--	276	---	------
1	7.06	1.22	15		41	.00096
2	6.48	1.80	22		60	.00074
3	5.32	2.96	36		99	.00089
4	4.16	4.12	50		137	.00103
5	2.46	5.82	70		194	.00146
6	2.12	6.16	74		205	.00137
7	1.90	6.36	77		213	.00127
8	1.74	6.54	79		218	.00117
9	1.60	6.68	80		223	.00110
10	1.52	6.76	81		225	.00102
					Average	.00110

Per Cent Sewage in Mixture. 1

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per litre sewage	Phelps coeff. K
0	8.54	----	--	854	---	------
1	7.94	.60	7		60	.00132
2	7.34	1.20	14		120	.00137
3	7.20	1.34	16		134	.00103
4	6.64	1.90	22		190	.00113
5	6.48	2.06	24		206	.00100
6	5.95	2.59	30		259	.00109
7	5.54	3.00	35		300	.00112
8	5.26	3.28	38		328	.00109
9	5.00	3.54	41		354	.00107
10	5.04	3.50	41		354	------
					Average	.00113

Per Cent. Sewage in Mixture...

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per litre sewage	Phelps coeff. K
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

TABLE. XII

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source.. Raw Urbana Sewage

Dissolved Oxygen.. 0.00

Date and Time of collection.. 11:00 a.m. May 5, 1914.

Per Cent Sewage in Mixture.. 3

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per liter sewage	Velocity Coeff. K
0	8.62	----	--	287	---	------
1	4.70	3.92	45		130	.00366
2	3.72	4.90	57		163	.00253
3	2.66	5.96	69		199	.00236
4	1.70	6.92	81		231	.00246
5	1.12	7.50	87		250	.00246
6	.83	7.79	90		259	.00235
7	.50	8.12	94		271	.00245
8	.24	8.38	97		279	.00320
9	.20	8.42	98		281	.00252
10	.14	8.48	98		283	.00248
					Average	.00265

Per Cent Sewage in Mixture.. 1

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per liter sewage	Velocity Coeff. K
0	8.84	----	--	884	---	------
1	6.90	1.94	22		194	.00448
2	6.50	2.34	26		234	.00278
3	6.24	2.60	29		260	.00210
4	5.92	2.92	33		292	.00181
5	5.50	3.34	38		334	.00171
6	5.22	3.62	41		362	.00158
7	5.00	3.84	43		384	.00147
8	4.60	4.24	48		424	.00147
9	4.10	4.74	54		474	.00154
10	3.80	5.04	57		504	.00153
					Average	.00205

Per Cent. Sewage in Mixture.. .5

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per liter sewage	Velocity Coeff. K
0	8.40	----	--	1680	---	------
1	7.60	.80	9		160	.00362
2	7.42	.98	12		196	.00234
3	7.16	1.24	15		248	.00192
4	6.60	1.80	21		360	.00218
5	6.24	2.16	26		432	.00215
6	6.05	2.35	28		470	.00198
7	5.84	2.56	30		512	.00188
8	5.73	2.67	32		534	.00173
9	5.61	2.79	33		558	.00162
10	5.52	2.88	34		576	.00152
					Average	.00208

TABLE XIII

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source.. Urbana Septic Tank Effluent

Date and time of collection 11:00 a.m. May 5, 1914

Dissolved Oxygen.. 0.00

Per Cent Sewage in Mixture..3..

Time of Incubation Days	P.p.m. O in diluted sewage	P.p.m. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Veloc. coeff. K
0	8.24	----	--	275	---	------
1	6.50	1.74	21		58	.00143
2	4.84	3.40	41		113	.00160
3	3.40	4.84	59		161	.00178
4	3.26	4.98	61		166	.00140
5	2.56	5.68	69		189	.00141
6	2.24	6.00	73		200	.00139
7	1.62	6.62	80		221	.00147
8	1.30	6.94	84		231	.00145
9	1.32	6.92	84		---	------
10	1.30	6.94	84		231	------
					Average	.00149

Per Cent Sewage in Mixture..1..

Time of Incubation Days	P.p.m. O in diluted sewage	P.p.m. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Veloc. coeff. K
0	8.36	----	--	836	---	------
1	7.60	.76	9		76	.00172
2	6.80	1.56	19		156	.00186
3	6.46	1.90	23		190	.00155
4	5.86	2.50	30		250	.00160
5	5.52	2.84	34		284	.00150
6	5.20	3.16	38		316	.00143
7	4.82	3.54	42		354	.00142
8	4.40	3.96	47		396	.00145
9	4.00	4.36	52		436	.00147
10	4.08	----	--		---	------
					Average	.00155

Per Cent. Sewage in Mixture....

Time of Incubation Days	P.p.m. O in diluted sewage	P.p.m. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Veloc. coeff. K
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

TABLE XIV

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source... Raw Champaign Sewage .... Date and Time of

Dissolved Oxygen... 0.00 ... collection. 11:00 a.m. May 9, 1914.

Per Cent Sewage in Mixture..3..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per litre sewage	Constant coeff. K
0	6.92	----	--	231	---	------
1	4.80	2.12	31		71	.00221
2	2.86	4.06	59		135	.00266
3	1.48	5.44	79		181	.00310
4	.26	6.66	96		222	.00494
5	.20	6.72	98		224	.00427
6	.10	6.82	99		227	.00426
7	.00	6.92	100		231	------
8						
9						
10						
					Average	.00357

Per Cent Sewage in Mixture..1..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per litre sewage	Constant coeff. K
0	7.28	----	--	728	---	------
1	6.00	1.28	18		128	.00350
2	5.54	1.74	24		174	.00247
3	5.28	2.00	27		200	.00193
4	4.26	3.02	41		302	.00242
5	3.64	3.64	50		364	.00260
6	2.80	4.48	62		448	.00288
7	2.31	4.97	69		497	.00297
8	1.87	5.41	74		541	.00307
9	1.34	5.94	82		594	.00354
10	1.34	5.94	82		594	.00306
					Average	.00284

Per Cent. Sewage in Mixture..5..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per litre sewage	Constant coeff. K
0	7.56	----	--	1512	---	------
1	6.40	1.16	15		232	.00602
2	5.96	1.60	21		320	.00430
3	5.58	1.98	26		396	.00366
4	5.35	2.21	29		441	.00312
5	4.94	2.62	35		524	.00308
6	4.49	3.07	41		614	.00314
7	4.16	3.40	45		680	.00308
8	3.75	3.81	50		762	.00317
9	3.24	4.32	57		864	.0030_6
10						
					Average	.00357

TABLE. XV.

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source. Raw Champaign Sewage   Date and time of collection. 11:00 a.m. May 11,1914

Dissolved Oxygen... 0.00

Per Cent Sewage in Mixture.. 2..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per liter sewage	Phelps Coeff. K
0	7.80	----	—	390	---	------
1	2.26	5.54	71		277	.01120
2	.14	7.66	98		383	.01818
3	.00	7.80	100		390	------
4						
5						
6						
7						
8						
9						
10						
					Average	.01469

Per Cent Sewage in Mixture. 1..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per liter sewage	Phelps Coeff. K
0	7.80	----	—	780	---	------
1	5.66	2.14	27		214	.00580
2	3.54	4.26	54		426	.00714
3	1.00	6.80	87		680	.01238
4	.58	7.22	92		722	.01175
5	.24	7.56	97		756	.01260
6	.00	7.80	100		780	------
7						
8						
9						
10						
					Average	.00993

Per Cent. Sewage in Mixture. .5..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 liter sewage	Mg. O absorbed per liter sewage	Phelps Coeff. K
0	7.90	----	—	1580	---	------
1	6.48	1.42	18		284	.00716
2	5.72	2.18	28		436	.00583
3	4.90	3.00	38		600	.00576
4	4.29	3.61	46		722	.00552
5	3.87	4.03	51		806	.00516
6	3.31	4.59	58		918	.00524
7	2.92	4.98	63		996	.00514
8	2.68	5.22	66		1044	.00489
9	2.57	5.33	68		1066	.00451
10	2.40	5.50	70		1100	.00431
					Average	.00535

TABLE XVI.

OXYGEN DEMAND OF SEWAGE IN VARIOUS CONCENTRATIONS ON INCUBATION AT 20° C. FOR TEN DAYS.

Source...Raw Champaign Sewage........ Date and time of

Dissolved Oxygen...0.00... collection. 11:00 a.m. May 14,1914

Per Cent Sewage in Mixture..1..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Average coeff. K
0	8.26	----	--	826	---	------
1	6.30	1.96	12		196	.00490
2	5.62	2.64	32		264	.00348
3	5.08	3.18	38		318	.00293
4	4.62	3.64	44		364	.00263
5	4.10	4.16	50		416	.00253
6	3.46	4.80	58		480	.00262
7	2.88	5.38	65		538	.00272
8	2.41	5.85	71		585	.00278
9	1.74	6.52	79		652	.00313
10	1.16	7.10	86		710	.00355
					Average	.00313

Per Cent Sewage in Mixture..5..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Average coeff. K
0	8.44	----	--	1688	---	------
1	7.22	1.22	14		244	.00581
2	7.02	1.42	16		284	.00333
3	----	----	--		---	------
4	6.80	1.64	19		328	.00195
5	6.43	2.01	24		402	.00197
6	6.10	2.34	28		468	.00196
7	5.84	2.60	31		520	.00190
8	5.60	2.84	34		568	.00185
9	5.29	3.15	37		630	.00188
10	4.96	3.48	41		696	.00192
					Average	.00251

Per Cent. Sewage in Mixture..25..

Time of Incubation Days	P.P.M. O in diluted sewage	P.P.M. O absorbed in diluted sewage	% O absorbed in mixture	Mg. O added to 1 litre sewage	Mg. O absorbed per litre sewage	Average coeff. K
0	8.72	----	--	3488	---	------
1	7.82	.90	10		360	.00788
2	7.52	1.20	13		480	.00536
3	7.38	1.34	16		536	.00402
4	7.28	1.44	17		576	.00326
5	7.00	1.72	20		688	.00318
6	6.80	1.92	22		768	.00300
7	6.54	2.18	25		872	.00297
8	6.26	2.46	28		984	.00299
9	----	----	--		---	------
10	5.60	3.12	36		1248	.00317
					Average	.00398

TABLE XVII.

Limits of consumption which give most concordant values of K.

Table	Per cent mixture	Minimum %	Maximum %
VII	3	60	83
"	2	38	67
VIII	5	67	94
"	2	38	70
"	1	36	50
IX	3	34	62
"	1	30	47
X	4	75	82
"	2	41	63
"	1	19	55
XI	3	70	80
"	1	30	41
XII	3	57	94
"	1	41	57
"	.5	21	32
XIII	3	61	84
"	1	23	52
XIV	3	59	79
"	1	62	74
"	.5	29	57
XVI	1	38	71
"	.5	19	41
"	.25	17	36
Average		42	64

TABLE XVIII.

RAW URBANA SEWAGE.

	Urbana I				Urbana II				Urbana III				Urbana IV			
Diln. %	% used	Mg add.	Mg used	K	% used	Mg add.	Mg used	K	% used	Mg add.	Mg used	K	% used	Mg add.	Mg used	K
.5	---	---	---	-----	---	---	---	-----	---	---	---	-----	34	1680	576	.00208
1.	---	---	---	-----	50	780	388	.00144	55	856	468	.00143	57	884	504	.00205
2.	73	429	314	.00151	70	372	260	.00114	67	430	288	.00122	--	----	---	-----
3.	81	282	226	.00135	---	---	---	-----	---	---	---	-----	98	287	283	.00265
4.	---	---	---	-----	---	---	---	-----	100	211	211	.00179	--	----	---	-----
5.	100	162	162	.00145	100	148	148	.00210	---	---	---	-----	--	----	---	-----

SEPTIC URBANA SEWAGE.

Diln. %	% used	Mg add.	Mg used	K	% used	Mg add.	Mg used	K	% used	Mg add.	Mg used	K	% used	Mg add.	Mg used	K
1.	---	---	---	-----	47	808	376	.00136	41	854	354	.00113	52	836	428	.00155
2.	75	409	306	.00144	---	---	---	-----	---	---	---	-----	--	---	---	-----
3.	85	276	239	.00143	62	263	163	.00091	81	276	225	.00110	84	275	231	.00149

RAW CHAMPAIGN SEWAGE.

	I				II				III			
.25	---	----	---	-----	---	----	---	-----	36	3488	1248	.00398
.5	57	1512	864	.00357	70	1580	1100	.00535	41	1688	696	.00251
1.	82	728	594	.00284	100	780	780	.00993	86	826	710	.00313
2.	---	----	---	-----	100	390	390	.01469	--	----	----	-----
3.	100	231	231	.00357	---	----	----	-----	--	----	----	-----

days, there is still a considerable oxygen consumption; the variability of the mg. oxygen absorbed per liter of sewage is so great that no reliance can be placed upon this method of reporting oxygen demand. The amount of oxygen absorbed depends entirely upon the amount added, and is always higher in higher dilutions. The values of K seem to be more concordant. Table XVII shows the limits of oxygen consumption which give most concordant values, the range being from 42-64%. The values are generally higher in the higher dilutions.

Table XVIII gives comparisons of raw and septic sewage from the Urbana tank, and shows that little improvement is effected in I and II as regards oxygen demand, but considerable improvement in III and IV; the chemical data shows quite an improvement in II as regards oxygen consumed, residue and nitrogen factors, and not very much improvement in III. This indicates the desirability of oxygen consumed data in dealing with disposal of raw or septic sewage.

GENERAL CONCLUSIONS.

1. The amount of oxygen absorbed in a given time by sewage, obtained by dividing loss of dissolved oxygen by the dilution, gives very discordant results, and increases in the higher dilutions.

2. The rate of oxygen consumption seems to follow roughly the course of a mono-molecular reaction when the amount consumed is 42-64% of that added.

3. A standard test should extend over 4-5 days at

20° with final oxygen consumption of about 70%; at least three determinations should be made between 30 and 70%; dilutions between 0.5 and 3.0% give approximately this absorption. The "oxygen demand" should be reported by Phelp's coefficient.

4. The test is indispensable in estimating the strength of sewage as regards its disposal in streams, lakes or harbors