CXXVII. THE DIURNAL VARIATION OF THE GASEOUS CONSTITUENTS OF RIVER WATERS.

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(Received June 17th, 1927.)

HISTORICAL INTRODUCTION.

MORREN [1841] studied the variations of dissolved oxygen in an aquarium throughout almost a year and made observations of diurnal changes of the oxygen content of the water. His figures, however, record the percentage oxygen in the total dissolved gases, and he makes only one reference to the actual amount present. He says: "Le volume de l'air dissous était variable et augmentait notablement avec la quantité d'oxygène. La quantité d'azote restait sensiblement constante mais l'acide carbonique contenu dans l'eau variait aussi." He gives no figures of actual quantity present, but it is of interest that he records supersaturation.

In rivers, however, he finds no such variation. He suggests that his failure to detect a maximum is due to a rapid current, and a sandy bed, and without giving any figures says that a slow river flowing over mud does not contain so much dissolved oxygen, and that the figures obtained show considerable variation.

Considerable work has been done on the seasonal variations of dissolved gases in lakes and reservoirs, and on the relation of the dissolved gases to the presence of algae.

Birge and Juday [1911] have recorded the dissolved oxygen content of Lake Mendota at various depths over a period of 12 months, but showed no diurnal variation.

Butler and Coste [1923], working in the Thames estuary, showed seasonal variation of dissolved oxygen, and commented on the phenomenon of supersaturation.

The relation of dissolved gases to algae has been demonstrated by Chambers [1912] on the results of his work in the lagoons at the botanical gardens of St Louis; of special interest is his observation that on clear sunny days the water became supersaturated with dissolved oxygen, while on cloudy days the percentage of oxygen fell below saturation, sometimes as low as 40 %.

Moore [1921], correlating the results of 10 years' work, showed the seasonal variations and the interrelations of dissolved oxygen, diatoms, light, temperature, nitrite and alkalinity in the sea.

The present paper giving the diurnal variation of dissolved gases in small rivers is an addition to the data there recorded.

Cowles and Schwitalla [1923] have recorded some similar variations in hydrogen ion concentration, but no figures have been given for diurnal variation in ammoniacal nitrogen.

OBSERVATIONS ON RIVER WATERS.

During the past year several surveys have been made of the River Lark in connection with the pollution by the effluents from the beet-sugar factory at Bury St Edmunds. The River Lark is a small river rising in the chalk hills to the south of Bury St Edmunds. From here it flows in a north-westerly direction and joins the Great Ouse near Prickwillow, 25 miles from the source.

The beet-sugar factory at Bury St Edmunds discharges its waste waters into the river about a mile north of the city, and the part of the river under observation stretches from Bury through the villages of Fornham, Lackford, Icklingham, Barton Mills, Mildenhall to Westrow, a distance of 14 miles. The usual determinations made on these surveys were:

1. Dissolved oxygen.
2. Ammoniacal nitrogen.
3. p_H value.
4. Water temperature.

It was noticed that occasional anomalies occurred in the values obtained from the dissolved oxygen determinations, *e.g.*

At Icklingham, July 29th, 1926, 10.20 a.m., 59 % of saturation of O_2 .

2.5 p.m., 105 " "

At Fornham, March 22nd, 1927, 3.35 p.m., 112 % of saturation of O_2 .

23rd, 1927, 4.20 p.m., 88 " "

24th, 1927, 12.20 p.m., 118 " "

25th, 1927, 11.20 p.m., 90 " "

and it was concluded that such factors as time of sampling, weather conditions, amount of light, etc., have a greater effect upon the amount of dissolved oxygen present than was previously supposed.

RIVER LARK. SERIES I.

Accordingly, it was decided to carry out hourly determinations of dissolved oxygen, ammoniacal nitrogen, p_H and water temperature, over a period of 24 hours at a fixed point.

A convenient place for sampling was chosen at Icklingham, 7 miles below the confluence of the river and the leet from the beet-sugar factory.

The figures obtained over a period of 10 months are given below to indicate the changes produced at this spot during the beet-sugar campaign.

Table I.

Date	Time	Temp. ° C.	Dissolved oxygen. Parts per 100,000	% satura- tion of oxygen	p _H value	Am- moniacal nitrogen. Parts per 100,000	Remarks
29. vii. 1926	10.20 a.m.	15	0.59	59	7.5	0.05	
29. vii. 1926	2.5 p.m.	17	1.01	105	—	—	
14. ix. 1926	7.20 p.m.	15	1.05	102	8.2	0.02	
6. x. 1926	—	14.5	—	86	8.0	0.01	Fermented effluent dis- charged from factory
27. x. 1926	5.15 p.m.	6	0.395	31	7.5	0.02	Unfermented effluent discharging from fac- tory
28. x. 1926	2.5 p.m.	6	0.485	38	7.5	0.02	
29. x. 1926	10.15 a.m.	7	0.203	17	7.4	0.15	
16. xi. 1926	3.10 p.m.	9.5	0.096	8	7.3	0.01	Process water and wash water discharging from factory
17. xi. 1926	2.10 p.m.	10	0.090	8	7.3	0.015	
23. ii. 1927	5.45 p.m.	9	0.702	60	7.6	0.03	Effluent ceased, but pits being washed out Full flood
24. ii. 1927	9.45 a.m.	8	0.602	52	7.6	0.08	
25. ii. 1927	4.45 p.m.	6	0.845	67	7.8	0.02	
7. iii. 1927	5.45 p.m.	7	1.021	83	7.7	0.04	
8. iii. 1927	4.35 p.m.	8	1.098	91	7.8	0.035	
10. iii. 1927	1.45 p.m.	6.5	1.112	90	7.7	0.04	
22. iii. 1927	2.15 p.m.	12	1.588	144	7.8	0.02	
23. iii. 1927	3.10 p.m.	12	1.555	141	8.0	0.015-0.02	
25. iii. 1927	12.15 p.m.	8	1.221	102	7.8	0.03	
26. iv. 1927	11.40 a.m.	8.75	1.354	118	7.7	0.035	

From the above figures it will be seen that, at this spot during the months of October and November, 1926, the river was badly de-oxygenated when the various effluents were being discharged from the factory, and that, after February, 1927, when the beet-sugar campaign ended, the recovery in oxygenation was rapid.

As a result of the October and November pollution, the whole bed of the river over a stretch of 10 miles had been covered with a growth of *Sphaerotilus natans*, a sewage fungus, which in February, 1927, commenced to turn brown, decay and break up.

By March 11th, the sewage fungus had almost disappeared and on the date of the experiment, March 30/31st, large quantities of diatoms had grown on the weeds and river bottom (see below). At Icklingham, the river is about 30 feet wide, and has an average depth of 3-4 feet, and 200 yards below the point of sampling is a mill where the river is dammed. The speed of flow is about 600 yards per hour.

The period of observation extended from 7 p.m., March 30th to 7 p.m., March 31st; hourly samples were taken, and the following determinations made:

1. Dissolved oxygen (Winkler's method).
2. Ammoniacal nitrogen (by direct nesslerising and subsequent comparison against artificial colour standards).
3. p_H value. (On the River Lark, by addition of cresol red or phenol red and comparison against Clarke's colour chart. On the River Itchen, by Gillespie's method.)

4. Water temperature.

The results obtained are given in Table II and graphically in Fig. 1.

Table II.

Time G.M.T.	Temp. ° C.	Dissolved oxygen. Parts per 100,000		% saturation dissolved oxygen		Ammoniacal nitrogen. Parts per 100,000	pH value	Remarks
		Without prelimin. oxidation	With prelimin. oxidation	Without prelimin. oxidation	With prelimin. oxidation			
Mar. 30th, 1927								
7 p.m.	9.4	1.384	1.377	119	119	0.01-0.015	7.9	Fine
8 "	9.2	1.260	1.249	108	107	0.015	7.9	"
9 "	9.2	1.147	1.127	98.5	97	0.02	7.9	"
10 "	8.6	1.036	1.017	88	86	0.025-0.03	7.9	"
11 "	8.0	0.972	0.711	81	59	0.03-0.035	7.8-7.9	"
Midnight	8.0	0.865	0.846	72	70.5	0.11	7.7-7.8	"
Mar. 31st, 1927								
1 a.m.	7.7	0.798	0.784	66	65	0.13	7.7-7.8	
2 "	7.1	0.797	0.796	65	65	0.16-0.17	7.6-7.7	
3 "	7.1	0.795	0.694	65	56	0.15	7.6-7.7	
4 "	7.0	0.800	0.805	65	65	0.15-0.16	7.6-7.7	
5 "	6.75	0.806	0.791	65	64	0.16	7.6-7.7	Dawn
6 "	6.9	0.808	0.769	66	63	0.13-0.14	7.6-7.7	Bright
7 "	6.9	0.810	0.783	66	63	0.1	7.6-7.7	Bright sunlight
8 "	6.9	0.838	0.861	68	70	0.07	7.6-7.7	"
9 "	7.0	0.953	0.920	77	75	0.06	7.6-7.7	"
10 "	7.5	1.094	1.089	90	90	0.07-0.08	7.7	"
11 "	8.2	1.413	1.405	119	118	0.03	7.8	"
Midday	8.9	1.535	1.501	131	129	0.02	7.8-7.9	Dull
1 p.m.	9.25	1.679	1.646	144	141	0.01-0.015	7.9	"
2 "	9.5	1.758	1.692	151	146	0.01-0.015	7.9-8.0	"
3 "	10.0	1.803	1.819	157	158	0.01	7.9-8.0	"
4 "	10.0	1.767	1.726	153	150	0.01	7.9-8.0	"
5 "	9.75	1.690	1.614	146	139	0.01	7.9-8.0	Rain
6 "	9.6	1.513	1.467	130	126	0.01	7.9-8.0	"
7 "	9.25	1.343	1.270	116	109	0.01-0.015	7.9-8.0	Sunset

Sunset March 30th, 1927, 6.28 p.m.

Sunrise " 31st, " 5.40 a.m.

Sunset " 31st, " 6.29 p.m.

Variation of dissolved oxygen.

The dissolved oxygen content of the river showed a remarkable periodic variation between 0.795 and 1.803 parts per 100,000, *i.e.* between 65 and 157 % of saturation of oxygen at the temperature of sampling.

From 7 p.m., March 30th, the values obtained decreased steadily until 1 a.m., March 31st, from 1 a.m. to 7 a.m. the dissolved oxygen content was at a minimum, after which a very rapid increase took place, reaching the maximum value at 3 p.m.; from 3 p.m. onwards, a rapid decrease took place for the remainder of the period of observation.

From 9 p.m., March 30th, until 10 a.m., March 31st, all samples had a dissolved oxygen content below 100 % of saturation, while for the remainder of the 24 hours the water was supersaturated.

The samples which underwent preliminary oxidation before estimation of dissolved oxygen generally gave values about 2 % less than those fixed and estimated in the ordinary way.

Variation of ammoniacal nitrogen.

Considering the fact that the ammoniacal nitrogen content of a normal river water is about 0.01 parts per 100,000, the figures obtained during this experiment must be regarded as abnormal, and it may here be pointed out that very high ammonia figures have been obtained at various stations on this river, coincident with the presence of large quantities of broken and decaying sewage fungus.

At 7 p.m., March 30th, the water contained 0.01–0.015 parts N per 100,000, which increased to 0.015 parts at 8 p.m. From 8 p.m. until 11 p.m. the increase in the ammoniacal nitrogen content was more rapid, and after 11 p.m. it increased still more rapidly, reaching a maximum value of 0.165 parts per 100,000 at 2 a.m., March 31st, and remaining at about this figure until 5 a.m.

After 5 a.m. the values obtained fell very rapidly until 1 p.m.; the minimum value of 0.01 parts per 100,000 was reached at 3 p.m. and this figure was maintained until 6 p.m., followed by a slight increase at 7 p.m.

Variation of p_H value.

During the period of observation the reaction of the water changed slightly between p_H 7.6 and 8.0.

After 10 p.m., March 30th, the p_H value decreased gradually, reaching a minimum at 2 a.m., March 31st, and remaining constant until 9 a.m., after which a steady increase took place to a maximum value at 2 p.m. which persisted until 7 p.m.

Variation of water temperature.

From 7 p.m., March 30th onwards, the water temperature fell steadily, reaching a minimum of 6.75° at 5 a.m., March 31st. After 10 a.m. it increased constantly to a maximum of 10° at 3 p.m., after which a steady decrease took place. The range was from 6.75° to 10°.

Conclusions based on the chemical data.

It is well known that all green plants under the influence of light consume carbon dioxide and liberate oxygen. On the date of the experiment, the river contained very few of the larger green plants, but diatoms were at the spring maximum of their growth. The result is seen in the abnormal figures of super-saturation of dissolved oxygen obtained during the experiment. Large clots of these organisms, floating in the water, gave evidence of their abundance. Rough estimations of this growth have been made by putting glass slides on the river bed. The slides are each 2.5 × 8.2 cm. and four are fixed in an ordinary photographic printing frame. These are taken up after a fortnight's immersion, washed with distilled water and the deposit dried at 100° and weighed.

Dates of immersion	Amount in g. per sq. cm.	
	No. 1 frame	No. 2 frame
1. xi. 1926 to 15. xi. 1926	0.003	0.004
9. iii. 1927 to 23. iii. 1927	0.010	0.015
23. iii. 1927 to 7. iv. 1927	0.073	0.070
7. iv. 1927 to 21. iv. 1927	0.047	—

Animals and fungi, as well as green plants, take up oxygen during both day and night and give out carbon dioxide. During the night, photosynthetic production of oxygen ceases, while biological and chemical consumption of oxygen continues, so that the dissolved oxygen content of the water is at its minimum during this period.

Fig. 1.

At Lackford (2 miles above Icklingham) a small sewage effluent enters the river with an ammoniacal nitrogen content of 0.8 parts per 100,000. Previous samples, taken during the day, 400 yards below the confluence of the leet and river, show that the dilution is sufficient to reduce the nitrogen content to 0.01 parts per 100,000.

By the decay of vegetable matter a considerable amount of ammonia is produced; some figures, obtained on previous surveys, are given below showing

very high ammonia values coincident with the presence of large quantities of broken sewage fungus.

		N parts per 100,000
Feb. 23rd, 1927, Barton Mills	...	0.095
„ 23rd, 1927, Mildenhall	...	0.135
„ 23rd, 1927, Westrow	...	0.125
Mar. 7th-10th, 1927, Fornham to Westrow (15 miles)	...	0.03-0.15
„ 22nd, 1927, Barton Mills	...	0.16

Fig. 2.

During the day, when the oxygen content of the river is high, the ammonia is oxidised to nitrates, with the result that after 3 p.m., when the oxygen content is at a maximum, the ammoniacal nitrogen content is at a minimum [cf. Bonazzi, 1919]. Correspondingly, when the oxygen content has fallen below 100 % of saturation, less of the ammonia produced is removed by oxidation, and during the minimum of oxygen period, 1 a.m. to 7 a.m., the free ammonia figures are at a maximum.

Another possible cause of the rapid increase of free ammonia with the coming of night is that the fixation of nitrogen from ammonia may cease with the disappearance of sunlight.

During the day the photosynthetic reactions of the plants remove CO_2 ; at night, when photosynthesis ceases, carbon dioxide is still being liberated by plant and animal respiration with the result that a certain amount of normal carbonate is converted to bicarbonate and the p_{H} value of the water falls to its minimum during this period.

RIVER LARK. SERIES II.

On April 27/28th, at Icklingham, a further set of observations over a period of 24 hours was made confirming the results obtained on March 30/31st. The figures are given in Table III and graphically in Fig. 2.

Table III.

Time G.M.T.	Temp. ° C.	Dissolved oxygen. Parts per 100,000	% satura- tion dis- solved oxygen	Am- moniacal nitrogen. Parts per 100,000	p_{H} value	Remarks
6 p.m.	11	1.532	137	0.02	7.9-8.0	Bright sunshine
7 "	10.6	1.463	130	0.02	7.9-8.0	Good light. Sundown
8 "	10	1.422	124	0.02	7.9-8.0	Dusk
9 "	10	1.291	112	0.025	7.9-8.0	Dark. Fine
10 "	9.5	1.177	101	0.02	7.9-8.0	Clear and starry. No moon. Fine
11 "	9.5	1.058	91	0.02	7.8	" " "
Midnight	9	0.960	82	0.03	7.7-7.8	" " "
1 a.m.	8.5	0.808	68	0.09	7.6-7.7	" " "
2 "	8	0.738	61.5	0.13	7.6-7.7	" " "
3 "	8	0.702	58.5	0.14	7.6	Sky just lightening. Fine
4 "	8	0.710	60	0.16	7.5-7.6	" " "
5 "	7	0.708	57	0.15	7.5-7.6	" " "
6 "	7	0.723	58	0.15	7.5-7.6	" " "
7 "	7	0.792	64	0.15	7.5-7.6	" " "
8 "	7.5	0.894	73	0.15	7.6-7.7	Bright sunshine. Fine
9 "	7.8	1.005	83	0.14	7.6-7.7	" " "
10 "	8.5	1.212	102	0.1	7.7	" " "
11 "	9.5	1.459	126	0.04	7.7-7.8	" " "
Midday	9.7	1.580	137	0.03	7.8	" " "
1 p.m.	10.5	1.787	158	0.02-0.025	7.9-8.0	" " "
2 "	10.6	1.889	167	0.02-0.025	8.0	" " "
3 "	11.2	1.969	176	0.02-0.025	8.0	" " "
4 "	11.2	1.995	178	0.02	8.0	Cloudy. Fine
5 "	11.2	1.863	168	0.02	8.0	" "
6 "	11.5	1.807	163	0.02	8.0	" "
Sunset April 27th, 7.15 p.m.						
Sunrise " 28th, 4.40 a.m.						
Sunset " 28th, 7.16 p.m.						

April 27th was a bright sunny day, following several bright days, whereas on March 30th the morning, although fine, was not so bright and the afternoon was dull. The effect of this difference in the weather conditions is seen in the greater difference between the maximum and minimum values of percentage saturation of oxygen, viz.:

March 30th	Maximum	157 % at 3 p.m.
April 27th	Maximum	178 % at 5 p.m.
March 30th	Minimum	65 % from 1 a.m. to 7 a.m.
April 27th	Minimum	57 % from 4 a.m. to 7 a.m.

The effect of the longer period of light on April 27/28th, compared to that on March 30/31st, is seen in the shorter period of minimum of oxygen during the night. By superimposing the March and April curves these differences are very clearly shown.

RIVER ITCHEN. SERIES I.

For the purposes of comparison a similar experiment was made on the River Itchen in Hampshire. The general topography of this stream has been previously described [Butcher, 1927]. The Itchen is not polluted in any way. The place of sampling was immediately above a small weir at the Ministry of Agriculture and Fisheries' Research Station, Alresford, where the river is about 2 feet deep and 20 feet wide, and its speed of flow is about 1300 yards per hour.

The results are given in Table IV and graphically in Fig. 3.

Table IV.

Time G.M.T.	Temp. ° C.	Dissolved oxygen. Parts per 100,000	% satura- tion dis- solved oxygen	Am- moniacal nitrogen. Parts per 100,000	p _H value	Remarks
9 p.m.	9.4	1.050	90.5	<0.01	8.0	Dark
10 "	9.0	1.053	90	<0.01	7.8	Clouds obscuring moon
11 "	8.6	1.024	87	<0.01	8.0	
Midnight	8.0	1.027	86	<0.01	7.8	Moonset
1 a.m.	8.0	0.979	82	<0.01	7.7	
2 "	7.8	0.995	82	<0.01	7.8	
3 "	7.5	1.035	85	<0.01	7.6	Raining
4 "	7.5	0.978	80.5	<0.01	7.5	" Sky just lightening
5 "	7.3	0.974	80	<0.01	7.6	" Dawn
6 "	7.1	0.985	81	<0.01	7.5	"
7 "	7.1	1.040	85	0.01	7.5	"
8 "	7.1	1.095	90	0.0015	7.5	" River rising and turbid
9 "	7.1	1.135	93	0.02-0.025	7.6	"
10 "	7.0	1.135	93	0.01	7.6	"
11 "	7.0	1.199	97	0.01	7.5	" slightly
Midday	7.3	1.321	108	0.015	7.4	" "
1 p.m.	7.4	1.322	109	0.01	7.6	" "
2 "	7.8	1.349	112	<0.01	7.6	Fine. Dull
3 "	8.0	1.247	104	<0.01	7.6	Brighter. No sun, cold wind
4 "	8.1	1.280	107	<0.01	7.6	Fine. Storm at 4.30
5 "	8.2	1.313	109	<0.01	7.5	Fine
6 "	8.0	1.279	107	<0.01	7.6	Sun shining
7 "	8.0	1.121	93	<0.01	7.6	Sunset
8 "	7.5	1.075	88	<0.01	7.5	Clear night
9 "	7.0	0.994	81	<0.01	7.5	"

Sunset April 6th, 6.39 p.m.

Sunrise " 7th, 5.25 a.m.

Sunset " 7th, 6.41 p.m.

Variation in dissolved oxygen.

The dissolved oxygen curve is similar to that obtained from the Lark figures. The variation is less, ranging from 0.974 parts per 100,000 to 1.349 parts per 100,000 compared to 0.795 and 1.803 for the Lark.

Variation in ammoniacal nitrogen.

The ammoniacal nitrogen content is normally less than 0.01 parts per 100,000. It seems probable that the higher values of 0.01 to 0.025 obtained between 7 a.m. and 1 p.m. are due to the washing in of ammonia compounds from the soil by flood-water. There is in the Itchen nothing comparable to the diurnal variation of ammonia in the Lark.

Variation in p_H .

The maximum p_H value, 7.8–8.0, was obtained from 9 p.m. until 1 a.m. after which a rapid decrease was observed to 7.5–7.6 at 3 a.m., the reaction remaining constant at this figure for the remainder of the period of observation.

Fig. 3. River Itchen. April 6/7th, 1927.

— Oxygen, percentage saturation of dissolved
 - - - Ammoniacal nitrogen, parts per 100,000
 p_H value Temperature °C

Variation in temperature.

The temperature curve showed a minimum from 6 a.m. to 11 a.m., after which it increased steadily to a maximum at 5 p.m.

RIVER ITCHEN. SERIES II.

A further set of observations was made on the Itchen on May 4/5th and the results are given in Table V and graphically in Fig. 4.

Table V.

Time G.M.T.	Temp. ° C.	Dissolved oxygen. Parts per 100,000	% saturation dissolved oxygen	pH value	Remarks
6 p.m.	11.6	1.170	105	8.0	Cloudy. Fine
7 "	11.3	1.043	93	7.8	Dull. Raining
8 "	11.0	0.974	87	7.7	Dusk. Dull. Raining
9 "	11.0	1.000	89	7.6	Dark. Raining
10 "	10.8	0.935	83	7.6	Cloudy. Fine
11 "	10.6	0.939	83	7.55	" "
Midnight	10.3	0.897	79	7.55	" "
1 a.m.	10.1	0.886	77	7.6	" "
2 "	10.0	0.885	77	7.55	" "
3 "	10.0	0.882	77	7.55	Sky just lightening. Cloudy. Fine
4 "	10.0	0.875	76	7.55	Dawn. Cloudy. Fine
5 "	10.0	0.893	78	7.5	Sunrise. Cloudy
6 "	9.9	0.949	83	7.55	Bright
7 "	9.9	1.035	90	7.5	Cloudy. Fine
8 "	10.0	1.135	99	7.6	" "
9 "	10.1	1.253	109	7.55	" "
10 "	10.4	1.170	103	7.7	Heavy thunderstorm at 9.45
11 "	10.2	1.170	102	7.6	Very dull. Raining
Midday	10.3	1.214	106.5	7.6	Raining
1 p.m.	11.2	1.285	115	7.75	Sun shining
2 "	12.8	1.409	130.5	8.0	"
3 "	13.2	1.302	122	8.0	"
4 "	13.7	1.299	122	7.9	"
5 "	13.8	1.325	124	7.9	"
6 "	13.6	1.255	118	7.9	"

Sunset May 4th, 7.26 p.m.

Sunrise " 5th, 4.27 a.m.

Sunset " 5th, 7.27 p.m.

Fig. 4. River Itchen. May 4/5th, 1927.

————— Oxygen, percentage saturation of dissolved
 - - - - - pH value Temperature °C.

Variation in dissolved oxygen.

This curve shows greater similarity to those obtained during the Lark experiments. The greater difference between the maximum and minimum values, 1.409 and 0.875 parts per 100,000 respectively, is due to the brighter day of May 5th compared with April 7th. The irregularity in the oxygen curve after 9 a.m. was coincident with a heavy thunderstorm, the effect of which is also shown on the p_H and temperature curves.

Variation in p_H .

The p_H dropped gradually from 8.0 at 6 p.m. to 7.5 at 11 p.m., at which value it remained constant until 9 a.m. when it began to rise, was checked by the storm, and then went on to 8.0 at 3 p.m. After 4 p.m. a slight fall began.

Variation in temperature.

The temperature shows a regular fall from 11.6° at 6 p.m. to 9.9° at 7 a.m., after which a regular rise, again checked by the storm, to 13.8° occurred.

Variation in ammonia.

As in the experiment of April 6/7th, the ammoniacal nitrogen content showed no significant variation comparable to that obtained on the River Lark.

DISCUSSION OF RESULTS.

Dissolved oxygen curves.

All four curves show a similarity of structure with a minimum during darkness and a maximum 2 or 3 hours after noon.

Owing to the continuous absorption of oxygen by all organisms during the night, it seems that the oxygen content should fall continuously to a minimum value at dawn. In practice each curve shows a minimum *period* extending over several hours of the night, and it seems probable that an equilibrium is established between solution of oxygen from air and absorption of oxygen by organisms. The time-lag after dawn and after noon is in accordance with the known facts of photosynthesis [Stiles, 1925].

It will be noticed that the difference between the maximum and minimum values of oxygen obtained in the River Lark is considerably greater than that in the case of the Itchen and a comparison of the physical conditions of the two rivers is made below.

<i>River Lark</i>	<i>River Itchen</i>
Speed of flow 600 yards per hour	Speed of flow 1300 yards per hour
Depth 4-5 ft.	Depth 2-3 ft.
Polluted during the winter by effluents from beet-sugar factory	Unpolluted
Bottom—mud containing decomposing organic matter	Bottom—clean stones
Higher green plants very small and young: <i>Sparganium simplex</i> and <i>Potamogeton lucens</i> dominant	Higher green plants in some quantity and of continuous growth: <i>Callitriche stagnalis</i> and <i>Ranunculus penicillatus</i> dominant

Since the River Itchen is the more rapid and shallow stream, it would be expected that the greater agitation would keep the oxygen content closer to the saturation value than in the slower and deeper River Lark.

The spring maximum of diatoms in the River Lark is considerably greater than in the River Itchen (possibly due to the recent pollution). This difference in the quantity of diatoms causes increased photosynthetic production of oxygen resulting in the higher values of supersaturation obtained on the River Lark.

The oxidation of the organic matter in the mud of the River Lark would tend to give lower minimum oxygen values than in the Itchen, where mud is absent, and this is borne out by the minimum values obtained.

The larger quantity of higher green plants in the Itchen would tend to increase the maximum oxygen values, but, at the time of the experiment, diatom activity overshadows that of the larger plants.

SUMMARY.

Day

Photosynthesis by plants causes assimilation of carbon dioxide and liberation of oxygen, while decay of organic matter produces ammonia which is removed by the high concentration of oxygen, resulting in:

Oxygen maximum.

Ammoniacal nitrogen minimum.

p_H value maximum.

Night

Photosynthetic production of oxygen ceases, and the ammonia produced by organic decay is not removed. Animal and plant respiration continues, taking up oxygen and producing carbon dioxide, resulting in:

Oxygen minimum.

Ammoniacal nitrogen maximum.

p_H value minimum.

In conclusion, the authors wish to express their thanks to the Ministry of Agriculture and Fisheries and to Sir R. Robertson, the Government Chemist, for permission to publish these results and to Mr A. C. Gardiner, of the Ministry of Agriculture and Fisheries for his assistance in the Itchen experiment.

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Note added August 16th. Since writing the above we have seen a reference to a paper by B. Seydel "Ueber die Schwankungen des Sauerstoffgehaltes in Teichen" (*Mitt. d. Fisch-Ver. f. d. Prov. Brandenburg*. Bd. **4**, 1912-13) in which are given figures for the diurnal variation of the oxygen content of ponds. His work seems merely to amplify that of Morren [1841].