XLV.—*Organic Matter in Sea-Water.*

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ON page 133 of the Sixth Report of the Rivers Commission, it is stated that the proportion of organic elements in sea-water varies between such wide limits in different samples as to strongly suggest that much of the organic matter consists of living organisms so

minute and gelatinous as to pass readily through the best filters. It was suggested to me by Dr. Frankland that further investigation of the quantity and properties of this organic matter would be of service; of which suggestion this paper is one of the results.

Through the kindness of Mr. J. P. Knight, manager of the London, Brighton, and South Coast Railway, I was enabled to make the following experiments on water collected in mid-channel between Newhaven and Dieppe by the engineers of the Company's boats. Written directions accompanied each of the stoppered glass carboys used, to the effect that the sea-cock in the engine-room was to be allowed to run for a minute; the carboy was then to be filled, emptied and re-filled, and then immediately to be tied down with a piece of wash-leather and forwarded. I have to thank Captain Harvey, the Marine Superintendent at Newhaven, for personally seeing that these directions were attended to.

Microscopic examinations were made from time to time with the highest power at my command (an eighth), but I was unable to detect infusoria by means of it.

The water was examined by the combustion method, and also the nitrogen evolved as ammonia and as albuminoid ammonia, was estimated. The following table (p. 322) gives the result of analyses extending over a period of about two months.

These samples collected in approximately the same place show a considerable amount of variation; but in no case does the amount of organic N exceed that of organic C, although the ratio varies between the limits of 5·3 and 1·29, the mean being 3·2.

The water being sometimes not perfectly clear, an experiment was made in order to determine whether the solid matter contained an important quantity of organic constituents. Two litres of the water of March 18th were filtered through a Casamajor's funnel with a disc of Swedish paper one inch in diameter, and the suspended matter dried at 100° C. and weighed. Its amount equalled 0·900 part per 100,000. A litre of the water was placed in a tall cylindrical jar, and allowed to subside; the clear water was syphoned off and examined. The sediment with 60 c.c. of clear water was also tested, allowance being made for the organic matter in the water. The following are the results:—

	Organic		Ratio.	Nitrogen as	
	Carbon.	Nitrogen.		Ammonia.	Albuminoid ammonia.
The clear water...	0·210	0·075	2·8	0·006	0·004
The sediment....	0·036	0·008	4·5	—	—

It should be mentioned that this experiment was commenced on the 2nd April, and the water allowed to stand for six days before syphoning

Results expressed in Parts per 100,000.

Date.	Organic carbon.	Organic nitrogen.	Ratio.	Nitrogen as ammonia.	Nitrogen as albuminoid ammonia.	Remarks.
March 1st	—	—	—	0·00025	0·003	
„ 4th	0·536	0·137	3·8	0·00015	0·004	
„ 6th	0·728	0·149	4·8	0·00	0·008	
„ 9th	0·373	0·102	3·6	0·0005	0·014	Water turbid.
„ 11th	0·309	0·104	2·9	0·0006	0·006	„ fairly clear
„ 13th	0·322	0·103	3·1	0·0002	0·015	„ „
„ 16th	0·290	0·073	3·9	0·0006	0·014	„ slightly turbid.
„ 18th	0·264	0·112	2·3	0·00025	0·010	„ fairly clear.
„ 20th	0·452	0·163	2·8	0·0002	0·004	„ clear.
„ 23rd	0·287	0·103	2·8	trace	0·009	„ „
„ 27th	1·188	0·222	5·3	0·905	0·038	„ very turbid.
„ 30th	0·216	0·075	2·9	0·0003	0·012	„ clear.
April 1st	0·494	0·094	5·2	trace	0·003	„ „
„ 3rd	—	—	—	0·00	0·003	„ „
„ 6th	0·228	0·128	1·78	0·00	0·010	Syphoned water used.
„ 10th	—	—	—	0·0013	0·0035	Water clear.
„ 13th	0·315	0·220	1·43	0·0001	0·003	Syphoned water used.
„ 16th	0·151	0·117	1·29	0·0002	0·002	„ „
„ 19th	—	—	—	trace	0·001	„ „
„ 22nd	—	—	—	trace	0·001	„ „
„ 24th	—	—	—	trace	0·002	„ „

off the supernatant liquid. The loss of organic N and of organic NH_3 , together with the increase of free NH_3 , suggests a breaking up of some of the organic constituents.

The sediment being practically inorganic, most of the succeeding analyses were made in the syphoned water. An examination of the tabulated results given above shows that the ratio of the organic nitrogen, to that evolved on distillation with alkaline permanganate, is very much higher than that in the case of fresh waters. This, indicating that the organic matter in sea-water is more stable than that in potable waters, led me to endeavour to ascertain by experiment how far a change in the condition of organic matter from organic compounds in solution to organisms in suspension in a water affected the results of the various methods of analysis in common use. Two series of experiments, besides some isolated ones, were made on hay solutions; but as the results in every case were similar, those of one series only are appended.

The solution was made by boiling hay in water for about half an hour, and then filtering.

This was placed in a glass flask and covered with a beaker. An estimation of organic matter was made in 50 c.c. by evaporation and combustion immediately the solution was made up on May 11th; it was then found to contain:—

Organic carbon....	28·426	} per 100,000.
„ nitrogen..	2·420	

The following determinations represent the nitrogen evolved as free and also as albuminoid ammonia, and the quantity of oxygen absorbed in accordance with the oxygen process of Dr. Tidy respectively during one and six hours. The nitrogen experiments were made by taking 10 c.c. of the hay infusion, and adding previous to distillation 500 c.c. of water from the Brighton Water Company's mains, which is practically of constant composition. A deduction was made for the amount of nitrogen in the Brighton water as albuminoid ammonia, which amounts to '001 part per 100,000.

For each determination by the oxygen process 5 c.c. were taken, and 20 c.c. of potassium permanganate solution, 1 c.c. of which = '001 oxygen added, the one sample being titrated with hyposulphite at the end of one hour; the second at the expiration of six hours.

To the water of May 11th but 10 c.c. of permanganate were added for the first determination; but as at the end of the hour the solution was almost decolorised, 20 c.c. were used in all following experiments (p. 324). The sample in which the second estimation was made stood only five hours.

On May 31st a second combustion of 50 c.c. was made, which gave—

Organic carbon....	22·552	} per 100,000.
„ nitrogen..	2·350	

I have since much regretted that intermediate combustions were not made, in order to observe the rate at which this decrease of carbon took place, a result probably of oxidation into carbon dioxide. It will be noticed that the experiments with permanganate are somewhat similar to those of Kingzett (*Chem. Soc. J.*, 1880, 15), but though the results closely agree with his, the experiments were made quite independently, and with a different object in view.

As surmised, the capacity of resistance of the organic matter to the action of agents of limited oxidation, as in the oxygen and albuminoid processes respectively, diminishes rapidly with the development of organisms, and the changes which accompany their presence. The free ammonia entirely disappears, and the nitrogen as albuminoid ammonia is steadily reduced from 0·912 to 0·257, the actual quantity of organic nitrogen present in the liquid remaining practically the same. The oxygen absorbed decreases from 34·09 on May 12th, to

Dates.	Nitrogen as		Oxygen required after		Remarks.
	Ammonia.	Albuminoid ammonia.	One hour.	Six hours.	
May 11th...	0·1	0·912	17·640	33·74	Special quantities used for oxygen process.
„ 12th...	0·1	0·75	24·20	34·090	
„ 13th...	0·1	0·75	25·256	33·500	
„ 14th...	0·09	0·70	22·452	33·468	
„ 15th...	—	—	20·290	29·656	Bacteria in large quantity.
„ 16th...	—	—	19·122	28·456	
„ 17th...	—	—	18·304	27·046	
„ 18th...	0·012	0·4	16·600	24·950	
„ 19th...	—	—	16·634	24·400	{ Solution began to have strong putrescent odour.
„ 20th...	trace	0·3	15·830	22·855	
„ 21st...	„	0·275	15·736	23·244	
„ 22nd...	„	0·3	15·662	22·934	
„ 24th...	„	0·25	14·354	21·420	{ Towards end of experiment became turbid and deposited sediment.
„ 25th...	—	—	14·352	21·698	
„ 26th...	trace	0·3	—	—	
„ 27th...	—	0·26	13·810	—	
„ 28th...	absent	0·25	13·964	22·264	
„ 29th...	—	—	13·710	—	
„ 31st...	—	—	13·774	21·710	

21·71 on May 31st, the lesser quantity indicating a diminution of 36·4 per cent. of the higher. During the same time a diminution of 19·3 per cent. of organic carbon + nitrogen has taken place.

A number of experiments were made by the oxygen process on sea-water, but the presence of bromides in such large quantity rendered the results unsatisfactory. The estimations were made in accurately stoppered bottles, to avoid volatilisation of bromine. Instead of standardising the hyposulphite on pure water and permanganate, a solution was made of ignited sodium chloride and potassium bromide in the proportions in which they are present in sea-water. In order, however, to have excess of permanganate solution present, it was necessary to add much more of the solution than was used of sea-water: for instance, the following quantities were used in most of the experiments:—Sea-water, 10 c.c.; permanganate, 25 c.c. On the water of March 4th, after standing 19 hours, it was found that 26·15 c.c. of hyposulphite were required. A duplicate sample gave the result of 26·20 of hyposulphite, while the standard required 26·40 of hyposulphite, the results calculated from these are respectively 0·25 and 0·19 part of oxygen absorbed per 100,000, giving a mean of 0·22.

ACTINIC TRANSPARENCY OF OXYGEN COMPARED WITH ITS OPACITY AFTER OZONISATION.

Stratum of gas 36 inches in length. Proportion of $O_3 = \frac{1}{2000}$ vol.

SPECTRA TRANSMITTED BY DIFFERENT QUANTITIES OF OZONISED OXYGEN.

The experiments, so far as they have gone, show the organic matter of sea-water to be much more capable of resisting oxidising agents than that of common fresh waters. This fact, and also the behaviour of the hay infusion, are in my opinion evidence strongly in favour of the supposition that the matter in sea-water is not only organic, but also organised and probably alive. They at least show the behaviour of such organic matter to be much more like that of a solution containing living organisms than the same solution when known to be devoid of them.

Subjoined is a table showing the ratio of organic nitrogen to organic nitrogen evolved as ammonia in several waters; and also the ratio of the organic carbon + nitrogen to the oxygen required in the permanganate process. The results, which are expressed in parts per 100,000, are calculated from those given in the Sixth Report of the Rivers Commission, p. 253 and in Dr. Tidy's paper in the Chemical Society's Journal of 1879, p. 101).

	Organic ni- trogen.	Nitrogen as organic ammonia.	Ratio.	Organic nitrogen + Carbon.	Oxygen absorbed.	Time allow- ed to stand.	Ratio.
Chelsea	0·023	0·0058	3·9	0·153 —	0·087	3 hours	1·7
W. Middlesex ..	0·026	0·0046	5·6	0·146 —	0·025	"	5·9
Southwark	0·021	0·0093	2·2	0·157 —	0·075	"	2·0
Lambeth	0·038	0·0069	5·5	0·187 —	0·063	"	2·9
New River	0·015	0·0046	3·2	0·077 —	0·038	"	2·0
E. London	0·046	0·0069	6·6	0·185 —	0·057	"	3·2
Kent	0·017	0·0034	5·0	0·073 —	0·010	"	7·3
Hay, May 11th.	2·42	0·912	2·6	May 12th, 30·846	34·090	6	0·9
" " 31st.	2·35	0·257	9·1	" 31st, 24·902	21·710	"	1·1
Lea, March 16th	0·073	0·014	5·2	Lea	0·673	0·22	19 "
" April 16th.	0·117	0·002	58·5	March 4th			
Mean of 14 analyses.... }	0·120	0·0081	14·8				

I have at present a series of experiments in progress, with the view of ascertaining the capability of the organic matter in sea-water to resist oxidation by atmospheric air, as compared with that of other waters. I also hope to be able to make some reliable estimations of the oxygen-absorbing power of this organic matter by a modification of Dr. Tidy's oxygen process, and at some future time to have the honour of laying the results of these experiments before the Chemical Society.