

THE SUSPENDED MATTER OF SEA WATER

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Many chemical analyses have been made of the minor constituents of sea water which are utilized by plants and accordingly show definite seasonal variations. Analyses have also been made of the plankton strained out by fine-mesh silk nets. According to Harvey (1945) the finest bolting silk used, when wet and swollen, has a mesh of $42 \times 50 \mu$. This will let through the dwarf or nanoplankton, namely the smaller flagellates and diatoms, also bacteria, at least until the net is partially choked, as well as the finest clay particles, if any are still unprecipitated. Clay usually comes down close to the land, due to the action of the divalent magnesium and calcium ions of sea water as shown by Joly (1900).

METHOD OF SAMPLING

An attempt to measure the amount of these suspensions, living, dead and inanimate was made as follows. Carboys of sea water were filled at Station E 1, about 10 miles south-west of the Eddystone, in the English Channel, where the depth is 72-74 m. The water was taken in a carefully scrubbed and washed oak bucket, poured in through a clean wooden funnel, under the eye of the authors. The water surface was always free from oil and care was taken that the rim of the bucket should not touch the side of the ship, which sometimes had dried mud remaining on it above the wetted portion.

The carboys used were well washed with hot lime-free tap water and finally with distilled water, as customary here, and closed with a clean cork sealed in position. It was found that some of the suspended matter adhered to the glass, so during filtration it was loosened with a brush, which was then well washed. After the first four samples we considered that the customary cleaning of the carboy was likely to leave some of this matter on the glass. So from June 1948, inclusive, the carboys were cleaned with hot strong sulphuric acid in addition. The analyses for February to May 1948 show that this adherence of previous deposits gave results which were too high, but the matter removed was similar in composition to the usual suspension.

FILTRATION AND DETERMINATION OF DRY MATTER

The volume of sea water filtered varied, as some was used for other analyses, but lay between 15 and 29 l., with a mean close to 22. It was filtered through a Whatman No. 50 paper, 11 cm. diameter, the ash of which, 0.2 mg., was negligible. This was done on a Buchner funnel with the water pump. The first 10 l. was always re-filtered.

As a test of the efficiency of the filtration sea water collected 8 November 1949 was first filtered as usual; 25.0 l. gave 24.7 mg. or 990 mg./m.³ of incinerated matter. Then 22.0 l. of the filtrate were filtered through 'Gradocol' membranes having an average pore diameter 1.09 μ . As these became clogged four had to be used in succession. The washed residue and the filters were ignited and gave 0.9 ± 0.2 mg., or 40 mg./m.³, of which gravimetric analysis showed that 60% was silica, and ferric oxide 13%, found colorimetrically using 2-2'-dipyridyl.

Thus the filter-paper, with re-filtration as described, allowed about 4% of the matter to pass through, which was later collected on the membrane. The appearance and composition of the fine suspended matter on the membrane were similar to that on the paper. Examination in the Tyndall beam showed that there was still matter in suspension in sea water filtered in succession through 'Gradocol' membranes 1.09, 0.61 and 0.2 μ A.P.D., but the amount must have been exceedingly small by weight.

After washing free from salts the residue was also washed with 20 ml. portions of acetone till colourless, and dried at 100° C. The net weight is that of organic and inorganic matter, insoluble in water and acetone. But only occasionally was there enough on the paper to render this weighing worth while, as it is necessarily less accurate than that of the incinerated residue.

The paper was incinerated below red heat till carbonaceous matter was destroyed. The ratio of the organic matter to the inorganic and ash was 0.68 in July 1948 and 1.01 in February 1949. In March, April and May 1948 the imperfectly cleaned carboys gave respectively the ratios 0.91, 1.82 and 0.31, but the March and April samples were not filtered till 4½ and 3½ months after collection.

The values for July 1948 and February 1949 give the insoluble organic matter as 1.77 and 1.62 g. dry weight for a cubic metre of water at the surface. This is a direct determination, but may be low on account of the loss of soluble substances.

The July 1948 ratio, 0.68, is moreover low, as on this occasion the inorganic matter was enriched with calcium carbonate which constituted 70% instead of about 20%. The high calcium content is probably due to high temperature and pH value, which combine to cause precipitation.

The incinerated dry matter is shown in the table as mg./m.³ The constituents are shown both in mg./m.³ to afford a comparison with analyses of the salts in solution and in percentages, using the oxide formulae as customary in the analyses of clays in agricultural work and in the Challenger analyses.

GRAVIMETRIC ANALYSIS OF THE RESIDUE

Silica was determined by the loss of silicon tetrafluoride. The factor to correct to Si is 0.467.

Iron was found by fusion of the residue with potassium hydrogen sulphate, followed by acid extraction, formation of the cupferron complex and its extrac-

tion with chloroform. The solvent was removed and the complex destroyed with sulphuric acid and heat, followed by hydrogen peroxide, solution in acid and ammoniacal precipitation when just alkaline to methyl red. The precipitate was ignited and weighed as Fe_2O_3 ; the factor to convert to Fe is 0.700.

Aluminium was precipitated in the aqueous solution after the cupferron extraction by addition of ammonium chloride and then hydroxide till just alkaline to methyl red. The precipitate was ignited and weighed as Al_2O_3 . The factor to convert to Al is 0.529.

The filtrate from the aluminium determination was freed from ammonium salts, organic matter if present being destroyed with hydrogen peroxide. Calcium was then precipitated as oxalate, and ignited and weighed as the carbonate. The factor to convert to Ca is 0.400.

One determination of phosphorus was made on a duplicate carboy of 30 November 1948. In view of the acid extraction necessary later on this was filtered on a Jena grade 3 (medium porosity) sintered glass crucible. With re-filtration of the first 10 l. this proved efficient, and gave 2100 mg./m.³ residue dried at 100° C. Cold extraction with 0.28 N- H_2SO_4 gave 3.1 mg./m.³, and hot extraction (in autoclave, Harvey, 1948) gave a further 2.2 mg. The residue when incinerated and extracted gave 0.2 mg., so total phosphorus in residue was 5.5 mg./m.³

Since the other carboy gave 950 mg./m.³ incinerated residue a further value for the organic/inorganic matter ratio is obtainable, namely 1.21 and the insoluble organic matter is 1.15 g./m.³ The samples of water may not have been identical in the two carboys, but are likely to have been closely similar.

DISCUSSION OF RESULTS

The results are given in Table I. Neglecting results from inadequately cleaned carboys the incinerated dry matter ranges from 2.77 to 0.45 g./m.³, namely parts per million, with silica as the main constituent in all but four cases. In one of these calcium carbonate, probably from the sea, constituted 70%.

The silica may have three origins: silica as such from diatom tests, silica fairly pure from small sand grains and apparently buoyed up by organic matter, and silicates of aluminium and iron, namely clay, brought down by rivers.

Incinerated dry matter varied from 100 to 16; the silica from 100 to 9; the iron oxide from 100 to 20; the aluminium oxide from 100 to 7. The greatest variation in silica was, very strangely, between 8 and 17 August 1949, with 80 and 880 mg./m.³ respectively. As against this Atkins (1926) found silica in solution at E I, 0 m., to vary from 240 to 40 mg. between 1923 and 1926. It appears, therefore, that the silica in suspension must—from the aluminium figures—be largely present as silicate and capable of enriching water depleted by diatom growth by slow solution. There is, however, no sign of any regular seasonal change in the silicate. The figures appear quite fortuitous. Nor do

TABLE I. WEIGHT OF SUSPENDED MATTER IN 1 M.³ OF SEA WATER, SHOWN AS INORGANIC MATTER AND ASH, AFTER INCINERATION, IN MILLIGRAMS, EQUIVALENT TO PARTS PER THOUSAND MILLION

The major constituents are shown, also the percentage composition. The years are 1948, above, and 1949.

Date	Weights (mg.)				Composition (%)					° C.	Salinity (‰)	
	Total	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaCO ₃	Total	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃			CaCO ₃
11 Feb.	1,060*	465	96	81	250	85	44	9	8	24	10.1	35.27
10 Mar.	6,770*	3,700	740	1,300	630	95	55	11	20	9	9.3	35.35
12 Apr.	6,900*	3,100	650	810	1,360	86	45	9	12	20	10.2	35.33
10 May	15,300*	7,900	—	1,800	2,400	80	52	—	12	16	12.4	35.46
9 June	1,140	520	130	70	200	89	54	11	6	18	12.6	35.34
15 July	2,770	700	86	< 20	1,900	99	25	3	< 1	70	14.7	35.34
16 Aug.	890	380	130	50	160	82	43	15	6	18	15.4	35.34
4 Oct.	490	220	60	60	90	88	44	12	13	19	14.7	35.37
30 Nov.	950	160	140	140	200	73	17	21	14	21	13.2	35.38
5 Jan.	760	160	160	130	190	84	21	21	17	25	11.2	35.35
1 Feb.	1,600	420	250	160	310	71	26	15	10	19	10.2	35.27
1 Mar.	740	160	130	80	90	62	21	17	11	13	10.1	35.38
13 Apr.	800	300	100	90	190	84	37	13	11	23	9.9	35.27
9 May	800	250	180	80	110	77	31	23	10	13	11.5	35.32
9 June	1,360	710	110	150	250	89	52	8	11	18	13.9	35.30
8 July	1,880	770	300	270	310	88	41	16	14	17	16.5	35.41
8 Aug.	450	80	120	70	110	89	18	28	16	27	15.3	35.43
17 Aug.	2,020	880	260	160	490	89	44	13	8	24	16.0	—
29 Aug.	800	340	120	90	240	98	42	15	12	29	19.4	—
6 Oct.	590	260	150	60	100	92	43	24	9	16	16.4	35.25
8 Nov.	1,190	520	210	190	310	103	44	17	16	26	14.0	35.26

* Inadequately cleaned carboys.

delays in the filtration of the carboys appear to cause any serious error, for filtration of the 8 August sample was begun on 16 August and that of 17 August on 20 August.

On the whole, the aluminium values appear to be low in the summer, giving the impression that it might be the more soluble. The amount of iron present in suspension was far more than that found in solution by Cooper (1935). Atkins (1945) showed that the reduction in silica in solution due to diatom production was only about 10% of that which should have been found had all the phosphate used gone to diatom production. The present demonstration of another source of silicate does tend to lessen this discrepancy, but can hardly be accepted as adequate to account for the great difference. One is thus justified in thinking that the non-siliceous phytoplankton may be quite important quantitatively.

SUMMARY

Sea water collected at Station E1, surface, between June 1948, and November 1949, contained suspended matter from 2.77 to 0.45 g./m.³ (or parts per million) dried and ignited. A few determinations of insoluble organic matter gave 1.77 to 1.15 parts per million dry weight at 100° C. The ignited residue contained from 55 to 17% silica, 28 to 3 of ferric oxide, 20 to under 1 of alumina and 70 (or excluding one high value 29) to 9 calcium carbonate. There was nothing in the records for temperature or salinity to suggest that the water mass had changed during the period of sampling.

The analyses reveal an unsuspectedly large amount of iron, compared with that found in solution. The ignited residue is rich in silicate, judging from the silica alumina ratio, but it is quite doubtful whether the additional supply of silicate available for diatoms is at all adequate to balance their requirements calculated on a phosphate utilization basis. It seems more probable that a considerable amount of the phosphate is available for non-siliceous phytoplankton.

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