

**A PRELIMINARY RECORD OF SOME OF THE  
CHEMICAL AND PHYSICAL CONDITIONS IN  
WATERS OF THE BOMBAY HARBOUR  
during 1944-45**

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CONTENTS		PAGE
1. INTRODUCTION	.. .. .	60
2. METHODS	.. .. .	61
3. CHEMICAL AND PHYSICAL CONDITIONS	.. .. .	63
4. SUMMARY	.. .. .	70
5. ACKNOWLEDGEMENTS	.. .. .	71
6. BIBLIOGRAPHY	.. .. .	71

1. INTRODUCTION

THE parallelism between the variations in the occurrence of phytoplankton and the available nutrient salts has been so repeatedly established that it is now taken for a fact. The chemistry and physics of sea-water and their bearing on the life in the sea have been thoroughly studied by a host of workers over a number of years. The chemical constituents of biological importance in the English Channel have been worked out by Atkins<sup>6-11</sup>, Cooper<sup>13-16</sup>, Harvey<sup>17</sup>, Orr<sup>28</sup> etc. and those of Clyde sea by Marshall<sup>25</sup>. Rakestrav<sup>31</sup> has likewise studied the biology and chemistry of the Gulf of Maine, and Orr<sup>29</sup> the chemical and physical conditions in the sea in the neighbourhood of the Great Barrier Reef. Howat<sup>21</sup> has recently made additions to our knowledge about the variations in the composition of the sea in West African waters. In fact the importance of such a type of work has been widely recognised, as this problem is investigated in most of the Marine Biological Laboratories all over the world.

The history of Oceanographic research in Indian waters dates as far back as 1875 when the survey ship "Investigator" was chartered for the Marine Survey under the leadership of Surgeon-Naturalist Alcock. The bottom deposits were studied by him, but the systematic investigation of hydrography was not commenced until 1910. In the initial stages only the air

and water temperatures and salinity of sea-water were recorded. An intensive study of the physical conditions in Indian waters was made by Sewell<sup>32</sup> and the results of his investigation extending over several years were published in his monumental memoir on "Geographic and Oceanographic research in Indian waters". His investigation started with the study of the nature of the sea-bed and deep-sea deposits of the Andaman sea and the Bay of Bengal. A series of observations on the surface salinity and temperature of the Andaman sea, the Bay of Bengal and the Laccadive sea were made by Sewell and graphically shown in his memoir. Matthews has likewise examined a large number of samples of surface sea-water brought by "Sealark" and other merchant ships from different localities of the Indian Ocean and has given a comprehensive account of his investigation in his paper on "Physical Oceanography of the Indian Ocean"<sup>27</sup>.

Thompson<sup>35</sup> has however recorded some chemical constituents in the Indian waters during the John Murray Expedition, 1933-34. Recently Chidambaram and Menon<sup>12</sup> have correlated the occurrence of plankton and certain oceanographical factors with the fisheries of the West Coast (Malabar and South Kanara). Their investigation extends over a period of five years 1938-42 and includes only two hydrographical factors namely, the temperature and the specific gravity.

It will be seen from the above resume that the study of the chemistry of the Indian Ocean has received comparatively little attention in the past and practically no work has been done on the chemical and physical conditions prevalent in Bombay waters. We have therefore recently undertaken a systematic study of the chemistry of sea-water, the knowledge of which is essential in all marine and fishery research. The data regarding the chemical and physical conditions of Bombay waters, when accumulated over some years, will enable us to account for the periodical fluctuations seen in our study of the local plankton, fish eggs and fish larvæ. The present paper is only a preliminary record of the chemical constituents like silicate, phosphate, nitrite and ammonia and of a few physical factors present in Harbour waters during 1944-45. The meteorological data is also recorded along with it.

## 2. METHODS

A weekly analysis of a sample of surface water from the Bombay harbour was made from July 1944 to June 1945. During this period 47 samples taken from near the shore were examined and the results shown in Table I. The meteorological data for the same period was also recorded (Table II).

The temperature of water was read on a standard Centigrade thermometer immediately after taking the water sample.

The salinity was determined by the silver nitrate titration method<sup>18</sup> with the necessary precautions and corrections applied to this method.

The hydrogen-ion-concentration was estimated on Helengis comparator.

TABLE I  
*Hydrographical Observations during 1944-45*

Date	Time	Tem. (°C)	Den- sity	pH	Salinity o/oo	Phos- phate (Mg. per M <sup>3</sup> )	Silicate (Mg. per M <sup>3</sup> )	Nitrate (Mg. per M <sup>3</sup> )	Ammonia (Mg. per M <sup>3</sup> )
17-7-1944	3 P.M.	27.5	1015	8.1	23.56	20	1000		142
24-7-1944	3 "	28.5	1016	8.15	27.5	21	586.5	6.56	99
2-8-1944	3-30 "	29	1016	7.95	34.2	25.5	815	7.4	38.9
7-8-1944	" "	28.5	1017	8.15	24.6	27	833.3	18.3	28.2
14-8-1944	4 "	29	1017	8.1	30.1	26	990	23.2	30.8
21-8-1944	3-30 "	27.5	1016	8.15	25.1	22	960	22.4	37.7
2-9-1944	12 Noon	29	1015	8.1	27.75	25.5	930	36.0	49.9
7-9-1944	" "	29	1017	8.2	32.35	21.5	750	39.20	70
18-9-1944	3-40 P.M.	30	1023	8.1	359.5	23.5	344	13.6	50.5
25-9-1944	1-45 "	30	1021	8.15	33.35	26.5	315	45.6	85.5
2-10-1944	1-40 "	30	1023	8.15	36.9	28.75	500	32.0	47.5
9-10-1944	3-30 "	29.5	1022	8.15	33.5	28	416	88	133
20-10-1944	11-30 A.M.	29	1024	8.15	35.9	29.5	375	14.46	10.8
24-10-1944	" "	29.8	1023	8.3	35.6	27.3	450	16.0	13.3
2-11-1944	" "	30	1024	8.15	36.5	37.8	528	14.02	11.5
6-11-1944	" "	30	1024	8.15	35.5	51.9	644	20.02	9.84
13-11-1944	11-20 "	29.8	1024	8.15	35.7	28.0	405	16.0	12.9
20-11-1944	11-30 "	28	1024	8.1	35.2	26.0	460.4	14.4	14.3
28-11-1944	12-30 P.M.	29	1024	7.9	36.0	21.0	1406	20.68	42.38
4-12-1944	3-30 "	27.5	1025	7.90	37.1	27.3	735.3	25.6	156.3
11-12-1944	11 A.M.	29	1025	7.85	36.0	23.7	588.2	90.31	50.58
19-12-1944	11-30 "	29	1025	7.8	36.5	26.0	366	15.6	49.03
25-12-1944	12-30 P.M.	26.8	1024	7.9	36.3	23.5	365	27.04	18.99
1-1-1945	2-30 "	26.8	1025	8.0	35.4	32.5	378	16.8	40.02
9-1-1945	12-30 "	24	1024	8.15	30.1	27.5	862	17.6	73.07
17-1-1945	12-30 "	25	1026	8.1	29.9	22.4	1812	17.6	60.01
23-1-1945	11-30 A.M.	26	1025	8.1	34.2	20.15	1953	52.11	40.99
3-2-1945	2 P.M.	26	1024	8.15	30	24.91	1338	126	73.07
17-2-1945	12 Noon	26	1025	8.1	30.4	27.83	836.8	24.3	52.52
24-2-1945	" "	26	1025	8.1	30.5	28.69	1842	69.68	84.0
28-2-1945	11-20 A.M.	26.9	1024	8.15	30.6	22.61	784.8	54.78	44.22
7-3-1945	11-20 "	25.4	1025	8.2	37.1	18.26	533.3	59.58	60.01
17-3-1945	1-45 P.M.	28.8	1025	8.3	30.8	27.7	470.0	73.6	39.07
24-3-1945	1-20 "	29.2	1025	8.3	32.3	21.5	540	45.4	42.2
31-3-1945	2-30 "	29.7	1024	8.3	35.2	20.0	1810	30.4	49.4
7-4-1945	1-45 "	28.5	1024	8.2	33.4	25	1363	124.0	44.22
14-4-1945	1-25 "	29.4	1024	8.3	33.2	13.04	649.5	22.1	51.64
20-4-1945	1-30 "	30.5	1025	8.35	34	27.08	537.6	153.9	38.42
28-4-1945	2-30 "	30	1025	8.2	34.1	15.5	458.9	167.1	47.28
5-5-1945	12-30 "	30.5	1025	8.15	38.3	33.7	1220.0	11.5	..
21-5-1945	1 "	31.0	1025	8.2	38.4	..	700.0	11.04	91
30-5-1945	11-45 A.M.	31.5	1025	8.25	38.3	20.8	606.0	5.06	93
9-6-1945	10-30 "	30.5	1025	8.15	36.2	15.1	700.0	4.60	65.5
16-6-1945	11-45 "	32.0	1025	8.2	35.3	13.5	845.0	5.06	64
23-6-1945	12-45 P.M.	32.5	1025	8.2	34.1	32.2	693.0	5.52	73.3
3-7-1945	11-20 A.M.	27.0	1018	8.25	31.4	23.0	500	5.06	63.7
10-7-1945	11-20 "	26.8	1018	8.15	26.8	24.5	600	5.52	90.3

Denige's method for phosphates as adopted by Atkins<sup>6</sup> was followed for the estimation of dissolved phosphates. The reagents were prepared according to Florentin's formula<sup>6</sup> and the comparison of the colour of the standard solution with that of the sample of water to be tested was made on Hehner's tubes.

Dissolved silicates were determined by the colorometric method of Dienert and Wandenbuleke. The colour, developed on the addition of reagents, was matched against a suitable standard picric acid solution<sup>15</sup>.

The Nitrite content was estimated by Gries method as modified by Ilosvay and used by Orr<sup>28</sup>. The Gries-Ilosvay reagent was renewed very often and to ensure accuracy of results, a suitable standard solution was made by diluting a standard solution of higher concentration just before the addition of reagents as the dilute standard solutions change their nitrite content readily. The colours were compared in Hehner's tubes.

For the determination of Ammonia, 100 c.c. of sea-water, treated with 4 drops of a saturated solution of mercuric chloride, was brought in a separate jena glass flask. The estimation was made according to Wattenberg's method<sup>36</sup> by use of Nessler's reagent. All reagents excepting Nessler's reagent were prepared each time ammonia was estimated. Every possible precaution was taken to avoid contamination of the reagent with ammonia in the air and all bottles containing the reagents were specially fitted with 'U' tubes containing pumic salts and sulphuric acid.

### 3. CHEMICAL AND PHYSICAL CONDITIONS

#### *Temperature:—*

The records of temperature of water are shown in Table I. The maximum temperature was 32.5° C. on 23rd June, 1945 and the minimum 24° C. on 9th January, 1945. The range of temperature during this period was therefore 8.5° C. On comparing with the meteorological data (Table II) it was found that there was a close relation between the temperature of air and water and the maximum and minimum temperature of water fell almost with the same range as the daily maximum and minimum temperature of air.

The dry and wet-bulb thermometer readings (Table II) indicate that the evaporation of sea water is going on all the year round. The rate of evaporation is influenced by the following factors:—(1) Atmospheric pressure, (2) Atmospheric temperature, (3) Atmospheric humidity, (4) Atmospheric movements—Wind, and (5) Variations in salinity. Sea-water evaporates

TABLE II  
*Meteorological Observations during 1944-45*

Date	Atmospheric pressure	Dry Bulb Temp. (°F)	Wet Bulb Temp. (°F)	Humidity (%)	Maximum Temp. (°F)	Minimum Temp. (°F)	Wind		Cloud	
							Direction	Force	Form	Amount
17-7-1944	29.683	84	78.5	89	84	79.1	WSW	12	ScCu; AcAs (7)	10
27-7-1944	29.631	79.8	76.8	84	83.6	79.1	WSW	16	ScCu; AsAc	9
2-8-1944	29.661	79.4	77.6	92	79.8	75.0	SW	10	1 1 5 2 ScCu; As	10
7-8-1944	29.771	80.1	77.8	90	86.3	79.1	WSW	8	ScCu; Ac	9
14-8-1944	29.744	80.4	76.7	84	86.5	77.7	SSW	14	ScCu; Ac; Ci	3
21-8-1944	29.675	78.7	76.5	90	82.1	75.7	WSW	16	2 T 1 Sc, Cu, As, Ns, Fb	10
2-9-1944	29.861	80.0	76.3	84	86.5	79.0	SW	6	Sc, Cu, AcAs	6
7-9-1944	29.874	79.2	75.1	82	87.4	76.2	WNW	9	4 ScCu; Ac	5
18-9-1944	29.787	79.5	76.6	87	86.5	77.	W	3	ScCu; Ac	6
25-9-1944	29.900	78.7	76.2	89	88.3	74.4	ESE	6	4 ScCu; Ac	6
2-10-1944	29.807	79.4	77.2	90	88.6	77	ESE	10	3 ScCu; AcCs, Ci	9
9-10-1944	29.826	79.1	76.2	85	88	78	NNE	5	2 2 4 1 ScCu; Ac	8
20-10-1944	29.882	81.5	73.0	65	96.6	79.3	NE	9	Sc; Ac	1
24-10-1944	29.853	80.8	77.3	85	93.8	78.9	E	3	T 1 ScCu	7
2-11-1944	29.860	78.7	75.2	84	88.8	75.9	NE	4	7 ScCu	2

6-11-1944	29.896	70.9	72.1	81	80.7	73.3	N	5	ScCu 4	4
13-11-1944	29.847	76.8	70.7	73	87.8	74.7	N	2	ScCu 1	1
20-11-1944	29.901	77.2	73.5	83	94.1	75.4	ENE	6	Ci T	T
28-11-1944	29.825	77.4	73.5	82	95.4	75.2	NE	8	Sc, Cs, Ci T, 6, 2	7
4-12-1944	29.853	75.1	71.3	82	90.6	73.2	NE	7	Ac, Ci T, 1	1
11-12-1944	29.921	74.6	70.8	82	91.3	72.1	NE	9	Sc T	T
19-12-1944	29.920	71.5	67.0	78	84	67	NNE	6	Clear sky	
25-12-1944	29.876	72.6	67.5	76	85	70	ENE	9	Clear sky	
1-1-1945	29.906	68.7	62.4	68	86.3	67.2	NNE	2	Clear sky	
9-1-1945	29.957	68.7	67.2	92	80.1	61.2	N	9	ScCu 1	1
17-1-1945	29.980	68.7	65.3	82	83	66.4	NNE	8	Sc T	T
23-1-1945	29.906	70.8	66.2	78	89.0	67.4	ESE	7	Sc; Ac T, 1	1
3-2-1945	29.930	67.7	61.6	69	82.9	62.2	E	9	Clear sky	
17-2-1945	29.884	68.5	61.5	65	82.7	64.4	NNE	6	Ci T	T
24-2-1945	29.886	74.6	66.1	61	91.9	72	ENE	4	Ci 1	1
28-2-1945	29.893	73.7	64.1	57	87.6	70.8	NE	4	Clear sky	
7-3-1945	29.898	70.4	60.9	55	90.0	65.4	NE	5	Clear sky	
17-3-1945	29.911	75.5	69.8	78	91.1	71.3	ENE	3	Clear sky	
24-3-1945	29.861	79.4	72.6	71	103.1	76.8	NEN	4	Clear sky	
31-3-1945	29.798	81.4	78.3	87	90.8	78.0	S	6	Sc, Cu, Ac T, 1	1
7-4-1945	29.855	77.9	73.2	79	87.2	75.9	NNE	2	Cu 2	2
14-4-1945	29.910	77.9	74.6	85	88.1	74.4	SE	3	Cu T	T

Date	Atmospheric pressure	Dry Bulb Temp. (°F)	Wet Bulb Temp. (°F)	Humidity (%)	Maximum Temp. (°F)	Minimum Temp. (°F)	Wind		Cloud	
							Direction	Force	Form	Amount
20-4-1945	29.857	80.4	76.6	84	90.0	76.6	Calm	0	Sc T	T
28-4-1945	29.762	81.3	78.7	76	90.21	79	NNW	2	Sc Cu Ac 2	-2
5-5-1945	29.824	81.4	76.3	78	90.5	78.9	NE	4	Cu Sc Ac 1 3 3	7
21-5-1945	29.766	84.1	79.1	79	92.2)	82.1	SW	3	Cu Sc Ac 2 T T	2
30-5-1945	29.812	83.1	75.9	70	92.1	80.2	N	3	Cu Sc Fc 2 T T	2
9-6-1945	29.665	84.4	80.7	84	94.0	83.2	S	3	Cu Cu Sc Ns Ac T 1 2 4 1	8
16-6-1945	29.707	82.0	79.5	89	82.6	78.9	SW	9	Cu Cu Ac Ci 1 2 5 T	8
23-6-1945	29.682	78.5	76.7	92	86.7	75.3	SSE	5	Cu Sc Ac 4 2 4	10
3-7-1945	29.678	82.2	77.9	82	88.1	74.4	WSW	13	Cu Sc Fu As Ac 1 4 T 2 2	9
10-7-1945	29.544	79.2	77.6	93	88.1	76.2	WNW	14	Pu Ns As 2 6 2	10

more slowly than fresh water. Harvey<sup>17</sup> has shown that the cooling of sea-water is to some extent dependent on the seasonal changes in evaporation.

**Salinity:—**

The variations in salinity are shown in Fig. 1. The maximum salinity recorded during the period under review was 38.4‰ on 21st May, 1945 and the minimum 23.56‰ on 17th July, 1944. The fluctuations of salinity during July-September were due to sudden influx of fresh water. It increased during

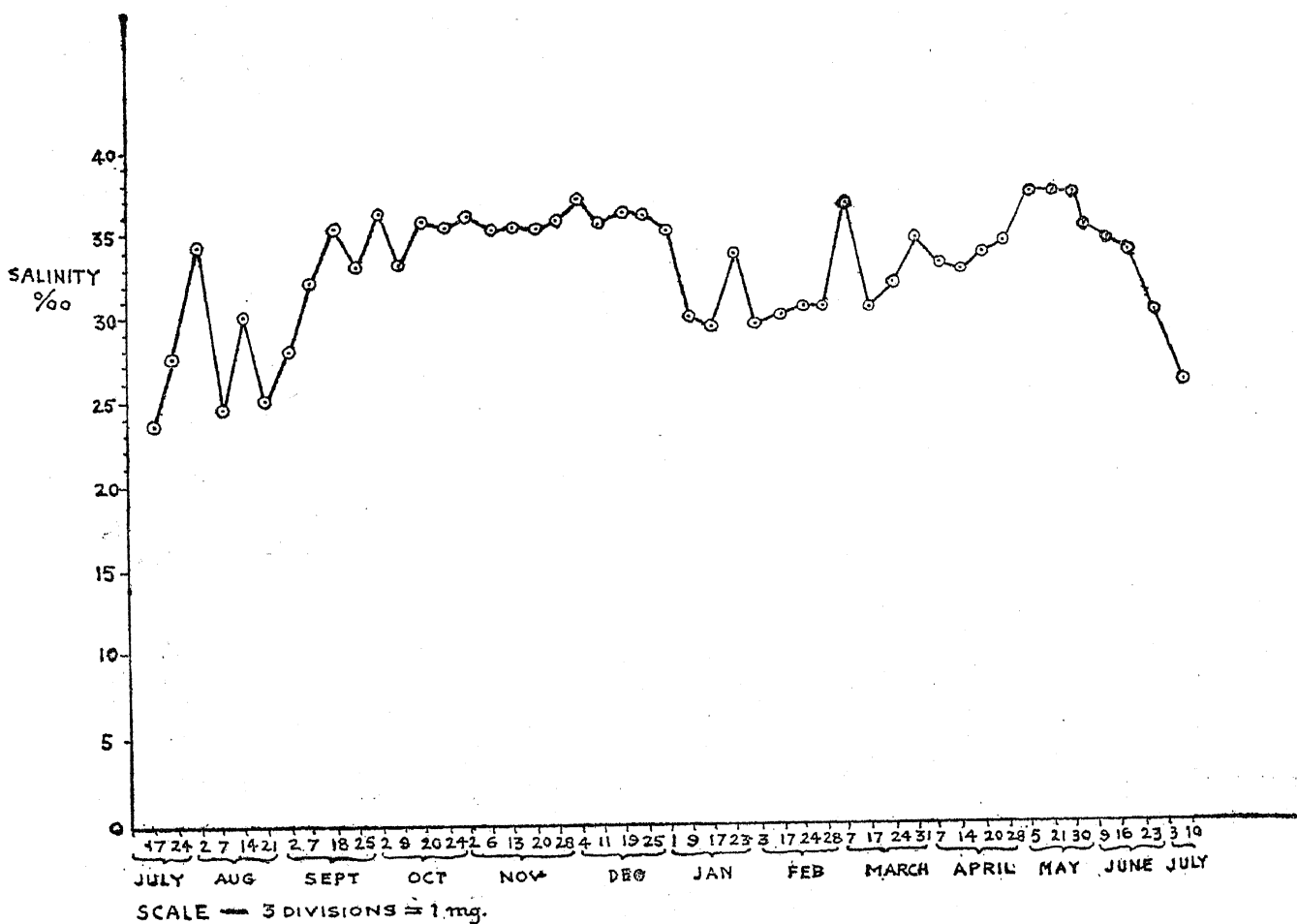


FIG. 1. Seasonal Variations in Salinity

the succeeding months with intermitent rise and fall and reached its maximum in May 1945.

**Density:—**

The variations in the density of water were in accordance with the salinity of water. The maximum and minimum values recorded were 1026 and 1015 respectively (Table I).



**Hydrogen-ion Concentration:—**

The hydrogen-ion concentration of our harbour waters varied between 7.8 to 8.35 (Table I). It was highest on 20th April, 1945 and lowest on 19th December, 1944.

**Phosphates:—**

Phosphate though found in small quantity in sea-water is one of the essential food constituents of phytoplankton. The phosphate content showed no marked fluctuations excepting once and was found in varying quantities throughout the year, the average being about 22 mg. per m<sup>3</sup>. It will however be seen from Fig. 2 that there was a sudden increase in the

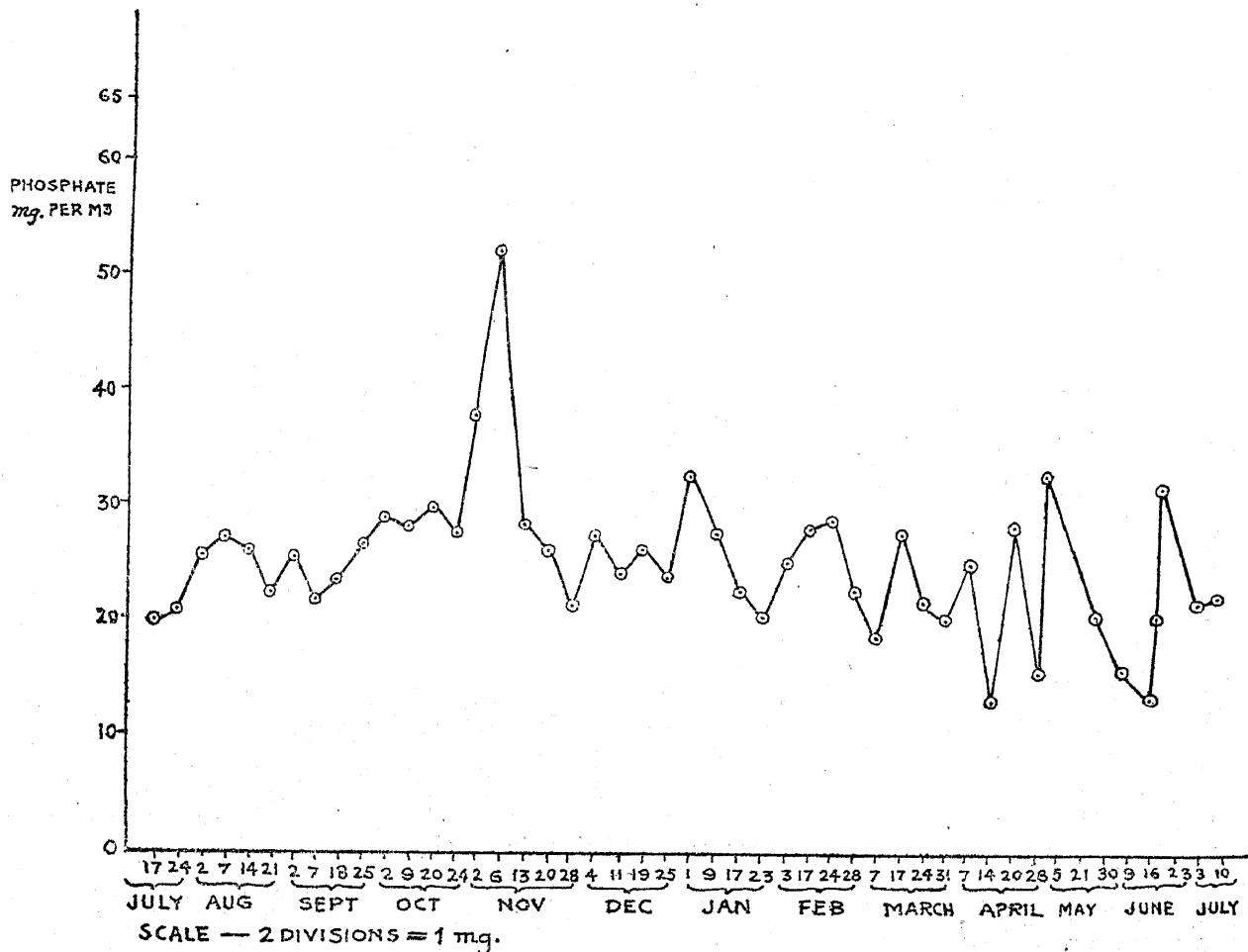


FIG. 2. Seasonal Variations in Phosphate Content

phosphate content on 6th November, 1944. Such a sudden rise has also been recorded elsewhere previously by other workers. This high value might be due to the excess of bacterial decomposition of the organic matter

at the bottom of the sea or as suggested by Cooper<sup>16</sup> might be due to direct oxidation caused by a number of factors acting on the air-water interface. The lowest quantity recorded was 13.04 mg. per m<sup>3</sup> on 14th April, 1945 (Table I).

*Silicates:—*

The amount of dissolved silica in harbour waters was found to be much greater than other chemical constituents recorded here. The minimum value during this period was 315 mg. per m<sup>3</sup> and the maximum 1953 mg. per m<sup>3</sup> in September 1944 and in January 1945 respectively (Fig. 3). The quantity of silica was found to be higher particularly during January, February and March than the other months of the year.

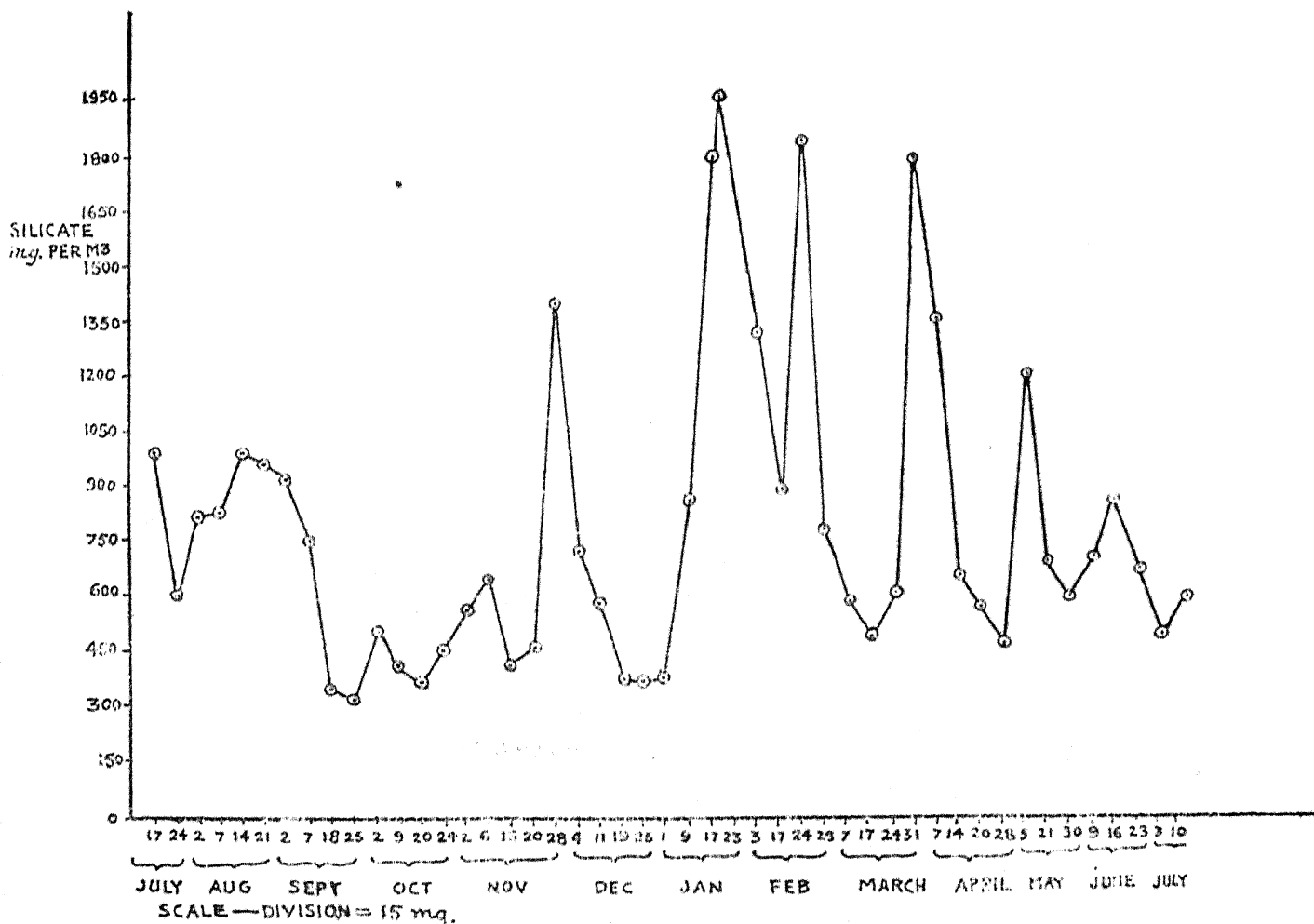


FIG. 3. Seasonal Variations in Silica Content

*Nitrites and Ammonia:—*

The concentration of nitrite varies much as it occupies an intermediate position in the oxidation of ammonia to nitrates. The nitrite content may be taken as a useful indication of rapid transformation of ammonia to

nitrites. It will be seen from Fig. 4 that there was in general a correspondence in the occurrence and variations of nitrite and ammonia during

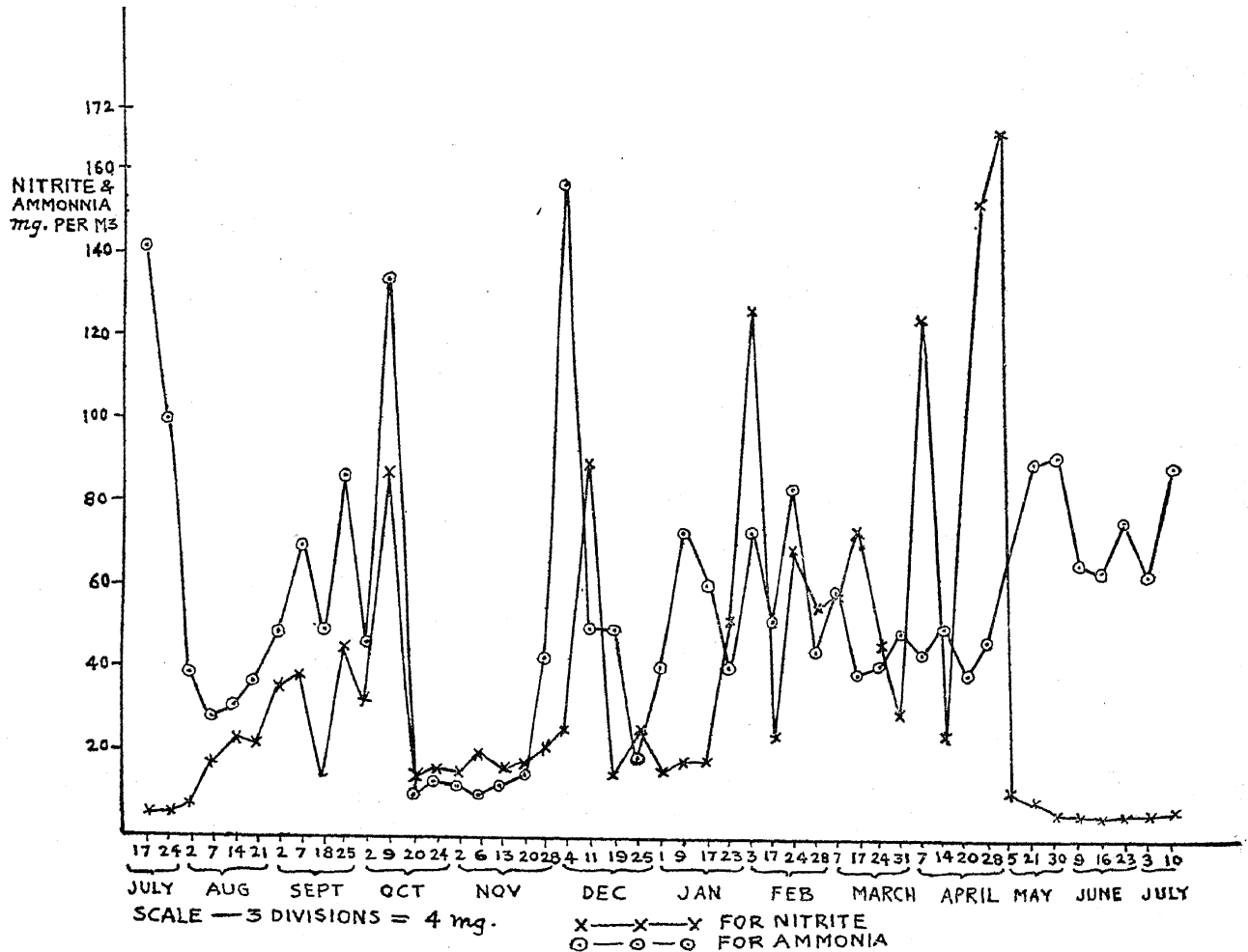


FIG. 4. Seasonal Variations in Nitrite and Ammonia

this period. The minimum and maximum values for nitrite were 4.60 and 167.1 mg. per m<sup>3</sup> and for ammonia 9.84 and 156.3 mg. per m<sup>3</sup> respectively (Table I).

*Meteorological Data:—*

The meteorological data such as Atmospheric Pressure, Humidity, Wind, Cloud, etc., were recorded for the same period as these factors have direct relation with the prevalent physical and chemical conditions in the sea.

4. SUMMARY OF CONDITIONS IN WATERS OF THE BOMBAY HARBOUR DURING 1944-45

(1) In the rainy season (from June 15th to the end of September) the weather was less settled and there were thunder storms and heavy showers

of rain. There was a considerable disturbance in the sea and the water was mixed over great depths during this period. In the remaining part of the year the winds were lighter and the mixing of water less pronounced. The sky was overcast with clouds for the most part of the rainy season and there was a bright sun light from October to the end of May 1945.

(2) The temperature of water varied between 24° C. and 32.5° C. The maximum temperature of air was recorded as 103.1° F. on 24th March, 1945.

(3) The salinity was low in the rainy season—23.56‰ on 17th July, 1944 and high in the summer—38.4‰ on 21st May, 1945.

(4) The range of Hydrogen-ion concentration was 7.8 to 8.35.

(5) Phosphates were found in quantities varying between 13.04 mg./m<sup>3</sup> and 37.8 mg./m<sup>3</sup>. It was as high as 51.9 mg./m<sup>3</sup> in one sample.

(6) The amount of dissolved silica was greater than any other chemical constituents recorded here. The lowest value was 315 mg./m<sup>3</sup> and the highest 1953 mg./m<sup>3</sup>.

(7) The minimum and maximum quantities for nitrite were 4.60 mg./m<sup>3</sup> and 167.1 mg./m<sup>3</sup> and for ammonia 9.84 mg./m<sup>3</sup> and 156.3 mg./m<sup>3</sup> respectively.

## 5. ACKNOWLEDGEMENTS

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