

## DISTRIBUTION OF DISSOLVED ORGANIC PHOSPHORUS AND NITROGEN IN THE BAY OF BENGAL\*

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### ABSTRACT

Data on dissolved organic components presented in this paper deals with values obtained in the inshore waters of Bay of Bengal off the coast of Waltair for a period of two years (1961 and 1962) and also from the different regions of the Bay of Bengal obtained during March-April 1963 on board R. V. *ANTON BRUUN* in the International Indian Ocean Expedition. Dissolved organic matter described herein constitutes the compounds of nitrogen and phosphorus present in sea water that pass through a 0.5  $\mu$  filter.

Dissolved organic nitrogen is seen to accumulate to the extent of 0.28 mg/l in 1961 and 0.23 mg/l in 1962 in the surface waters a few weeks after the phytoplankton bloom during March-April period. High Dissolved Organic nitrogen (Don) value of 0.36 mg/l in 1961 and 0.22 mg/l in 1962 recorded in November are attributed partly to contribution from rivers waters and partly to phytoplankton production.

High values of dissolved organic phosphorus (Dop) are encountered during May, June, July 1961 (2.63, 1.99, and 3.08  $\mu$ g. at/l respectively) in the surface water off the Waltair Coast and this fraction constitutes between 80-90% of the total phosphorus. Dissolved organic phosphorus is inversely related to phytoplankton production.

Average values in the surface water of the different regions of the Bay of Bengal during March-April 1963 reveal high Don content off the coast of Burma and in the rest of the Bay when compared to the Nicobar-Andaman Sea. Dop values in the central bay are high and this area has been shown to be very low in productivity from chlorophyll and primary productivity values during March-April period.

The vertical distribution of Dop reveals high values in the upper layers of the sea and exhibit a gradual decrease with depth and no Dop was noticed around and below 1000 metres. Between 2000 and 3000 metres values ranging from 0.18  $\mu$ g. at/l to 0.3  $\mu$ g. at/l are encountered.

### INTRODUCTION

THE dissolved organic compounds in the sea water come from the decay of organic matter produced in the body of water itself, from outside through the influx of fresh water and land discharges, from the excreted waste products of living organisms or by diffusion from the bodies of healthy phytoplankton or by external secretions from certain phytoplankton.

These dissolved organic substances may specifically promote or inhibit the growth of a particular species and thus play an important part in determining the number and kinds of different organisms concerned in the cycle of organic production.

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Some of the dissolved organic substances interact chemically with inorganic ions and form certain complexes and thus keep essential metals in solution thereby conditioning the ionic environment and enabling the aquatic organisms to survive and grow.

Dissolved organic compounds are utilised as 'nutrient' substances much in the same way as inorganic ions by some of the algae (Putter, 1909; Chu, 1946) and the colourless marine nannoplankton (Rodhe, 1955) it is believed that they serve as a source of accessory food substances for some zooplankton. Further, these compounds are the sole source of energy for bacterial growth.

Data on the nature and occurrence of dissolved organic matter in sea water from different areas is available from the contributions of Tatsumoto *et al.* (1961), Fogg and Westlake (1955), Wangersky (1952), Johnston (1955) Lochhead *et al.* (1957), Bantley (1959), Lucas (1955), Haldane (1955) and Duursma (1960).

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#### MATERIAL AND METHODS

Sea water samples for routine work were collected from the surface once in ten days from January 1961 to December 1962 from a station (Fig. 1) located about 5 km off the coast of Visakhapatnam opposite the entrance channel. The depth at this station was about 46 metres.

A clean polythene bucket was lowered from the boat with the help of a cotton rope. The bucket was rinsed twice with the sea water and a bucketful of surface sea water was sample collected. The sea water sample was immediately dispensed into a 5 litre polythene carboy provided with a screw cap and the sample was preserved with chloroform. Normally the samples were collected between 0730 hrs. and 0800 hrs. and brought back to the laboratory for immediate analysis. For the estimation of dissolved organic nitrogen the water sample was filtered through a 0.5  $\mu$  millipore membrane and stored, frozen at  $-10^{\circ}\text{C}$  in polythene bottles and were attended to on the succeeding days.

Sea water samples from different depths were collected by Nansen bottles coated on the inside by teflon. Two 75 ml samples were dispensed into 100 ml polythene bottles. Of these two samples one was filtered through 0.5  $\mu$  millipore membrane (for the estimation of particulate organic phosphorus) and the other sample unfiltered for estimation of total phosphorus. Both the samples were preserved by freezing them at  $-15^{\circ}\text{C}$ . The dissolved organic phosphorus content was obtained by deducting the inorganic phosphate from total phosphorus in filtrate from which particulate matter has been separated. Another 50 ml of surface sea water was also filtered through the millipore membrane, two drops of 1 : 1 sulphuric acid was added and the sample frozen at  $-15^{\circ}\text{C}$  for estimation of dissolved organic nitrogen. The samples were analysed later on a Unicam SP 600 Spectrophotometer. The dissolved organic nitrogen content was estimated by evaporating the sample to dryness with excess of nitrogen free sulphuric acid and converting the organic nitrogen to ammonia by

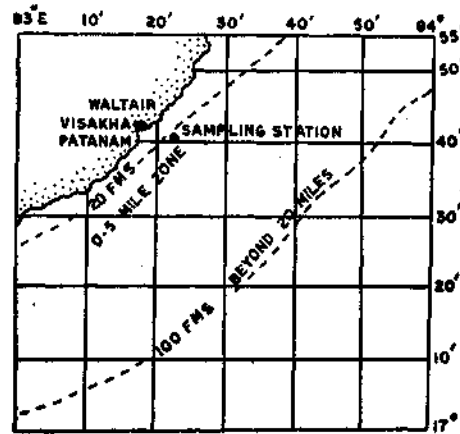


Fig. 1. Location of the sampling stations.

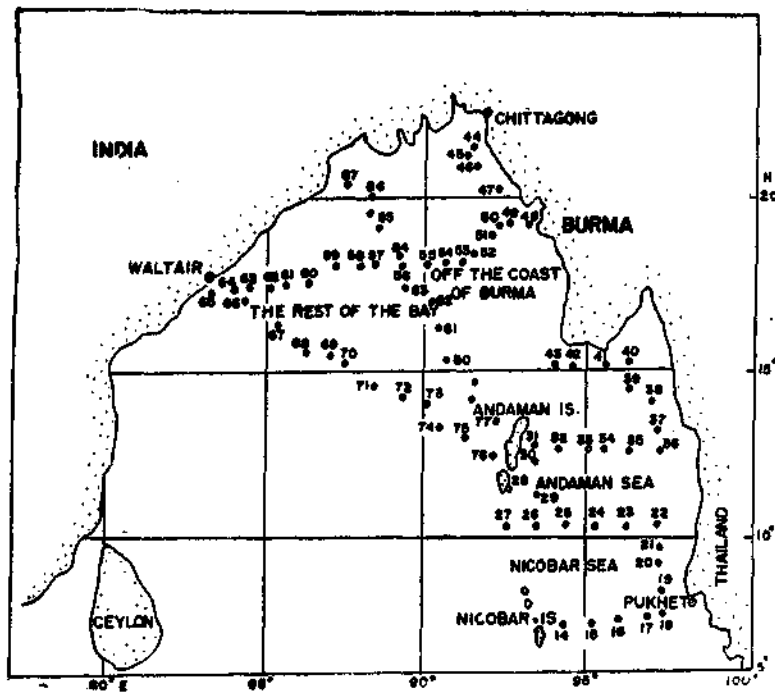


Fig. 2. Location of stations during the First cruise of ANTON BRUUN in the Bay of Bengal.

Kjeldahl digestion. The residue was dissolved in water, neutralised and the ammonia determined by the extraction method proposed by Kruse and Mellon (1953) and applied by Strickland and Austin (1959).

SEASONAL VARIATION OF THE MONTHLY AVERAGE VALUES OF DISSOLVED  
NITROGEN IN THE SURFACE WATER OFF THE COAST OF WALT AIR  
DURING 1961 AND 1962

Dissolved organic nitrogen in the surface water off the coast of Waltair showed a variation from 0.36 to 0.05 mg/l during 1961 thus showing a range of 0.135 mg/l. The average value for the January-May period was lower than the average during June-December period.

Values of dissolved organic nitrogen (Don) showed a reduction from January to February from 0.05 to 0.035 mg/l. From February through May the values showed a gradual increase. The highest value for Don was attained in May during this period. From May to September a decreasing trend in the value has been noticed, though during the month of August, a slight rise was recorded. From September through November the values of Don were seen to rise touching the highest value in November during this year. From November to December the values indicated a fall.

Thus it may be noticed that there are two peaks, one in May and the other in November during 1961. A comparison of the data of 1961 with the values of 1962 reveals the following features :

The annual average value of Don in both the years does not differ. The lower average value during January-May and the higher average value during June-December period also agree fairly in both the years. But the trend in variation from month to month during 1962 shows some departure from the sequence of changes in 1961. Highest value for the January-May period occur in April 1962 and in May 1961. Similarly the highest value for the year was recorded in October 1962, a month in advance of the November peak value of 1961. The increase in the value from April to May and October to November in 1961 is met with a fall in the values in 1962 for the same periods.

The increase in the dissolved organic nitrogen during February-April coincides with the increase in the phytoplankton during these months on this coast and this is accompanied by an increase of the particulate nitrogen. However, the highest value of Don for this period is seen only in May, a few weeks after the phytoplankton peak in April. During the period of increase in the phytoplankton numbers some of the populations may perish releasing the organic nitrogen from their bodies. This is reflected in the gradual increase of Don from February to April. From the highest value in May, it appears some time lapse is required for the accumulation of Don after the spring phytoplankton bloom and explains that dissolved organic compounds of the cell protoplasm will be liberated fairly rapidly, but it will take much longer before organic substances are brought into solution as a result of decomposition of cell walls and membranes by bacterial action. The quick fall of Don from May-June-July may be due to oxidation of the organic matter and this is reflected in the increase of the nitrite concentration from 0.02  $\mu\text{g at/l}$  in May to 0.71  $\mu\text{gat/l}$  in June (Table 1). According to Kleerekoper (1953) organic nitrogen compounds are very

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TABLE 1. Average monthly values of Nitrite-Nitrogen, Dissolved Organic Phosphorus, Dissolved Organic Nitrogen and Salinity off the coast of Walfair during 1961 and 1962

Month	NO <sub>2</sub> -N µg at/l	D.org.P µg at/l	D.org.N mg./l.	Salinity ‰
1961				
January	0.012	0.87	0.05	30.90
February	0.020	1.48	0.035	32.68
March	0.038	0.40	0.078	33.91
April	0.018	0.13	0.12	34.80
May	0.003	2.63	0.28	34.80
June	0.074	1.99	0.10	33.72
July	0.068	3.08	0.08	33.12
August	0.058	1.14	0.12	34.08
September	0.070	0.74	0.04	31.70
October	0.031	0.53	0.18	30.81
November	0.018	1.10	0.36	24.30
December	0.005	0.42	0.22	27.44
1962				
January	0.009	1.17	0.18	31.71
February	0.021	0.86	0.04	34.07
March	0.077	0.40	0.06	34.51
April	0.077	0.52	0.23	34.70
May	0.014	1.75	0.18	33.87
June	0.064	1.82	0.06	33.16
July	0.062	2.47	0.10	33.68
August	0.019	1.29	0.18	34.55
September	0.072	0.74	0.06	31.77
October	0.042	0.63	0.28	21.55
November	0.013	0.82	0.22	22.90
December	0.009	1.41	0.20	26.98

unstable in water. This probably explains why Don compounds are decomposed within a short time of formation and even more quickly than the dissolved organic phosphorus compounds as is revealed by the continuously high values of dissolved organic phosphorus for three months during May-July.

The increase of dissolved organic nitrogen during the growth of phytoplankton has been ascribed to excretion of Don by phytoplankton (Fogg, 1959). However, Duursma (1960) argues that nearly all the dissolved organic compounds are produced by the break down of dead phytoplankton organisms as was revealed by the peaks of carbon, nitrogen and phosphorus appearing only at the end of the phytoplankton bloom and excretion of Don is not directly demonstrable in sea water. He does not rule out the possibility of a small contribution of Don from the zooplankton.

In the present observations it is no doubt that the dissolved organic nitrogen values are high during March-April when compared with the values in January when there was no phytoplankton proliferation. The time lapse noticed in the accumulation of Don in the surface water after phytoplankton peak production during March-April and the coincidence of the zooplankton peak in April on this coast may suggest that it is more reasonable to expect that the high values of Don during this period to be due to break down of some of the plant populations coupled with some contribution from the excreta of zooplankton.

The low values of Don from June to September coincide with high values of nitrite-nitrogen (Table 1) and this would explain the oxidation of Don during this period. However, the slight rise in the value of Don in August may be due to contribution from local drainage after heavy rains in this month.

The magnitude of Don values during October-November period does not indicate a reasonable correlation with the magnitude of the phytoplankton production during this period. It may be pointed out in this connection that the concentration of Don after the primary peak of phytoplankton (March-April) is 0.28 mg/l in May. A comparison of this value with the Don value of 0.36 mg/l in November when the phytoplankton production revealed by plant pigment units is only 20% of the value obtained for March-April period is likely to suggest some contribution from sources other than the phytoplankton material in the water mass. One may expect a great proportion of this Don to be due to contribution from river waters carried down the coast by the southerly current during this period. There have been many instances of contribution of Don from river waters into the sea. Duursma (1960) observes that in many coastal seas supply of Don by rivers is by no means inconsiderable. Jerlov (1955) found a linear relationship between salinity and Don in the Gulf of Bothnia.

The value of Don remains rather high in December. This may indeed be due to the break down of the phytoplankton which reached a minor peak in November. It is very interesting to observe that the nitrate value during December is very low at 0.05  $\mu\text{g at/l}$ . This suggests that the decomposition rate of the Don in sea water may be slow when the temperature of the surface water is low during this month.

#### DISTRIBUTION OF DISSOLVED ORGANIC NITROGEN IN THE VARIOUS REGIONS OF THE BAY OF BENGAL DURING MARCH-APRIL 1963

##### *Nicobar Sea*

The values of Don in the surface water of the Nicobar Sea varies from 0.095 to 0.032 mg/l showing a variation of 0.063 mg/l. The average value for this region is 0.06 mg/l. The values indicate a slow rise towards the Thai Coast. They are seen to fall slightly westwards away from the Thai Coast and on approaching the vicinity of the Andaman Islands the values again rise.

##### *Andaman Sea*

Don values varied between 0.09 and 0.054 mg/l, thus showing a range of 0.036 mg/l. The average for this area is not different from the average value of the Nicobar Sea. Don content shows a gradual rise in a south to north direction off the east coast of Andamans. Away from these islands, the surface water across the Andaman Sea shows a fall in the values towards the southern tip of the Burmese Coast.

##### *Off the coast of Burma*

On this coast, the values of Don at station 40, 44, 45 are very high, showing 0.13, 0.24 and 0.28 mg/l respectively. Coupled with high phytoplankton production

a contribution from the river waters on this coast revealed by low salinities may also be responsible for the high values.

A good amount of fluctuation from 0.28 mg/l to 0.04 mg/l has been noticed in this area. The average value of 0.11 mg/l for this area happens to be the highest in different areas investigated during this period.

*The rest of the Bay*

Don in this region shows a variation from 0.20 mg/l to 0.04 mg/l with a range of 0.16 mg/l. The average value for this area is 0.08 mg/l.

The values of Don almost throughout the Bay are rather low, except at stations 60, 65, 80 and 87 with values 0.1, 0.1, 0.12 and 0.2 mg/l respectively. The high value of Don at station 87 near the head of the Bay may be ascribed to high phytoplankton production reported from this area during this period.

On the whole, the average Don values in the Nicobar Sea, Andaman Sea and in the central Bay do not reveal any significant variation whereas in the region of the coast of Burma, the average value is high.

In general the picture of the horizontal distribution of the Don in the Bay of Bengal (Fig. 3) reveals that the values are  $< 0.05$  in the Nicobar-Andaman Sea east

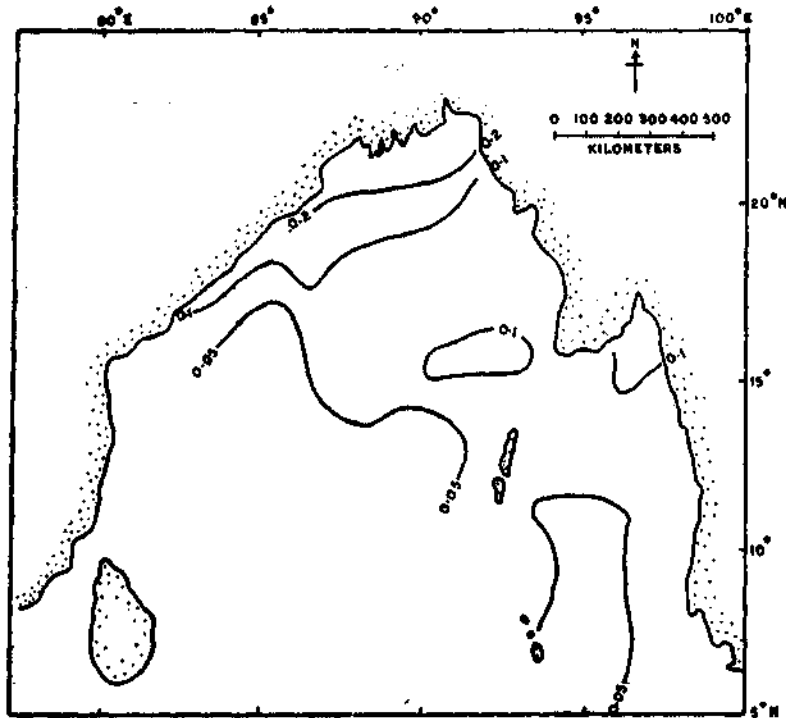


Fig. 3. Horizontal distribution of dissolved organic nitrogen (Don) in mg/l in surface water of the Bay of Bengal.

and north-east of the Nicobar Islands. In the remaining area covered by the Nicobar and Andaman Seas the values are  $> 0.05$ . From the coast of Burma in a westerly, southwesterly and southerly direction the values range between 0.05 and 0.1 mg/l.

However, there are two small 'cells' with values  $> 0.1$ , one immediately adjacent to the south Burma Coast and the other slightly extending in westerly direction from the same coast. From the central Bay the values are seen to increase towards the head of the Bay and are  $> 0.2$  mg/l.

#### Dissolved organic phosphorus (Dop)

*Monthly average values of dissolved organic phosphorus (Dop) in the surface water off the coast of Waltair during 1961 and 1962.*

Monthly average values of dissolved organic phosphorus (Table 1) exhibited a variation from  $3.07 \mu\text{g at/l}$  in July to  $0.13 \mu\text{g at/l}$  in April showing a range of  $2.95 \mu\text{g at/l}$  during 1961. The average value for this year was  $1.21 \mu\text{g at/l}$ .

After an initial rise from January to February during 1961 the Dop values showed a fall through April, reaching the lowest value of  $0.13 \mu\text{g at/l}$ . From April to May there was a sharp rise in the Dop and high values were sustained during July and August. The highest value of  $3.08 \mu\text{g at/l}$  was observed in August for the year. Thereafter the Dop concentration showed a gradual fall from September through December. However, the trend in the decreasing values was interrupted by a rise in the value in November.

The general trend in variation in the Dop content in the surface water during 1962 closely resembles that of 1961. The fall in the values from January to March during 1962 is continuous without any intermediate increase and they remain low during March-April. The period May-July is characterised by high values, with the peak value reaching in July as in 1961. The decrease in the Dop values between August and October compare well with 1961 for the same period. In both the years the values are seen to rise from October to November and this trend is continued during December also in 1962 while during 1961 values between November and December decrease. The average value in both the years is similar but the range in variation during 1962 is lower than in 1961.

Low values of dissolved organic phosphorus are encountered during March-April period in which the phytoplankton production reached a primary peak. One would expect death and decay of some of the populations consequent on which Dop concentration may be expected to increase in the surface water. This is based on the assumption that decomposition and regeneration takes place throughout the water column as suggested by Redfield, Smith and Ketchum (1937). Postma (1954) also observed that during spring a rise in the organic suspended matter on account of increased phytoplankton production is accompanied by a rise in soluble decomposition products containing phosphorus. Contrary to this expectation, the values are low; more than this, they are lower than the values of January-February, a period in which phytoplankton is sparse. The reasons governing the distribution of Dop during March-April seem to be based on the following facts: (1) Much of the organic phosphorus is bound in the particulate matter revealed by high particulate phosphorus values ranging between  $0.12$  and  $0.15 \mu\text{g at/l}$ . (2) There is the possibility of utilisation by the phytoplankton organisms as pointed out by Ketchum (1939) Chu (1946) and Harvey (1953). (3) It is also likely that accumulation of Dop in surface water along with the phytoplankton bloom has not been made possible due to the fact that though they are liberated fairly rapidly, it will take much longer (Duursma) 1960 before organic substances are brought into solution as a result of decomposition of cell walls by bacterial action.



The sharp rise in Dop values in surface water during May and continuously high values through July constituting between 80% and 90% of the total phosphorus would indicate a time lapse for their accumulation following a phytoplankton peak. There are a number of instances of accumulation of Dop compounds in certain months of the year, for example in the Dutch Wadden Sea (Postma, 1954), in the Gulf of Maine (Redfield *et al.*, 1937) and in the North Sea (Kalle, 1937).

It is of interest to point out that in spite of the fact that there is considerable evidence to show that organic phosphorus combinations are not stable but are broken down fairly rapidly (Cooper, 1935; Seiwel and Seiwel, 1938; Skopintsev, 1940; Hoffman, 1956) high values of Dop are maintained from May through July on this coast. The causes for the accumulation of Dop during May, June and July may be explained thus. (i) Considerable decomposition of the organic phosphorus in particulate matter thereby liberating organic compounds must have occurred in surface water. This is indicated by the decreasing values of particulate phosphorus during these months. (ii) The suggestion of Vinogradov (1953) seems pertinent in the present context. He estimates that about half the nitrogen and phosphorus in algae is water soluble. The remainder appears to exist in stable compounds which are decomposed after longer periods. In other words phosphorus remains in a dissolved organic state for a long duration. (iii) The break down of the Dop partly depends on the occurrence of the enzyme alkaline phosphatase. In certain areas and periods of the year in which the concentration of this catalytic enzyme low, but the Dop values may continue to remain high.

The reduction in the Dop content from July to August may be ascribed to its conversion into inorganic phosphate as revealed by the sharp rise in the inorganic  $\text{PO}_4\text{-P}$  from  $0.28 \mu\text{g at/l}$  in July to  $0.77 \mu\text{g at/l}$  in August during 1961 and from  $0.5 \mu\text{g at/l}$  in July to  $0.79 \mu\text{g at/l}$  in August 1962. The decreasing concentrations of dissolved organic P between August and October may also perhaps be due to a process of mineralisation which normally should result in an increase of the values of inorganic phosphate. But, during this period an increase in the phytoplankton activity culminating in a minor peak in November would probably explain why  $\text{PO}_4\text{-P}$  values are not on the rise.

From October to November in both the years 1961 and 1962 a rise in the dissolved organic P values has been noticed. Low saline river waters (Table 1) carried down from the head of the Bay by the southerly current are noticed on this coast during November. A small contribution of dissolved organic P compounds by these river waters may perhaps explain the rise in dissolved organic P content. Investigations of the dissolved organic matter content in fresh waters (Birge and Juday, 1934) show large quantities of organic matter. Jerlov (1955) found a linear relation between salinity and dissolved organic matter in the Gulf of Bothnia. Duursma (1960) also remarks that in many coastal areas supply of organic matter may not be inconsiderable. It is also possible that on this coast some quantity of dissolved organic P may have been the result of disintegration of some of the plankton population during this month.

It is well-known that the fertility of an area in the sea depends on a cycle in which carbon, nitrogen and phosphorus are assimilated by the green plants in surface waters and are set free again by processes of digestion and decay. It may be expected that the rate at which this cycle is completed would influence and limit the total organic productivity of the region. Hence it is apparent that the principal limiting factor is the restoration of the inorganic products of decay ( $\text{NO}_3$  and  $\text{PO}_4$ ) to the surface.

It is of importance to stress here that in the inshore waters of this coast phosphorus remains in a dissolved organic state for the most part of the year (except March-April) constituting anywhere between 50% and 90% of the total phosphorus. Though the reasons for this are not well-known it appears certain that the high percentage of Dop is not effectively utilized by phytoplankton as is the case with inorganic nutrients such as  $\text{PO}_4$  and  $\text{NO}_3$  and this may limit phytoplankton production.

#### HORIZONTAL DISTRIBUTION OF DISSOLVED ORGANIC PHOSPHORUS IN SURFACE WATER IN THE BAY OF BENGAL DURING MARCH-APRIL 1963

##### *Nicobar Sea*

Dissolved organic phosphorus in this area is seen to vary from 1.15 to 0.22  $\mu\text{g at/l}$ , showing an average value of 0.82  $\mu\text{g at/l}$  while the values are in general  $<1.0$ , values  $>1.0$  are noticed in two areas, one near the Thai Coast and the other towards north-west of this area (Fig. 4).

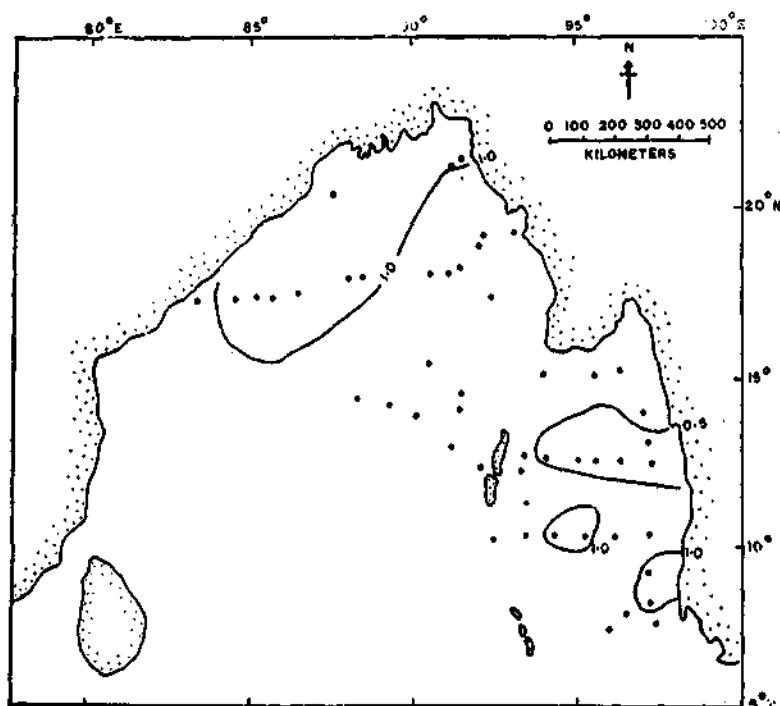


Fig. 4. Horizontal distribution of dissolved organic Phosphorus (Dop) in  $\mu\text{g at/l}$  in surface water of the Bay of Bengal.

##### *Andaman Sea*

The values of Dop vary between 0.75 and 0.36  $\mu\text{g at/l}$  with an average of 0.51  $\mu\text{g at/l}$ . It may be seen that the average concentration of Dop in the Andaman Sea is slightly lower than the average value in the waters south of this region. The distribution along the east coast of Andamans shows a slight fall in the values in a south

to north direction and this trend is seen to continue in an easterly direction towards the South Burma Coast, and here it is observed that the values slightly increase towards north.

*Off the coast of Burma*

A fluctuation from 1.11 to 0.53  $\mu\text{g at/l}$  has been noticed in the Dop content of the surface water in this area. The average value is 0.83  $\mu\text{g at/l}$ . While the values at stations near the South Burma Coast are lower and range between 0.5 and 0.6  $\mu\text{g at/l}$ , the values at stations off the North Burma Coast are higher and range between 0.7 and 1.1  $\mu\text{g at/l}$ .

*The rest of the Bay*

Dop varies from 1.63 to 0.64  $\mu\text{g at/l}$ , with a high average value of 1.06  $\mu\text{g at/l}$ , in this area. It is of interest to note that the average value obtained in these waters is the highest in the whole area investigated during March-April period. The values are seen to increase towards the Waltair Coast and are  $>1.0 \mu\text{g at/l}$  in the section between the Burmese Coast and the Indian Coast comprising stations 56-63 of this area. In the remaining areas of the Bay the values are  $>1.0 \mu\text{g at/l}$ .

VERTICAL DISTRIBUTION OF DISSOLVED ORGANIC PHOSPHORUS  
IN THE BAY OF BENGAL DURING MARCH-APRIL 1963

*Nicobar Sea*

The concentration of Dop in surface water is generally high and decreases with depth. About 1000 metre level the values are undetectable. There are also instances of low dissolved organic P content in surface water and an increase with the depth. For example at two shallow stations, 18 and 19 situated near the Thai Coast, the concentration of dissolved organic P about 50 metre level is 1.52 and 2.85  $\mu\text{g at/l}$  respectively whereas at other stations of this area the concentration for similar depths (about 100 metres) is 0.3  $\mu\text{g at/l}$ . It may also be noted that dissolved organic P content throughout the water column at these two stations is generally high when compared to the oceanic stations.

*Andaman Sea*

Surface values of dissolved organic P are high and show a fall with the depth. The concentration at 1000 metres is undetectable. The dissolved organic P content is generally high throughout the water column at station 30 situated near the coast compared to the oceanic station 34.

*Off the coast of Burma*

The vertical distribution of Dop in this area is different from that of the Nicobar-Andaman Sea. The values are low in the surface water and increase upto 500 metres reaching the maximum concentration at about this level. Since data from different depths between 500 and 1000 metres is not available it is difficult to point out the exact depth at which maximum concentration is attained. At about 1000 metres the values are very low.

*The rest of the Bay*

Values for Dop are available from a maximum number of 10 stations in this area and data upto 2,500 metres is also available from some deep stations. The general

pattern of the vertical distribution in this area is that the surface values are high and the values exhibit a gradual fall with increasing depth. But at a few stations a subsurface increase in the values at the 100 metres level has been recorded. Between 1000 and 2000 metres depth the values are generally undetectable, but below 2000 metres values ranging from 0.18  $\mu\text{g. at/l}$  (station 75) to 0.31  $\mu\text{g at/l}$  (station 71) are recorded.

The vertical distribution of the dissolved organic phosphorus in the Bay of Bengal during March-April 1963 reveals that it is not much different from the distribution reported from the Atlantic and the other oceans. The high values in the upper layers are probably associated with the decomposition of organisms in sufficient quantity. Ketchum, Corwin and Keen (1955) found that nearly 50% of surface samples from the North Atlantic contain more than 0.25  $\mu\text{g at/l}$  of dissolved organic P. As depth increases, however, the proportion of samples in which statistically significant quantities of organic phosphorus were present diminished and in waters deeper than 1000 metres none could be detected with certainty. Rakestraw (1947) found that when samples of water from the oxygen minimum layer and from greater depths were left in the dark at the *in situ* temperature for nearly 2 years the oxygen content did not change after the first 50 days of storage. During the initial period oxygen was consumed, but not in excess of a few per cent of the total content so that evidently the fraction of oxidisable organic matter in deep water is very small. These two lines of evidence would explain that in deeper parts of the oceans the oxidation of organic matter has gone nearly to completion and consequently no Dop could be detected.

The higher values of Dop recorded near the bottom of shallow stations (station 18 and 19 near the Thai Coast and station 48 near the Burma Coast) may be due to sinking of diatoms under gravity and their decomposition at the bottom.

TABLE 2. *Distribution of Dissolved Organic Nitrogen in surface water in the different regions of the Bay of Bengal during March-April 1963*

Station No.	mg/l	Station No.	mg/l
NICOBAR SEA		ANDAMAN SEA	
14	.039	29	.054
15	.032	30	.058
16	.040	31	.088
18	.068	32	0.90
19	.081	33	.065
20	0.78	34	.062
22	.070	35	.055
23	.050	36	.058
24	.048	37	.062
25	.042	38	.070
26	.068		
27	.095		

DISTRIBUTION OF DISSOLVED ORGANIC PHOSPHORUS AND NITROGEN 787

Station No.	mg/l	Station No.	mg/l
OFF THE COAST OF BURMA		THE REST OF THE BAY	
40	.13	56	.09
41	.08	57	.04
43	.09	58	.08
44	.24	60	.10
45	.28	61	.05
46	.09	62	.05
48	.08	63	.06
50	.04	65	.10
51	.07	67	.04
52	.08	71	.07
53	.08	72	.05
54	.07	73	.04
		75	.04
		76	.08
		78	.09
		79	.09
		80	.12
		81	.07
		82	.08
		84	.08
		87	.20

TABLE 3. *Distribution of Dissolved Organic Phosphorus in the various regions of the Bay of Bengal during March-April 1963*

Stn. No.	Depth (m)	D.org.P $\mu\text{g at/l}$	Stn. No.	Depth (m)	D.org.P $\mu\text{g at/l}$	Stn. No.	Depth (m)	D.org.P. $\mu\text{g at/l}$
NICOBAR SEA				284	0.29		292	0.28
14	1	..		578	0.09	24	0	1.15
	92	1.12	18	1	0.25	25	1	1.09
	480	0.11		50	0.52		100	0.35
	878	0.06		100	1.50		500	0.32
15	1	1.23	19	1	1.04		1000	0.00
	84	0.85		50	2.85	26	1	0.88
	451	0.16	20	0	1.05		117	0.65
	919	0.00	22	0	0.89		474	0.23
16	1	0.22	23	1	0.80		956	0.00
	93	0.31		97	0.28	27	0	0.88

Stn. No.	Depth (m)	D.Org.P $\mu\text{g at/l}$	Stn. No.	Depth (m)	D.Org.P $\mu\text{g at/l}$	Stn. No.	Depth (m)	D.Org.P $\mu\text{g at/l}$
ANDAMAN SEA				98	0.86		944	0.16
				491	2.89		1426	0.01
29	0	0.75		991	0.07		2680	0.31
30	1	0.63				72	0	0.87
	100	0.49	THE REST OF THE BAY			73	0	0.91
	400	0.18				75	1	0.84
31	0	0.53	56	1	1.01		100	0.64
32	0	0.48		98	1.50		300	0.07
33	0	0.45		493	1.84		500	0.15
34	1	0.36		992	0.04		800	0.10
	100	0.09	57	1	1.14		1000	0.00
	500	0.15		98	0.57		1500	0.00
	1000	0.01		491	0.37		1800	0.00
35	0	0.37		991	0.05		2200	0.00
36	0	0.42	58	1	1.39		2600	0.18
37	0	0.45		96	1.56		3000	0.01
38	0	0.67		482	0.45	76	0	0.75
				973	0.03	78	0	0.85
OFF THE COAST OF BURMA			60	1	1.35	79	1	0.91
				98	0.94		99	0.75
40	0	0.53		495	0.35		498	0.13
41	0	0.61		995	0.00		997	0.03
43	0	0.60	61	0	1.39	80	1	0.91
44	0	0.11	62	0	1.53		99	0.63
45	0	1.04	63	0	1.63		297	0.20
46	0	0.98	65	1	0.64		496	0.09
48	1	0.87		99	0.39		995	0.00
	10	0.50		495	0.22		1196	0.00
	30	0.96	67	1	1.10		1496	0.00
50	0	0.84		97	1.87		1781	0.00
51	1	0.72		487	0.34		2073	0.02
	92	0.89		991	0.00		2370	0.00
	452	1.15		1483	0.00	82	0	0.89
	941	0.12		2174	0.13		94	0.52
52	0	0.98	71	1	0.92		490	0.08
53	0	0.97		94	1.42		987	0.05
54	1	0.73		470	0.38	87	0	1.06

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