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PRELIMINARY OBSERVATIONS ON THE TOTAL PHOSPHORUS CONTENT OF THE INSHORE WATERS OF THE MALABAR COAST OFF CALICUT

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INTRODUCTION

ALTHOUGH the occurrence and distribution of phosphates in sea-water have been the subject of extensive studies and its significance as a plant nutrient influencing seasonal cycles of plankton production well recognised, investigations on total phosphorus content have been found to be also useful in the light of recent advances concerning the phosphorus cycle in the sea. While the observed fluctuations in the levels of readily available nutrients in soluble inorganic forms may throw some light on the factors controlling productivity, it has been suggested in recent years that total phosphorus may serve as an index of the potential fertility of water masses in different regions. Apart from the amount usually estimated which exists as orthophosphate, phosphorus in sea-water is made up of various fractions both organic and inorganic in nature. A small proportion of the total is present in the standing crop of plants, in zooplankton and in organic detritus in suspension. Dissolved organic phosphorus compounds are also prominent in certain seasons and some turbid waters contain in addition inorganic particles like ferric phosphate. Kalle (1937) envisaged the probability that total phosphorus in dissolved compounds was a stable constituent of water masses which could serve as 'Hilfsmittel zur untersheidung von wasserkörpern'. Redfield and co-workers (1937) have made a detailed study of the phosphorus cycle in waters of the Gulf of Maine which indicated that while the proportions of different forms undergo seasonal variations, total phosphorus content of a limited region was relatively constant. These results were later confirmed by Armstrong and Harvey (1950) by studies on the waters of the English Channel. Since the west coast of India supports a rich fishery and the region is also characterised by a marked seasonal cycle in its biological features, the present study of the total phosphorus distribution of the area was undertaken as a part of comprehensive hydrobiological investigations in progress. A few observations made on the waters of the east coast are also included in the present account.

MATERIAL AND METHODS

Samples of sea-water have been collected once a week from a station located in the 8 fathom area located two miles off West Hill, Calicut (70° 46′ E & 11° 17′) employing Casella bottles for the collection of bottom water samples. Samples were also collected from the 20 fathom area about 10 miles away from the coast on many occasions as also from the Quilandy Bay, 7 miles north of West Hill. A few observations on the total phosphorus levels in the Korapuzha estuary, 4 miles north of West Hill, were also available during the same period for assessing the influence of river drainage on the inshore hydrological conditions. Total phosphorus was estimated by the method described by Hansen and Robinson (1953) and correction for the reagent blank was applied. Soluble inorganic phosphorus was estimated by the well known Deniges-Atkins method (Atkins, 1923) but no allowance has been made for salt error.

RESULTS

Since regular collections could not be made from the offshore station in the 20 fathom area, data from the station in the 8 fathom region alone have been recorded in the form of monthly average values in Table I. However, it may be mentioned that values from the offshore station were of

TABLE I

Monthly average values of total phosphorus and inorganic phosphate in sea-waters off West Hill during 1954–55 *in microgram-atoms per litre*

Month	Total Phosphorus		Inorganic Phosphate		Percentage of total in inorganic from	
	Surface	Bottom	Surface	Bottom	Surface	Bottom
April 1954 ..	1·73	2·37	0·64	0·80	37·0	33·8
May ..	2·34	6·82	0·49	1·16	20·9	17·0
June ..	1·15	1·85	0·59	1·76	51·3	95·1
July ..	3·94	9·36	0·95	2·17	24·1	23·2
August ..	9·46	10·43	1·08	1·76	11·4	16·9
September ..	5·73	6·61	1·92	3·06	33·5	46·3
October ..	5·40	3·44	0·80	0·71	14·8	20·6
November ..	4·68	4·69	0·53	0·85	11·3	18·1
December ..	3·90	4·87	0·33	0·58	8·5	11·9
January 1955 ..	5·66	4·10	0·53	0·66	9·4	16·1
February ..	6·58	6·38	0·67	0·77	10·2	12·1
March ..	6·77	6·87	0·65	1·00	9·6	14·6

the same order. Table II refers to the observations on the waters of the Palk Bay and Gulf of Mannar near Mandapam during the winter months of 1953. Graphical illustration of the seasonal variation is provided in

TABLE II

Monthly average values of total phosphorus and inorganic phosphate in the inshore waters of the Palk Bay and Gulf of Mannar during 1953 *to* 1954 *in microgram-atoms per litre*

Month	Total Phosphorus		Inorganic Phosphate		Percentage of total in inorganic form	
	Surface	Bottom	Surface	Bottom	Surface	Bottom
			Palk Bay			
September 1953	0·58	0·56	0·10	0·12	17·2	21·4
October ..	0·53	0·53	0·13	0·13	24·5	24·5
November ..	0·60	0·86	0·16	0·15	26·7	17·4
December ..	0·59	1·16	0·11	0·18	18·6	15·5
			Gulf of Mannar			
October 1953	0·56	0·44	0·12	0·13	21·3	29·5
November ..	0·89	0·48	0·12	0·12	13·5	25·0
December ..	0·77	1·64	0·21	0·19	21·3	11·6
January 1954 ..	0·72	2·15	0·13	0·15	18·1	7·0

Figs. 1 and 2. It was observed that the total phosphorus content of inshore waters off Calicut was quite high, the range for surface waters being 1·15 to 9·46 microgram atoms per litre the corresponding range for inorganic phosphate being only 0·33 to 1·92. Total phosphorus levels registered a sudden increase in July followed by a gradual lowering from September to December. The values again showed an upward trend thereafter till March 1955. Seasonal variation of the inorganic phosphate fraction was more uniform in nature with a well-defined peak in September. Bottom values were generally higher but the trends of variation were closely related to the changes in the surface layers. Inorganic phosphate constituted only

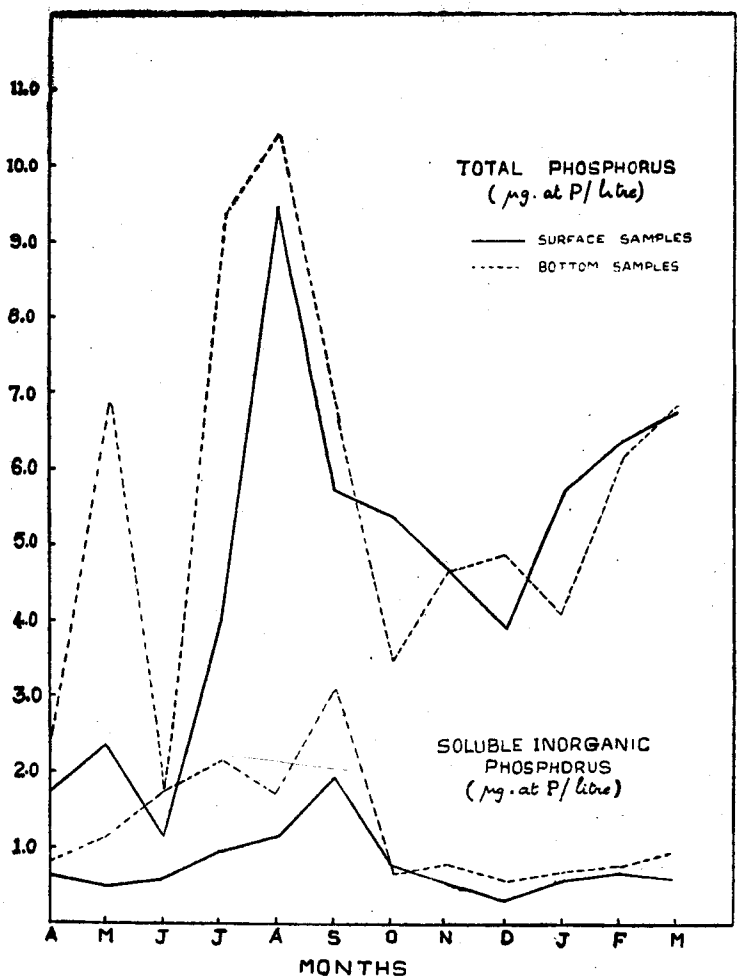

FIG. 1. Seasonal variations in total phosphorus and soluble inorganic phosphorus levels during 1954–55 in the inshore waters off West Hill, Calicut.

8·5 to 51·3% of the total throughout the year 1954–55. The same phenomenon was observed in the waters of the Palk Bay and Gulf of Mannar but the values recorded for total and inorganic phosphorus were much lower than in the Malabar waters.

DISCUSSION

For a proper understanding of the significance of the results of the present investigation, it would be necessary to consider the nature of the environment which is characterised by special climatological and topographical features. The Malabar Coast of India is subjected to a heavy rainfall

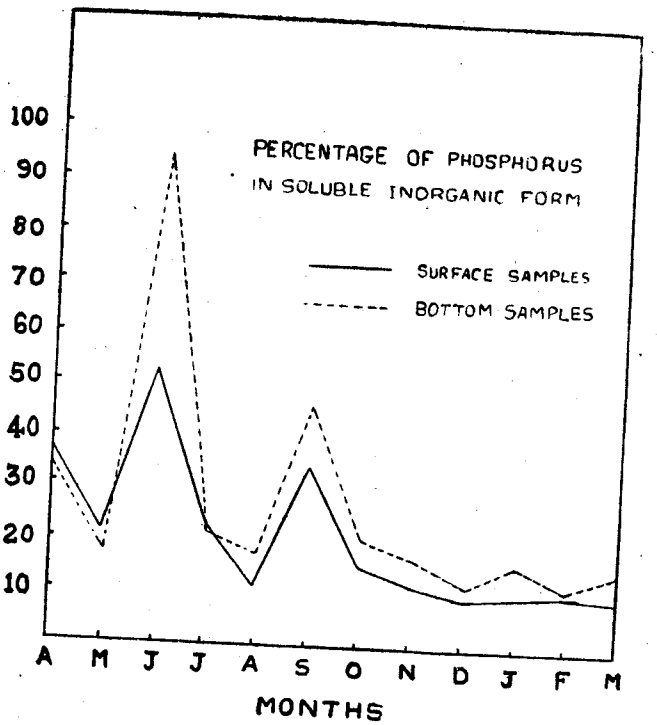

FIG. 2. Seasonal variation in the percentage of phosphorus present in soluble inorganic form in Calicut waters during 1954–55.

amounting to 120″ per annum and numerous streams carry enormous amounts of water so precipitated from the Western Ghats situated along the coast into the Arabian Sea. The sea bottom is predominantly muddy all along the west coast up to Mangalore with the presence of mud-banks at various places. The inshore waters in question are also influenced to a considerable extent by Korapuzha, Beypore and Kallayi rivers emptying within 10 miles of Calicut. Hydrological conditions off the Malabar Coast are primarily dependent on the S. W. monsoon which breaks out around June which results in severe agitation of the water column apart from the influx of fresh waters.

It may be observed from the data presented in the preceding section that the total phosphorus content of the inshore waters off the Malabar Coast is fairly high and is largely made up of the bound and organic forms. Inorganic phosphate levels in this region are known to be higher than the values reported from stations on the east coast (Jayaraman [a,b] 1953; 1954; George, 1953). The present study indicates that total quantity of phosphorus is much higher than the commonly estimated dissolved inorganic

component. Though the levels observed are greater than the values reported for the Gulf of Maine (0·45 to 1·15 μg.-ats./1.) and the waters of the English Channel (about 0·45 μg.-ats/1.) for the surface layers, the former refer to a region 30 miles away from the coast (250 m. deep). The latter concentrations were observed 5 miles off Plymouth. Investigations in the Gulf of Mexico along the Florida Coast in connection with the red tide phenomena showed that inshore waters, 3 miles off the coast contained only about 1·0 μg. at P per litre though the organic phosphorus fraction was generally more predominant. High concentrations of total phosphorus were observed to bear some relationship to local concentrations of *Trichodesmium*, (Graham *et al.*, 1954). Australian waters of the Bass Strait contain much lower quantities (0·09 to 0·36 μg.-ats. P/1.) according to Rochford (1956).

Redfield *et al.* (*loc. cit.*) observed that dissolved organic phosphorus compounds appear in large quantities in summer during the peak period of plankton production followed by an accumulation of inorganic phosphate in the winter months. The integral mean concentration of total phosphorus was practically unchanged being 9·4 to 11·0 gm. below one sq. metre. Their findings were confirmed by Armstrong and Harvey (*loc. cit.*) who attributed the changes observed in the total phosphorus content (integral mean) from 10 to 16 mgm. P/m.^{3} to the movements of water masses and their mixing.

Total phosphorus levels in the Malabar waters appear to vary within wide limits. Individual observations were far more variable than the monthly average values would indicate and ranged from 0 to 18·0 μg.-ats./1. for the surface waters. Monthly average values from the offshore station, 10 miles away from Calicut, showed a similar variation, 0·8 to 6·6 μg.-ats. in surface waters and 4·0 to 10·2 μg.-ats. in the bottom layers. The range for surface waters was 1·42 to 33·4 μg.-ats. in the Quilandy Bay. It does not, however, appear likely that rivers of this region contribute significant amounts of either organic or inorganic phosphorus compounds. Waters of the Korapuzha river were found to be poorer in both factors. However, the river mouth itself showed a higher concentration of total phosphorus presumably due to vertical mixing and replenishment from the bottom muds which were found to be rich in phosphates. The river itself is characterised by a sandy bottom.

Results of the present investigation indicate that the elevation of phosphate levels with the commencement of the monsoon is accompanied by more striking changes in the total phosphorus content. It is, however, possible that much of the total phosphorus, particularly in the monsoon

months, may represent phosphate liberated from colloidal soil phosphates by acid digestion and may not be directly available biologically (Rochford, 1951). A close study of the relative abundance of total and inorganic phosphate suggests that rise in total phosphorus precedes the replenishment of the inorganic phosphate levels and the changes are reflected earlier in the bottom waters in each case. All the three possible mechanisms suggested by Seshappa and Jayaraman (1956), namely release from the bottom muds, influx of silt-laden fresh-waters and large-scale mortality of bottom dwelling organisms at the commencement of the monsoon may account for the high concentrations of total phosphorus observed in the monsoon months. The last-mentioned probability appears to be more plausible and is of greater significance for the release of large quantities of dissolved organic phosphorus compounds in the bottom layers. However, it is not clear as to why the total phosphorus levels are relatively high during the post-monsoon months and the levels show an upward trend from December. Further work on the seasonal changes covering a longer period alone can give a fuller knowledge of the phosphorus cycle.

Apart from the usefulness of total phosphorus determinations for the identification of different water masses as adopted by Soule *et al.* (1954), a comparative study of the observations made at Mandapam with the data from the west coast confirms its value as an index of the fertility of different waters. The ease with which samples could be analysed after storage without noticeable deterioration and without the use of preservatives offers an additional advantage in oceanographical investigations as pointed out by Ketchum *et al.* (1955).

Summary

The object of this investigation was to study the total phosphorus content of the inshore waters with a view to understanding the phosphorus cycle in the sea. Seasonal variations in the total and soluble inorganic phosphorus concentration in the inshore waters of the Malabar Coast, a region highly productive from the fisheries point of view, was studied over a period of one year during 1954 to 1955 near West Hill, Calicut. Preliminary observations on the data collected have been presented in this account which also include some information on the total phosphorus content of the waters of the east coast near Mandapam. Sea-waters off Calicut were found to be rich in total phosphorus which varied from 1·2 to 9·5 μg.-ats. P/l. in the surface layers. Soluble inorganic phosphorus accounted for only 8·5 to 37·0% of the total except in the month of June when the onset of the S.W. monsoon is followed by a steep rise in the total as also the inorganic

phosphate. It is probable that release from the bottom muds as a result of the severe agitation of the water column in the monsoon months may explain the high levels of phosphorus compounds. Large-scale mortality of bottom dwelling animals may also play some part in this connection.

A comparative study of the levels on the east and west coasts confirms the usefulness of total phosphorus determinations as an index of the potential fertility of different regions.

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REFERENCES

Armstrong, F. A. J. and Harvey, H. W. — "The cycle of Phosphorus in the water of the English Channel," *Jour. Mar. Biol. Assoc. U.K.*, 1950, **29**, 145–62.

Atkins, W. R. G. .. — "The phosphate content of fresh- and salt-waters in its relationship to algal plankton," *Ibid.*, 1923, **13**, 112.

Graham, H. W., Amison, J. M. and Marvin, K. T. — "Phosphorus content of waters along the West Coast of Florida," *U.S. Dept. Int. Fish and Wild life Service Spl. Sci. Rep. Fish.*, 1954 (122), 1–43.

George P. C. .. — "The marine plankton of the coastal waters of Calicut with observations on the Hydrological conditions," *J. Zool. Soc. India*, 1953, **5** (1), 76–107.

Hansen, A. L. and Robinson, R. J. — "The determination of organic phosphorus in sea-water with perchloric acid oxidation," *Jour. Mar. Res.*, 1953, **12**, 31.

Jayaraman, R. .. — "Observations on the chemistry of the waters of the Bay of Bengal off Madras City during 1948–49," *Proc. Ind. Acad. Sci.*, 1951, **33**, 90–99.

——— .. — "Seasonal variations in salinity, dissolved oxygen and nutrient salts in the inshore waters of the Gulf of Mannar and Palk Bay near Mandapam, S. India," *Ind. J. Fish.*, 1954, **1** (1), 345.

Kalle, K. .. — "Nahrstoff untersuchungen als hydrographisches Hilfsmittel zur Unterscheidung von wasserkorpern," *Ann. Hydrogr.*, Berlin, 1937, **65**, 1–18.

Ketchum, B., Corwin, N. and Keen, D. J. — "The significance of organic phosphorus in ocean waters," *Deep-Sea Research*, 1955, **2**, 172–81.

Redfield, A. C., Smith, H. P. and Ketchum, B. — "The cycle of organic phosphorus in the Gulf of Maine," *Biol. Bull. Woods Hole*, 1937, **73**, 421–43.

Rochford, D. J. .. — "Studies in Australian Estuarine Hydrology. I. Introductory and Comparative Features," *Austr. Jour. Mar. and Fresh-water Res.*, 1951, **2** (1), 1.

Rochford, D. J. .. "Onshore Hydrological Investigations in East and S.W. Australia, 1954," *Ocean. Station list*, **24**, *C.S.I.R., Div. of Fish.*, Melbourne, 1956.

Seshappa, G. .. "Phosphate content of mud banks along the Malabar Coast," *Nature*, London, 1953, **171**, 526.

——— and Jayaraman, R. .. "Observations on the composition of bottom muds in relation to the phosphate cycle in the inshore waters of the Malabar Coast," *Proc. Ind. Acad. Sci.*, 1956, **43 B**, 288–301.

*Soule, F. M., Bush, A. L. and Murray, J. E. "International observation and ice patrol service in the North Atlantic Ocean—Season of 1953," *U.S. Coast Guard Bull.*, 1954, **39**.

* Not consulted in original.