J. Mar. biol. Ass. India, 1959, 1 (2): 212-223

HYDROLOGY OF THE KORAPUZHA ESTUARY, MALABAR, KERALA STATE*

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INTRODUCTION

A preliminary enquiry on the hydrological and planktological conditions in the river mouth region was conducted during the period 1950-52 and the results published in an abstract form (George, 1953*a*). This study was later extended to cover the 25 km seaward region of the estuary in 1954. As is well known, the Malabar coast is highly productive from the fisheries point of view and it was also observed that the sea waters of the inshore region off Calicut are rich in plankton and nutrient salts (George, 1953*b*). Results of the present investigation would therefore serve to assess the influence of land drainage in the enrichment and replenishment of the coastal waters and allied factors. The west coast of India which is subjected to a heavy rainfall amounting to more than 300 cm per annum, is characterised by numerous short and swift rivers which carry the enormous amounts of the waters from the Western Ghats into the sea.

TOPOGRAPHY OF THE ESTUARY

The Korapuzha is a short and shallow river, 52 km long and consists of the Elathur River which joins the Korapuzha backwater system close to the mouth of the estuary about a kilometer away from the sea and another stream running from the foot of the high mountain range surrounding the Kodiyanadumalai (700 Metres) which also empties into the back-waters near Kaniangode about 16 km away from the river mouth. The estuary is never dry. During the rainy season torrential flow of silt-laden fresh waters run down the river suppressing almost completely the ebbtide. Since there are no towns or factories or large villages on the bank of the river, the waters are mostly free from pollution. The river is shallow, never more than five meters deep anywhere in the estuary and the bottom is sandy.

METHODS

During the period 1950-52, collection of water samples was made near the Elathur road bridge, about a kilometer away from the river mouth and two other stations a few hundred meters below and above this point. However there are no significant differences in the data obtained from the three stations and the data

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from the Bridge region alone have been reported in this account. From April 1954, collections were made from seven additional stations located along the 25 km region of the estuary as shown in Fig. 1. Seawater samples were collected from Station I, close to the river mouth to serve as an index of the conditions in the sea. Though regular studies were confined to these stations, regions beyond the areas under study on the Payyoli and Tamarasseri sides were visited during the different seasons.

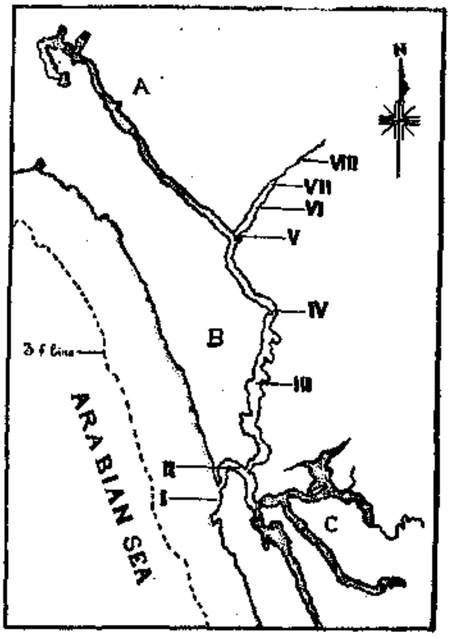

FIG. 1. Map (adapted from Admiralty chart) showing the different stations
A—*Payyoli* backwaters. (Seasonal observation centre)
B—Korapuzha river.
C—Elathur backwaters (Seasonal observation centre)

Salinity was determined by the method described by Harvey (1945). However during the monsoon season when low values were observed the method described by Ellis *et al* (1946) was adopted for the estimation. Phosphates were estimated by Deniges-Atkins method (Atkins, 1923*a*). No correction was applied for the Salt error. Nitrates were estimated by Harvey's reduced strychnine method as described by Jayaraman (1951). Silicates were estimated by the Dienert and Wandenbulcke method as modified by Atkins (1923*b*). A few samples of soil and bottom muds studied during the investigation were analysed for soluble and total phosphorus by methods described by Rochford (1951).

RESULTS

Data obtained from the study of the hydrological conditions in the mouth of the estuary (Station II) during the years 1950 to 1952 are presented. Monthly average values of salinity, silicates, phosphates and nitrates at this station composed of four seasonal cycles during the period 1950 to 1955 are represented in Figs. 9 to 12. The seasons are designated according to the following basis :

Summer	March, April and May.
SW. Monsoon	June, July, August and September.
Post-Monsoon	October and November.
Winter	December, January and February.

Temperature.—Seasonal variation of the temperature of the river waters at the mouth of the estuary during 1954-55 is shown in Fig. 2. Chlorinity variations at the same station as also the air temperature and rainfall data for Calicut are plotted in the same figure. Variation of water temperature (Fig. 2) is from 26.5°C to 32.5°C and that of air 27.5°C to 34.5°C. Water temperatures are always lower than air temperature at the corresponding period. The pattern of seasonal cycles is similar, though the water temperature distribution shows two minima during July and September as against July alone in the case of the air temperature. The deviation of water temperature from that of the overlying air is minimum during the period of the active S.W. monsoon from June to August and is maximum during the post-monsoon period.

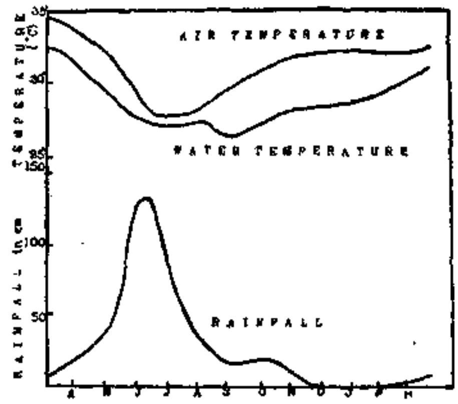

FIG. 2. Annual variation of Air and Surface water temperature of the Korapuzha estuary during 1954-55.

Chlorinity.—The data obtained from the study of the seasonal variation in chlorinity in the different parts of the estuary are graphically recorded in Fig. 3. Its longitudinal distribution during the four seasons of the year is shown in Fig. 7. As the post-monsoon period is characterised by large fluctuations from week to week the mean amplitude of variation is also shown in the graphs representing the seasonal cycles in chlorinity. One of the main results of the survey is the wide range in chlorinity exhibited in the estuarine region of the river ranging from fresh water conditions to strictly marine environments. In the summer months of March, April and May, chlorinity is as high as $18^{\circ}/_{oo}$ even up to 16 km from the river mouth (Station V) and no horizontal gradient exists for this region while it abruptly drops down to less than 1 $^{\circ}/_{oo}$even in the mouth of the estuary just after the onset of the S.W. monsoon in June. A sharp horizontal gradient exists however, for the river water between Station V to VIII throughout the year and the annual variation for Station VIII is 0 to 14°/$_{oo}$. The river water gets progressively less saline beyond this station and there is a drop in chlorinity from 9.5°/$_{oo}$ to 3.3°/$_{oo}$ within a distance of 3½ km. At Kottalluthazhae, 5 km from Station VIII, it was only 0.5°/$_{oo}$ on the same occasion. During the post-monsoon season a distinct time lag is evident in the recovery phase of the seasonal cycle. This period was also marked by sudden fluctuations in chlorinity. As against the active monsoon period during which even the Control station recorded chlorinities below 0.5°/$_{oo}$; the sea waters in the inshore region at this station varied between 16 to 18°/$_{oo}$ only.

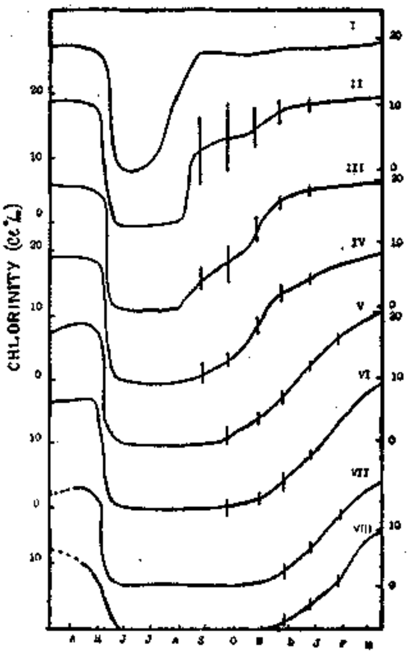

FIG. 3. Annual variation of chlorinity (Cl %$_{o}$) at different stations during 1954-55. Bars denote average deviation.)

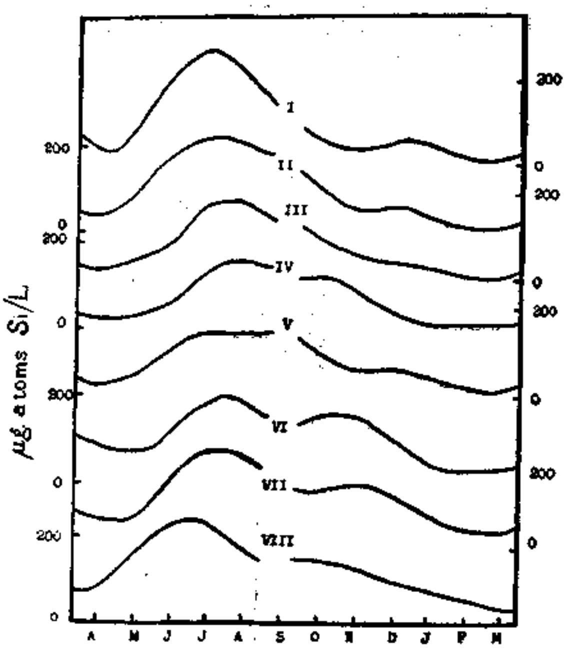

FIG. 4. Annual variation of silicates expressed as μg at. Si/L at the different stations during 1954-'55.

Silicates.—The distribution of silicates in the estuary is represented in Figs. 4 and 7. The waters of the estuary as also the sea water in the inshore region contain large quantities of silica in solution, the variation for the river mouth during the different seasons during 1954-55 being 40 to 220/ *μg at.* Si/L., the corresponding variation in the sea water being 20 to 260/*μg at.* Si/L. It must be remembered in this connection that the sea water samples have been collected close to the shore. Silicate concentration increases upstream and the annual variation for Station VIII is from 80 to 240/*μg at.* Si/L. Highest values have been recorded in July during the monsoon season and their concentration remains fairly high throughout this period. Stations in the upper reaches of the estuary exhibited a second major peak period in November. A well defined gradient exists in the horizontal distribution of silicates though, the region around the river mouth is always rich in this element.

Phosphates.—The data relating to the phosphate content of the water samples studied are shown in Figs.* 5 to 7. Annual variation for the river mouth (Station II) is 0.56 to 2.52 μg *at.* P/L during the period 1954 to 1955. The sea water of the Control station contained 0.84 to 4.20 μg *at.* P/L. On the other hand the river waters in the upper reaches of the estuary (Station VI to VIII) were very poor in phosphates and the variation is between 0 to 0.70 μg *at.* P/L except during period of onset of the S.W. monsoon when the values approach 1.40 μg *at.* P/L. The moderate rise in phosphates observed with the commencement of the S.W. monsoon at all stations is soon followed by a general fall to pre-monsoon values in July and while the head waters thereafter are uniformly low in phosphates, the

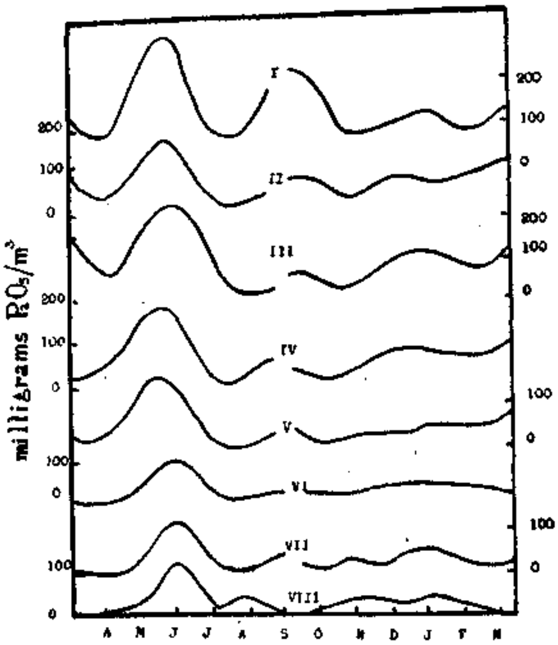

FIG. 5. Annual variation of phosphates expressed as mgm. P_2O_5/m^3 at the different stations during 1954-'55.

waters of the river mouth show two secondary maxima in the post-monsoon and winter seasons. Phosphate content decreases progressively towards the head waters during all the four seasons. The regions beyond the stations and in the backwater (Fig. 1) regularly studied, contained only traces of phosphates. The bottom muds collected during the pre-monsoon period in the mouth of the estuary are fairly rich in phosphates containing 78.8 μg in the soluble form and 1·83 μg as total phosphorus per gram of mud.

* In the graphs phosphate and nitrate values are expressed as mgm. P_2O_5/M^3 and mgm. $NO_3—N_2/M^3$ respectively.

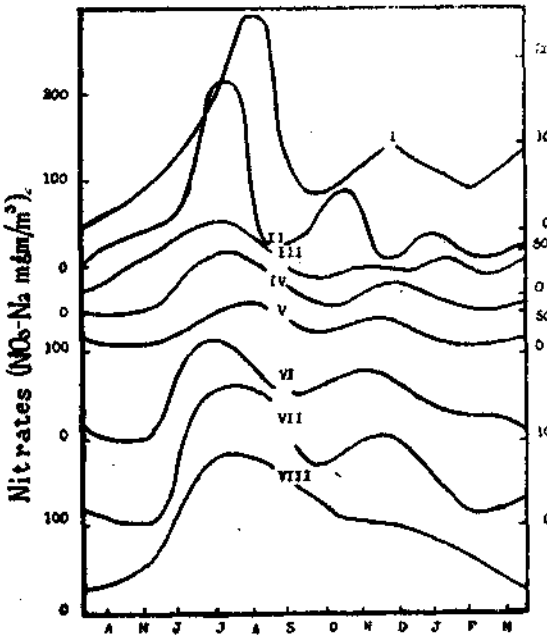

FIG. 6. Annual variation of nitrates expressed as mgm. NO_3-N_2/m^3 at the different stations during 1954-'55.

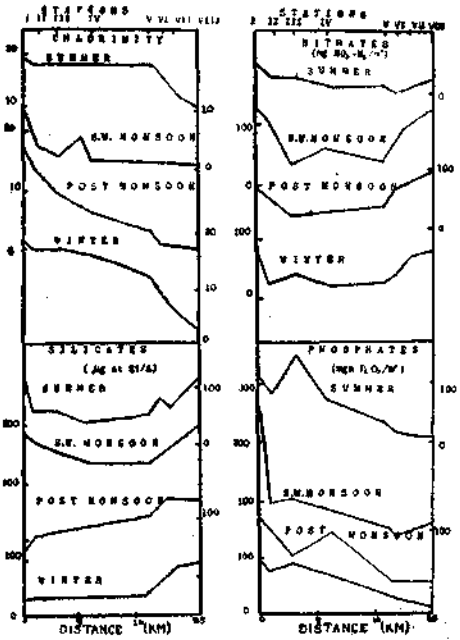

FIG. 7. Horizontal distribution of chlorinity, silicates, phosphates and nitrates in the different seasons during 1954-'55.

Nitrates.—Nitrate content (Figs. 9 and 10) of the river waters varied widely from week to week, however, the pattern of distribution is similar to that of silicates. The variation is as wide as 0 to 15.71 *μg at.* N/L for the river mouth (Station II) and 0 to 17.85 *μg at.* N/L for the Control station. The onset of the S.W. monsoon is accompanied by a general rise in the nitrate levels and the concentration of this nutrient remains high during the monsoon months from June to September. River waters in the mouth of the estuary show two more peak periods in October and January. A second peak is also seen in December in the neighbouring inshore region. The head waters of the river also show a second maximum which occurs in November. The horizontal distribution shows a progressive increase in nitrate content from Stations I to VIII as in the case of silicates, except during the pre-monsoon months. However, the nitrate content of the river waters at the head of the estuary remained high almost in all seasons.

DISCUSSION

Though extensive studies on the hydrology of estuarine waters have been made previously, such studies are usually confined to salinity variations or the problems connected with pollution. Detailed investigations on the seasonal changes in the hydrological factors of estuaries as in the present instance are few. A knowledge of the seasonal variations in salinity and plant nutrients as also their horizontal distribution would enable a better understanding of the factors contributing to the distribution and movements of animal populations. It would also incidentally contribute to the knowledge regarding the significance of land drainage in the replenishment of inshore regions with nutrient salts. The greater productivity of Atlantic as against Pacific and Indian Oceans has been attributed to its greater share in the drainage from the continents (Allee and Schmidt, 1937). The river under study is one of the numerous streams that drain into the Arabian sea off the West coast of India, and this coast is well known as a highly productive region from the fishery point of view. The present investigation was intended not only to study the hydrology of this estuary but also to evaluate its influence on the hydrological conditions in the neighbouring inshore regions. Since the waters of the estuary are free from pollution the results of this survey may be of considerable hydrological and geochemical interest.

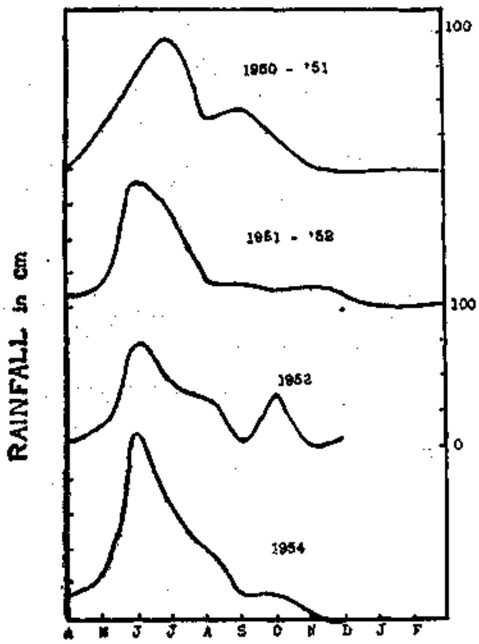

Fig. 8. Annual variation of rainfall at Calicut during the years under study.

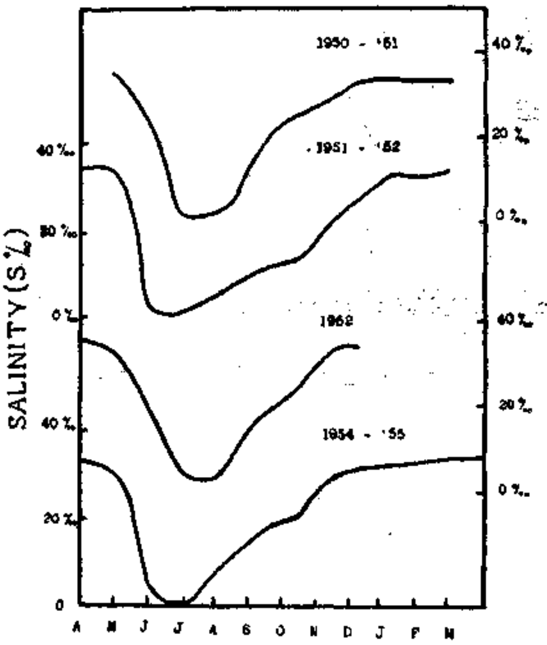

Fig. 9. Annual variation of salinity (S ‰) during the different years under study.

Temperature observations indicate the close correlation on the seasonal cycles of the water and overlying air temperature near the mouth of the estuary. Maximum divergence in temperature distribution has been recorded during the post-monsoon period and winter season, the temperatures being nearly equal during the active monsoon months. However the relative rates of temperature diminution and increase are different as can be observed from Fig. 2 depending on relative specific heats, being slower in case of water masses. Intermittent rains resulting in heavy influx of cooler fresh waters may explain the low water temperature in September.

Salinity distribution in estuaries are controlled by the tide and influx of fresh water. The direction of the prevailing winds are also important in this connection. Though a few observations recorded at the river mouth have revealed considerable salinity fluctuations due to tidal influence, seasonal variations alone have been dealt with in the present account. A detailed account of the results of a mathematical analysis of the dynamics of the water masses will be published elsewhere. An inverse relationship between chlorinity and rainfall is evident from the data (Fig. 2). This is not surprising when the magnitude of rainfall amounting to nearly 375 cms. during the year, shortness of the river course and the shallowness of the estuary are considered which would explain the absence of a time lag and vertical stratification. While marine conditions prevail up to Kaniangode 16 km away from the river mouth in Summer (March, April and May) with chlorinities as high as 18°/$_{oo}$ near fresh water conditions with chlorinities lower than 0.5°/$_{oo}$ are observed soon after the onset of the S.W. monsoon even at the river

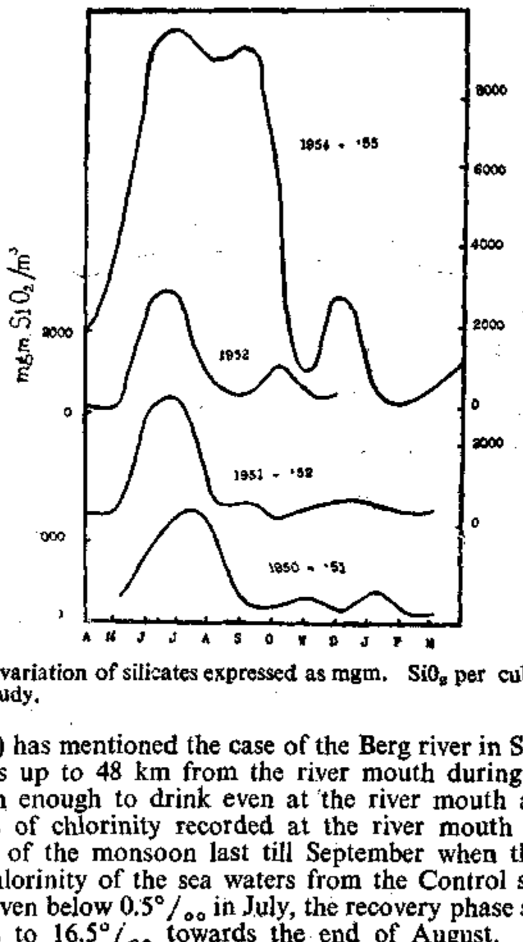

FIG. 10. Annual variation of silicates expressed as mgm. SiO_2 per cubic metre during the different years under study.

mouth. Day (1951) has mentioned the case of the Berg river in South Africa where saline water extends up to 48 km from the river mouth during dry season while the waters are fresh enough to drink even at the river mouth after the rains set in. The low levels of chlorinity recorded at the river mouth immediately after the commencement of the monsoon last till September when the recovery phase sets in. Though chlorinity of the sea waters from the Control station also shows an abrupt drop to even below 0.5°/$_{oo}$ in July, the recovery phase starts much earlier and chlorinity rises to 16.5°/$_{oo}$ towards the end of August. However the progress of recovery is not smooth and is characterised by violent fluctuations whose mean amplitude is recorded in Fig. 3. Sea water does not on the other hand show any evidence of large scale dilution during this post-monsoon period. Intermittent rains as also the high salinity of the sea waters would explain these wide variations. A consistent time lag during the recovery phase is reflected in the chlorinity curve from the different stations of the estuary. The horizontal distribution of chlorinity enables a broad division of the estuary into two well defined zones, i.e. from the river mouth from Kaniangode (Stations II to V and covering about 16 km) and from Kaniangode to Naduvannur (Stations V to VIII of about 8 km). The latter portion of the estuarine region studied is characterised by a large horizontal gradient in salinity whereas the region up to 16 km from the sea is highly saline. For the bridge station salinity data (Fig. IX), is available for four years during 1950 to 1955. Lowest salinities of 0.5°/₀₀ and 1.8°/₀₀ have been observed in July during 1950 and 1951. In 1952 the corresponding salinity was 3.1°/₀₀ in the same month. The pattern of variation is similar for the four annual cycles, June-August period showing lowest salinities and the correlation with rainfall is quite close.

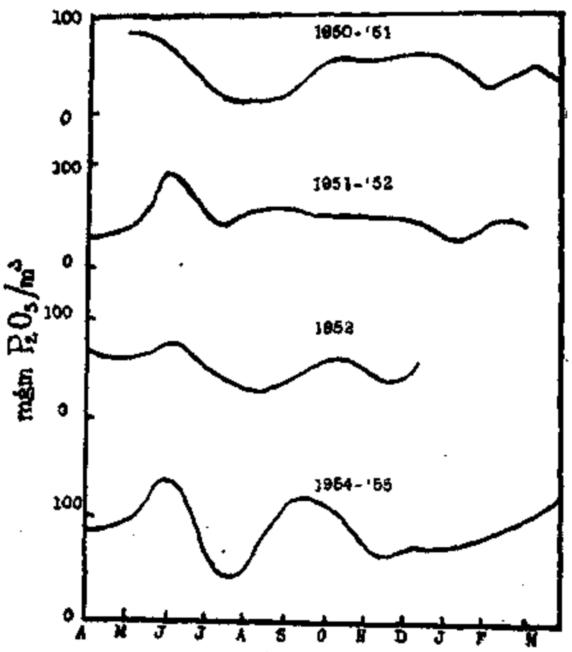

FIG. 11. Annual variation of phosphates expressed as mgm, P_2O_5 per cubic metre during the different years under study.

The horizontal distribution of silicates in the estuary and in different seasons confirms the well known phenomenon of their transport into the sea by fresh waters. The range of 20 to 220 *μg at.* Si/L observed in the river mouth and the head waters is rather high but it must be considered that the laterite nature of the drainage area may explain these high concentrations. Higher values for the control station as also the river mouth in July is perhaps governed by the vertical mixing at the river mouth and the higher pH of the sea waters which aids in the conversion of silica into the soluble forms (Atkins, 1923). Silicates also bear an inverse relationship to chlorinity in the horizontal distribution and seasonal variation. Patterns of seasonal cycles in the silicate content for the four years are similar though the values for 1955 are much higher.

Inorganic phosphate content of the river waters in the mouth of the estuary ranging from 0.28 to 2.50 μg *at.* P/L is high but the distribution of phosphate in the neighbouring inshore regions also showed high values for the sea waters during the same period (Suryanarayana Rao, 1957). Seasonal variations during the years studied is similar with two major peak periods in June just after the onset of the S.W. monsoon and during the post-monsoon period of September and October. Though

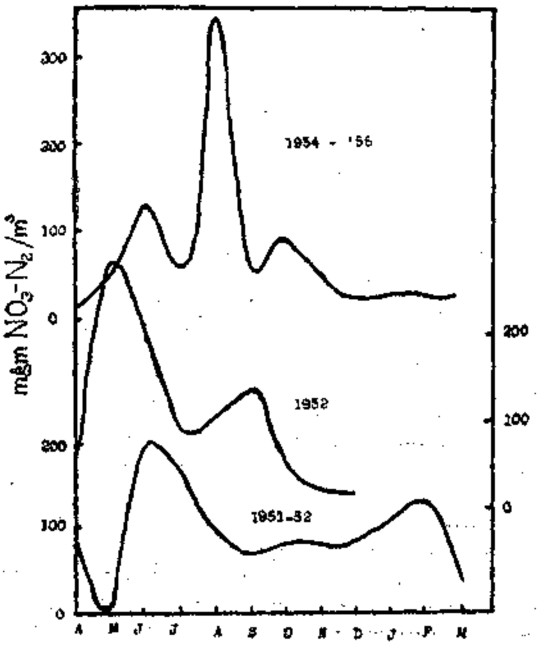

FIG. 12. Annual variation of nitrates expressed as mgm. NO_3-N_2 per cubic metre during the different years under study.

the phosphate content registers an abrupt rise to high levels with the commencement of the monsoon as in the case of silicates, the rise in phosphates appears to be a temporary phenomenon as the values fall by the end of June, though the rainfall continues to be heavy till the middle of August. A similar trend is conspicuous at all stations of the river. This does not indicate any active transport of phosphate leached from the soil but a local replenishment of surface waters by vertical mixing. Phosphate maxima observed near the river mouth at Stations I and II may be governed by the release of soluble inorganic phosphate from the bottom muds under the influence of the turbulence in the active monsoon period. The horizontal distribution of phosphates does not support the view that appreciable amounts of phosphates are transported by the river into the inshore region. The head waters of the river are poor in phosphates and in fact the concentration increases downstream.

Nitrates however show a similar seasonal variation to the pattern observed for the silicates and their distribution in the different regions of the river tends to indicate that the river waters may contribute significant amounts of nitrates along with the silicates. When the data regarding the nitrate values were plotted against the corresponding figures for the phosphates to study their inter-relationship, if any, the values range around a parabola showing a quadratic relationship. The data for Station II have been used in this connection. It has been suggested that a linear relation exists for the N/P ratio in case of sea waters (Cooper, 1938). The significance of these findings is being investigated.

Though Atkins (1923) had originally suggested that the incoming nutrients may be highly significant in the enrichment of sea waters near river mouths he had observed later that the rivers in the vicinity of the Plymouth sound contributed little phosphate to the ocean. Harvey (1928) attributed the same to the exhaustion of plant nutrients by algal growth before they reach the sea. However plankton observations in the river under study (George, unpublished) would not offer a similar explanation in the present instance. Day (*l.c.*) had on the other hand found the river waters to be always rich in phosphates in case of the rivers of South Africa which he had studied, though the nitrate values were lower. Newcombe and Brust (1940) observed a higher phosphate content in the head waters of the Patuxant river draining into the Chesapeake bay. Riley (1937) detected a zone of high phosphate content around the mouth of the Mississipi river. It is possible that these conflicting observations may be explained by the geochemical nature of the drainage area as suggested by Rochford (1951). The plains over which the rivers of the Malabar coast flow, of which Korapuzha is one, consists geologically of laterite formation fringed on the seaward side by narrow belt of recent alluvium (Bristow, 1938). Laterite is known to be deficient in plant nutrients and phosphates in particular (Raychaudari, 1937), though Seshappa (1953) had attributed the high phosphate content of bottom muds off Calicut to the laterite nature of the Malabar Coast. A sample of the laterite soil from the mountainous region lying close to the head waters of the river contained on analysis less that 100 μg./100 gm of the soil as interstial water-soluble inorganic phosphorus and even the total phosphorus was also low being 32 μg./100 gm of soil. It is therefore felt that these estuaries do not constitute a direct source of the high inorganic phosphate levels observed in the inshore regions of the West coast. Their contribution of silicates and nitrates is of considerable magnitude.

SUMMARY

An account of the seasonal and annual variations of chlorinity and nutrient salts in the Korapuzha estuary in Kerala State is presented based on the observations during a four year period from eight stations along a 25 km region.

Large seasonal variations in the distribution of chlorinity, silicates, phosphates and nitrates exist in the Korapuzha estuary, the observed fluctuations being largely the results of varying amounts of rainfall in different seasons. The [illegible] of chlorinity reaches a value below 0.1 ‰ with the commencement of the S[illegible] monsoon in June even at the river mouth though the waters up to 16 km fro[illegible] the river mouth are highly saline in the dry season.

Appreciable amounts of nitrates and large quantities of silicates are carried into the sea by the river.

It is unlikely that the contribution of phosphates is of similar significance and therefore the Korapuzha estuary may not constitute a direct source of the high phosphate levels of the neighbouring inshore waters.

ACKNOWLEDGEMENTS

The authors wish to express their grateful thanks to Dr. N. K. Panikkar for his interest in the investigation, and to Dr. B. S. Bhimachar and Dr. S. Jones for suggestions and encouragement.

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