

TABLE 1 — IRON AND MANGANESE IN BOTTOM SEDIMENTS OF THE EASTERN PART OF BAY OF BENGAL

Sample No.	Location	Depth fm	Iron %	Manganese %
SOUTHERN PART				
17	7°40'N 97°08'E	202	4.4	0.025
19	8°29'N 97°59'E	27	4	0.015
20	9°13'N 97°51'E	35	2	0.02
24	10°36'N 95°39'E	1360	12	0.165
28-I	11°20'N 92°40'E	30	5.7	0.015
28-II	11°35'N 92°40'E	25	8.3	0.016
28	11°49'N 92°52'E	49	6.9	0.02
28B	12°01'N 92°55'E	27	3.6	0.025
Range			2.0-12	0.015-0.165
Average			5.9	0.038
NORTHERN PART				
36A	13°00'N 97°41'E	37	19.1	0.34
40	15°19'N 96°24'E	10	9.4	0.095
42	15°08'N 94°54'E	16	9.6	0.04
43	15°08'N 94°04'E	30	6	0.055
50A	19°27'N 92°32'E	550	8.1	0.05
48	19°41'N 93°08'E	21	5.2	0.085
47B	19°50'N 92°55'E	17	6.6	0.06
Range			5.2-19.1	0.040-0.34
Average			9.1	0.104

Percentages of iron and manganese in the clay fraction of sediments along with the water depth of the sample are given in Table 1. Iron content varies from 2 to 19.1% with higher concentrations in the northern part of the study area. Average value of 7.4% of iron in these sediments is higher than the average (6.2%) of continental shelf clays in the western part of Bay of Bengal<sup>7</sup>.

In the present study, a regional variation in the concentration of iron has been observed; an increase is observed in the values of this element in the northern part where the continental source is nearer when compared to the southern part. This leads us to believe that the contribution is practically from land. The Brahmaputra and Irrawaddy river systems with considerable iron content (2.78 to 10.35 Fe)<sup>8</sup> join the Bay of Bengal in the north-eastern part. The sedimentary detritus discharged by the above rivers is mostly deposited in the northern part of the present study area resulting in the increase of iron content.

It is interesting to note that the sample (No. 36A) gives maximum iron and manganese percentages (Table 1). The positive relationship ( $r = +0.29$ ) between iron and manganese in these sediments (Fig. 1) indicates a geochemical affinity between them and their co-precipitation. Such a co-precipitation of iron and manganese might be possible due to the presence of positively charged  $Fe(OH)_3$  sols on the one hand and negatively charged  $Mn(OH)_4$  sols on the other in the sea water as reported<sup>9</sup>.

The present study reveals that the northern part shows relatively higher values for iron than the southern part. This higher concentration is attributed to the nearness of the continent, which is the ultimate source of the iron. The positive relationship between iron and manganese in these sediments suggests that the same set of environmental condi-

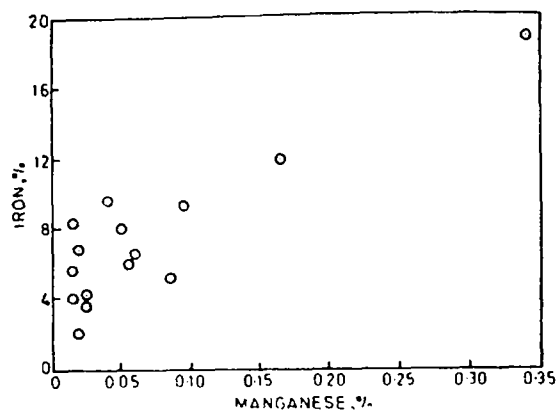


Fig. 1 — Relationship between total iron and manganese contents

tions might have favoured the co-precipitation of these two elements.

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#### Carbohydrates in the Estuarine & Coastal Waters Around Goa

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Carbohydrates, soluble and particulate, have been estimated in the estuarine and coastal waters around Goa from July 1974 to June 1975. Two large peaks of soluble carbohydrate (9 mg glucose/litre), observed in estuarine waters during postmonsoon, are attributed to phytoplankton activity. Particulate carbohydrate shows a large peak in monsoon (July) which is due to land drainage. Levels of soluble and particulate carbohydrates in offshore waters vary respectively from 0.5 to 29 and 0.2 to 0.6 mg glucose/litre. Some observations on the diurnal variations in the estuarine

waters indicate that the concentrations of soluble and particulate carbohydrates vary respectively from 0.12 to 26 and 0.3 to 0.6 mg glucose/litre. These variations are found to be mostly related to the phytoplankton activity.

**DISTRIBUTION** of carbohydrates in the Indian waters is not reported. In the marine environment concentration of carbohydrates is predominantly controlled by phytoplankton productivity. In view of the high productivity of the inshore and estuarine waters around Goa<sup>1,2</sup>, the present study has been undertaken to examine the distribution of particulate and dissolved carbohydrates.

Water samples from surface and bottom were collected at fortnightly intervals from station A (depth 4 to 5 m) at Dona Paula Jetty in Zuari estuary 15°27'N and 73°50'E, and at Station B (depth 20 m) in coastal waters off Cabo Nivas (15°27'N and 73°45'E). Station A is influenced by fresh water discharge during monsoon, while station B is predominantly marine. However, runoff of fresh water influence from Zuari and Mandovi rivers can also be felt at station B during monsoon. The samples were filtered through 0.45 µm membrane filter paper immediately after collections. The filter pads and filtrates were frozen till the carbohydrate analyses were performed.

Carbohydrates, dissolved and particulate, were determined according to Strickland and Parson<sup>3</sup>. The method used for particulate carbohydrate depends on a quantitative reaction of carbohydrates with anthrone in sulphuric acid. Ten ml of anthrone reagent (freshly prepared) were added to 25 ml test tube containing 1 ml of suspension as described in the method. The sample was then heated in a constant temperature water-bath (100°C) for 6 min and cooled immediately under tap water. The absorbance of the coloured solution of furfuran and its homologues<sup>4</sup> was measured at 620 nm on spectrophotometer. Carbohydrates were measured in terms of glucose concentration; percentage standard deviation is ±1%. For dissolved carbohydrate, the phenol sulphuric acid method was used. Two ml of filtrate were treated with 2 ml of phenol and 10 ml of sulphuric acid in a flask. The absorbance of the colour complex was measured at 490 nm on spectrophotometer. Percentage, standard deviation is ±8%. The blank absorbance do not exceed 0.1 and 0.05 for soluble and particulate carbohydrates respectively.

Since regular collections could not be made in the offshore waters at station B data from station A are alone recorded in Figs. 1 and 2. Annual variations in the concentration of soluble carbohydrates from estuarine waters of Goa were from nil to 9 mg glucose/litre in surface water and nil to 8 mg glucose/litre in bottom waters (Fig. 1A). Levels of particulate carbohydrates (Fig. 1B) in surface waters and bottom waters varied from 0.12 to 0.8 and 0.12 to 1.1 mg/litre respectively. Concentration of soluble carbohydrate at station B varied between 0.5 and 29.4 and 0.8 to 13.8 mg/litre in surface and bottom waters respectively, whereas particulate carbohydrate varied between 0.21 and 0.65 mg/litre in surface and bottom waters (Table 1).

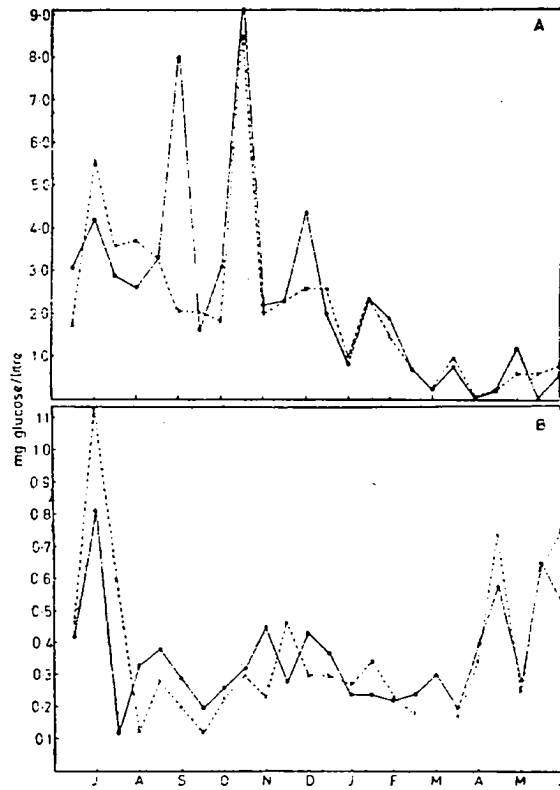


Fig. 1 — Annual variation of (A) soluble carbohydrates and (B) particulate carbohydrates at station A in Zuari estuary [●—●, surface and ×---× bottom waters]

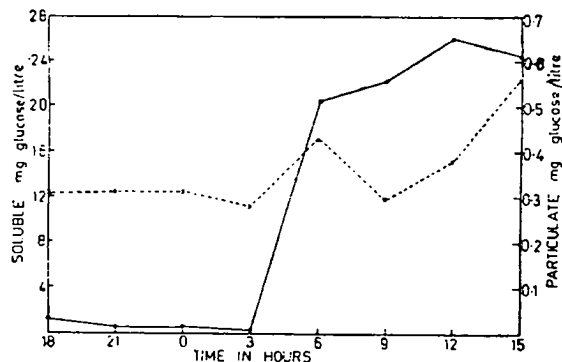


Fig. 2 — Diurnal variations of carbohydrates at station A, Zuari estuary [●—●, soluble carbohydrate and ×---×, particulate carbohydrate]

TABLE 1 — CONCENTRATION OF PARTICULATE AND SOLUBLE CARBOHYDRATES AT STATION B

Date	Particulate mg glucose/litre		Soluble mg glucose/litre		Salinity ‰	
	S	B	S	B	S	B
26-9-74	0.32	0.24	29.4	13.8	33.5	34.5
13-2-75	0.25	0.52	3.6	3.0	33.9	33.4
27-2-75	0.23	0.28	2.9	2.7	34.7	34.9
17-3-75	0.24	0.21	0.8	0.8	34.7	34.9
31-3-75	0.43	0.24	1.1	1.6	35.2	35.5
15-4-75	0.56	0.18	0.7	1.2	35.4	35.4
29-4-75	0.18	0.65	0.5	1	35.5	35.4

S=surface; B=bottom.

**Soluble carbohydrate** — In postmonsoon season soluble carbohydrates show 2 large peaks in surface waters and a single peak in bottom waters (Fig. 1). These high levels of soluble carbohydrates can be attributed to the growth of phytoplankton species such as diatoms. Diatoms are known to grow in postmonsoon and the blooms occur during this season along the west coast of India. The disappearance of the bottom peak during September may be due to the changes in the transparency of water affecting the phytoplankton activity in bottom layers<sup>5</sup>.

Soluble carbohydrate shows 2 short peaks in the surface water, one in monsoon in July and one in postmonsoon in December and in case of bottom water only a single short peak could be observed in July. The absence of any peak in bottom waters in December might be related to low productivity. The peak in July may be partly related with the germination of diatom spores<sup>5</sup>. Part of it might have been contributed by land drainage; on land the leaves of the green plants get decomposed and the carbohydrate gets dissolved in rain water and is transported to the estuary during monsoon. It is also possible that in water some of it must have been contributed by bacterial action on particulate carbohydrate of planktonic origin. Concentration of soluble carbohydrate changes significantly from January to May; it varied from nil to 2 mg glucose/litre and the surface and bottom values remain more or less the same. Lowest values are observed in April. These values may be due to the reduced activity of phytoplankton usually observed during the premonsoon season.

In general, the distribution pattern of soluble carbohydrates in the inshore waters off Goa is more or less the same except that the order of magnitude is 3-4 times higher than that of estuarine waters (Table 1). Soluble carbohydrates present in the inshore and the coastal waters of Goa are of higher order than those reported earlier for different waters<sup>6-8</sup>.

**Particulate carbohydrates** — Particulate carbohydrate shows some interesting patterns of distribution in surface as well as in bottom waters (Fig. 1B). Particulate carbohydrate may be formed by the activity of plankton or may be contributed by land drainage. Maximum concentration is obtained during monsoon in the estuarine waters. High particulate matter in monsoon discharges from land contains greater proportion of organic matter, which increases the levels of carbohydrates in the estuary. Level of particulate carbohydrate decreases during the last phase of monsoon (August) and this may be due to gradual sedimentation of particulate matter as evidenced by the relatively high concentration of particulate carbohydrate observed in the bottom waters.

During the early postmonsoon season in the first fortnight of September, particulate carbohydrate again increases due to the appearance of phytoplankton bloom. Thus the levels of particulate carbohydrate in surface layer remains higher than in the bottom layer. Marshall and Orr<sup>9</sup> studied the particulate carbohydrate in Loch Strive waters and observed that increase in particulate carbohydrate was accompanied with the rise in

diatom number. The level of particulate carbohydrate decreases considerably in the second fortnight of September which may perhaps be due to its active utilization by filter feeding organisms<sup>10</sup>. Part of the carbohydrate might have also been utilized by bacteria. In the later half of postmonsoon (November to December), significant changes are observed in the surface and bottom waters which can be attributed only to the turbulence of the waters by physical processes. The observed oscillatory type of distribution is caused by disturbances and resettlement of particulate matter.

During the premonsoon period, the particulate carbohydrate decreases and the concentration of about 0.26 mg glucose/litre is maintained in the water. Similar low concentration of particulate carbohydrate is reported by Biggs and Wetzel<sup>11</sup> in Chesapeake Bay. In May the levels show an increasing trend. This increase is due to the release of carbohydrate from the sediments by strong wave action. Due to this effect the bottom concentrations are higher than the surface. As the monsoon begins, the peak is again obtained largely due to the effect of land drainage.

Diurnal observations of the carbohydrate concentrations in the estuarine waters (Fig. 2) indicate significant variations. Soluble carbohydrate varied more (0.12 to 26 mg/litre) than particulate carbohydrate (0.3 to 0.6 mg/litre). High concentration was found during 1200 to 1500 hrs. Very high value of soluble carbohydrates observed (26 mg/litre) may be due to the effect of the prevailing phytoplankton bloom in the inshore waters being transported to the estuary by tidal currents. Changes in the concentration of both forms of carbohydrate are not synchronous and this feature may be related to the differences in the intensities of 2 mechanisms of release of soluble carbohydrate operating simultaneously during productive phase, viz. release by metabolic activity of viable phytoplankton, and release due to bacterial decomposition of dead phytoplankton.

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