

Distribution of Suspended Particulate Matter in the Waters of Eastern Continental Margin of India

CH MADHUSUDANA RAO

National Institute of Oceanography, Dona Paula, Goa 403 004

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(Distribution of total suspended matter (TSM) in surface and near bottom (~5 m above sea bed) waters reveals a wide variation in concentration and composition. TSM varies from 0.05 to 122 mg.l⁻¹ in surface waters, and from 0.25 to 231 mg.l⁻¹ in near bottom waters. TSM decreases away from the coast and from north to south. Higher concentrations of TSM generally occur off the river mouths and in the nearshore regions (< 30 m water depth). TSM is mainly composed of inert material in the nearshore region and off Godavari. Distribution pattern of TSM indicates that it closely follows the circulation pattern during the study period (Aug.-Sept. 1976). Combustible organic matter varies from 5 to 80% and these compositional differences in TSM are related to the biological productivity of these waters during the study period.

Distribution and composition of total suspended matter (TSM) in the deeper parts of the Indian Ocean have been studied¹⁻³, but very little information is available on the contribution of TSM from the continental margins. Such studies in this region are of considerable importance as large quantities of sediments are discharged by the rivers under the influence of heavy rainfall associated with the SW and NE monsoons. This paper reports distribution of TSM in the waters of the eastern continental margin (Bay of Bengal) of India.

Study Area

The Bay of Bengal is an embayment of the Indian Ocean, bounded by the Indian Peninsula and Ceylon on the west and by the Andaman-Nicobar Islands and Burma on the east. The uniqueness of the Bay is that 6 major rivers flowing through the various geological formations of the Indian subcontinent introduce into it about 2×10^{15} g of suspended particulate matter annually⁴, i.e. about 15% of the contemporary global discharge of fluvial sediments into the world oceans.

The 200 m isobath represents roughly the outer limit of the eastern continental shelf of India (Fig.1). The inner shelf and the continental slope are covered by clastic sediments, and the outer shelf by calcareous relict sediments whereas off the river mouths the shelf is covered by fine-grained terrigenous sediments^{5,6}.

The shelf at the mouths of the rivers receive a large part of its sediment supplies from the rivers Ganges, Brahmaputra and Mahanadi in the north, Godavari and Krishna in the central region and comparably smaller rivers such as Pennar and Cauvery in the south. The average annual discharges are very high for Ganges-Brahmaputra and very low for Cauvery and Pennar⁷.

Materials and Methods

Samples of surface and near bottom (~5 m above sea bed) waters were collected in the Bay of Bengal along the eastern continental margin of India (Figs 1 and 2) during 7 to 9 cruises of *R V Gaveshani* (25 Aug. to 24 Sept. 1976). The procedures and precautions generally adopted in the study are similar to those outlined by Manheim *et al*⁸. Surface water samples were collected with a clean plastic bucket and near bottom water samples were obtained with a Van Dorn sampler (7 l capacity). Samples of bottom water were collected largely from the shelf. These samples were filtered on board the vessel through 2 separately tarred 47 mm diam. nuclepore filters (0.4 µm pore size) under low vacuum. The volume of seawater filtered was 0.25 l for samples with larger concentrations of TSM and 10 l for samples with very low concentrations. The suspended material retained on the filter was washed 5 times with 50 ml of double distilled deionized water to remove salts. The filters were weighed to an accuracy of 0.001 mg on a Mettler balance (Model M5 SA) and an analytical precision of 10% was achieved using 2 stacked filters for each sample with the lower filter providing for a blank correction. Combustible organic matter of selected surface samples was determined by burning the filters at about 500°C in platinum foil crucible.

Results and Discussion

High concentration and wide variability characterise the distribution of TSM in the surface layer (Fig.1). TSM varies from 0.05 to 122 mg.l⁻¹, which is considerably higher than in the other oceans. The concentrations are generally higher off Ganges (1.2 mg.l⁻¹), and at the mouths off Godavari and Krishna rivers (122 and 2 mg.l⁻¹ respectively) and the

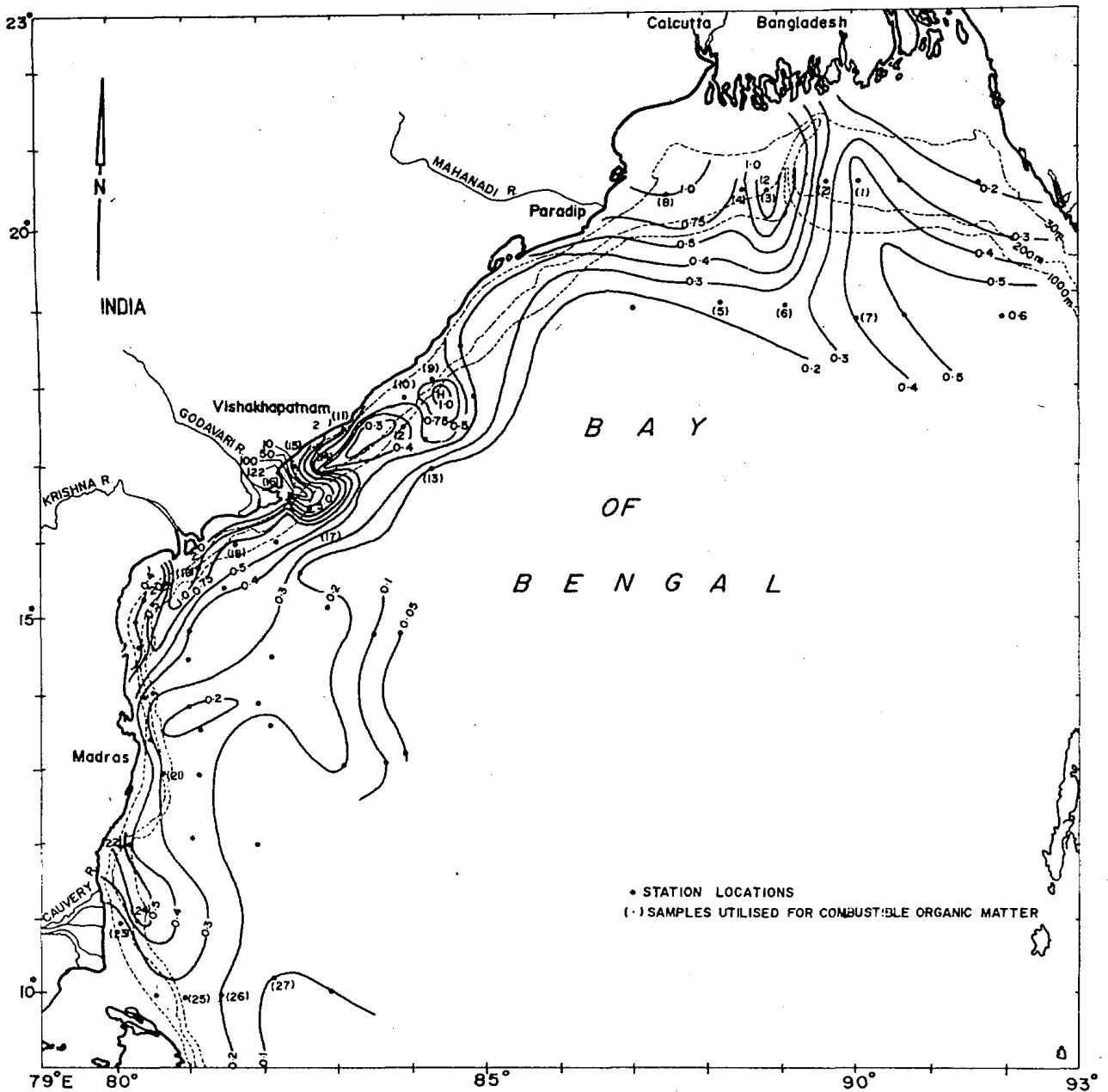


Fig. 1—Concentration of total suspended matter (mg.l^{-1}) in surface waters

1 mg.l^{-1} contour extends to as far as the 100 m isobath. Off Pennar and Cauvery rivers in the south, a maximum concentration of 0.5 mg.l^{-1} is observed and the TSM values are significantly low as compared to other 2 regions. Concentrations are higher on the innershelf (over 1 mg.l^{-1}) and decrease towards the shelf edge (1 to 0.3 mg.l^{-1}) and further seawards. A similar distribution pattern of TSM has been reported in the southeastern Atlantic Ocean⁹. In the northern region the maximum concentration of 1.2 mg.l^{-1} is observed near the head of the Bay but along the west

coast of Burma the concentrations are depleted to half (0.6 mg.l^{-1}). Between Visakhapatnam and Godavari river mouth the distribution of TSM is somewhat cellular with alternating highs and lows. The concentration of TSM shows a steep horizontal gradient off Godavari and a low gradient off Krishna river. In the offshore region, the contours of TSM show weak horizontal gradients.

The near bottom concentrations of TSM vary from 0.25 to 231 mg.l^{-1} , and are generally low except off Godavari and Krishna where high concentrations (231

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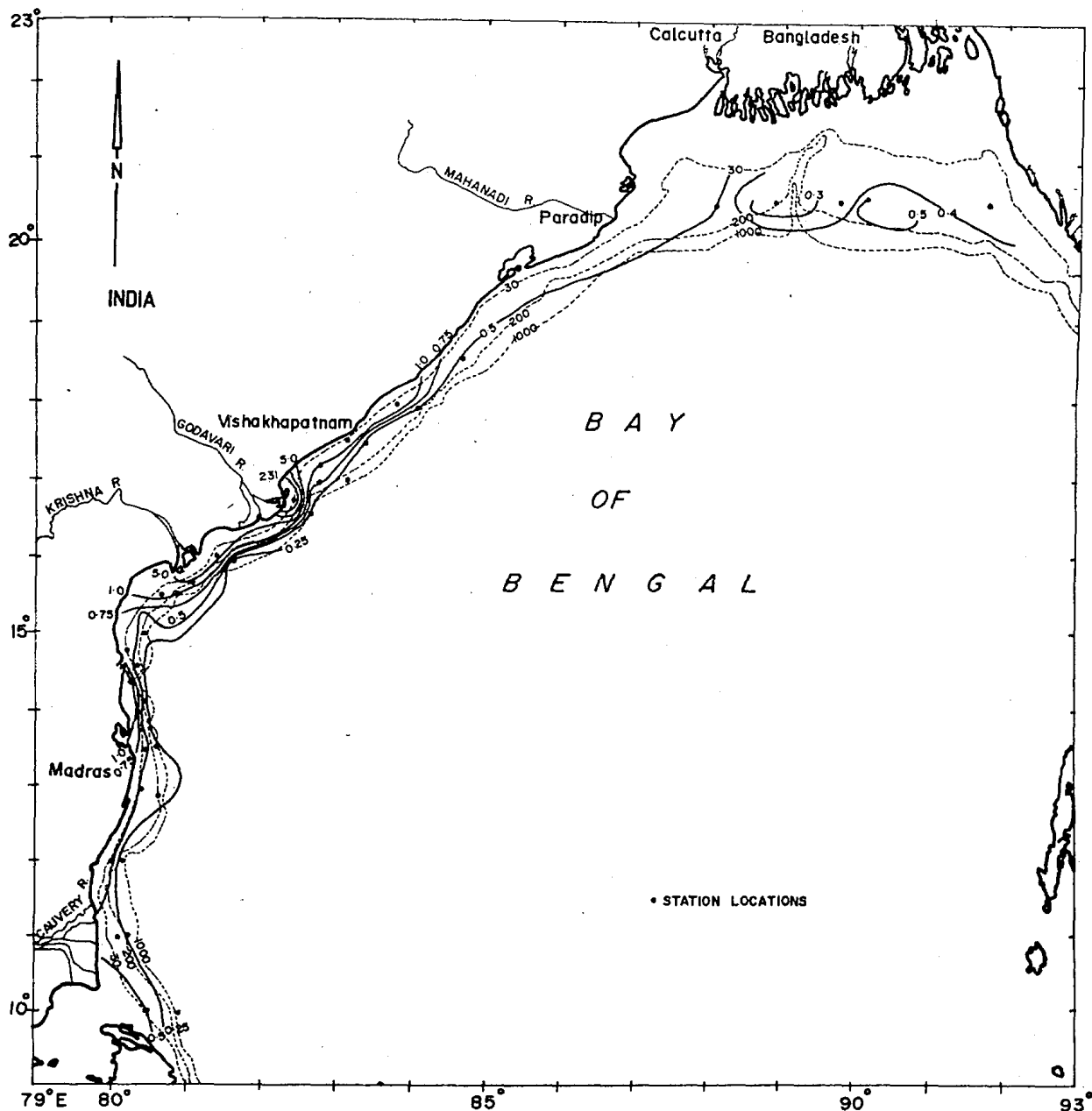


Fig. 2—Concentration of total suspended matter (mg.l^{-1}) in near bottom waters

and 5 mg.l^{-1} respectively) are encountered (Fig.2). The pattern of distribution of TSM at the surface and near bottom is more or less similar over the shelf but there is a slight seaward shift of the bottom concentrations as compared to those at the surface.

Combustible organic matter content varies from 5 to 80% (Table 1) and is generally higher in the entire area except off Godavari and Krishna rivers where the lowest content of 5 to 30% is recorded. The combustible organic matter i.e., biological productivity forms a major part of TSM in the southern region and off Visakhapatnam and Ganges.

The main sources of suspended particulate matter in the oceans are river run-off, biological productivity and eolian dust but the contribution from eolian dust is negligible in this area. TSM distribution shows higher concentrations near the river mouths indicating river run-off as the major source for the TSM in the Bay of Bengal. However, TSM at the head of Bay is comparatively low inspite of very high annual run-off by Ganges-Brahmaputra river complex⁷. Lower values of TSM may be attributed to the dispersal of suspended matter by the prevailing currents, which do not follow the coastline and have an eastward

Table 1—Combustible Organic Matter

St No.	Combustible organic matter (%)
Off Ganges	
1	50
2	55
3	58
4	62
5	70
6	75
7	73
8	35
Off Visakhapatnam	
9	65
10	50
11	35
12	70
13	80
Off Godavari & Krishna	
14	15
15	5
16	10
17	25
18	15
19	20
20	25
Off Madras coast	
21	55
22	50
23	65
24	60
25	75
26	80

component¹⁰, and its deposition on the wide shelf. Further the low lateral gradients observed suggest the possibility of deposition of TSM in the nearshore region. Obviously the main reason for the low concentrations of TSM may be due to the fact that all the stations occupied were on the outershelf and further offshore. The distribution of TSM closely resembles the current pattern¹⁰. The diverging flow at the head of the Bay in the vicinity of Swatch of No Ground also influences attendant particulate matter in suspension and possibly leads to transport of suspended matter from off Burma coast to the head of the Bay. These waters along with the TSM at the head of the Bay are further carried towards west along the coast by the prevailing currents. As there are no other major sources of supply up to Mahanadi river, the suspended matter appears to be dispersed by the advective processes resulting in low concentrations.

Similar close resemblances of TSM concentrations to the flow field could be noticed in the central and southern regions also. In the central region off Visakhapatnam TSM values are lower than the

Godavari and Krishna. Off Godavari river TSM concentrations are very high and persist far offshore although the annual run-off is 5 times less than that of Ganges and Brahmaputra rivers and is also biologically less productive. The reason for this may be either due to narrow shelf or low saline waters¹² extending offshore as far as 300 km. Off Krishna river the concentrations are relatively low which is evidently related to the lower annual run-off. Further the distribution is influenced by the prevailing southerly currents.

More or less similar distribution prevails further south. TSM concentrations indicate low horizontal gradients inspite of very high biomass production¹³, thus reflecting the low sediment discharge from Pennar and Cauvery rivers in this region.

The observed seaward shift of the bottom concentrations of TSM off Godavari and Krishna rivers may be attributed to the resuspension of bottom sediments due to strong bottom currents.

The occurrence of fine grained sediments on shelf off the river mouths particularly in areas with high concentration of TSM undoubtedly points to the river run-off as the source of these sediments on the shelf/slope. Gibbs¹⁴ observed a similar distribution pattern off Amazon and attributed the high concentration of suspended matter coming from the Amazon as a source for the mud zone of the bottom sediments. Occurrence of fine grained sediments on the outershelf/slope in association with high suspended matter containing high terrigenous material strongly suggests that cross shelf transport takes place towards the deeper parts of the bay particularly during high river discharge in the monsoon. The distribution pattern of TSM indicates that cross shelf transport is an important sedimentary process operating on the shelf of the Bay of Bengal.

Microscopic examination of the filters reveals that in the near shore region and at the head of the Bay the TSM is mainly composed of inert material. Combustible organic matter content is low (5-25%) in the nearshore region and high (50-80%) in the offshore region. Even in the offshore region it is higher off Visakhapatnam and in the southern region compared to the northern region which may be attributed to the variations in the biological productivity. The composition of TSM suggests that while at the mouth of the rivers, river run-off is the main source but in other areas biological productivity is the major contributor especially in the offshore region where the terrigenous input of suspended matter is minimal.

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References

- 1 Lisitsyn A P, *Okeanol Issled*, 2 (1960) 71.
- 2 Gordeyev Ye I, *Okeanol Issled*, 18 (1968) 156.
- 3 Jacobs M B & Ewing M, *Science Wash*, 163 (1969) 380.
- 4 Holeman J N, *Water Resources Res*, 4 (1968) 787.
- 5 Subba Rao M, *Mar Geol*, 1 (1964) 59.
- 6 Madhusudana Rao Ch & Murty P S N, *Bull Natl Inst Sci India Part 1*, 38 (1968) 442.
- 7 Rao K L, *India's water wealth: its assessment, uses and projections* (Orient Longman Ltd, New Delhi) 1979, 267.
- 8 Manheim F T, Meade R H & Bond G C, *Science Wash*, 167 (1970) 371.
- 9 Emery K O, Milliman J D & Elazar U, *J Sediment Petrol*, 43 (1973) 822.
- 10 Varadachari V V R & Sharma G S, *J Indian Geophys Union*, 4 (1967) 61.
- 11 Balarama Murty C & Rama Sastry A A, *Indian J Meteorol Geophys*, 8 (1957) 1.
- 12 Varadachari V V R, Murty C S & Das P K, *Bull Natl Inst Sci India Part 1*, 38 (1968) 301.
- 13 Nair V R, George P & Paulinose V T, *Mahasagar - Bull Natn Inst Oceanogr*, 10 (1977) 45.
- 14 Gibbs R J, in *Suspended solids in water*, edited by R J Gibbs (Plenum Press, New York) 1974, 203.