Indian Journal of Marine Sciences
Vol. 10, June 1981, pp. 161-164

Base-line Water Quality of the River Narmada (Gujarat)

M D ZINGDE, SURESH CHANDER, M A ROKADE & B N DESAI
National Institute of Oceanography, Regional Centre, Versova, Bombay 400061

Received 10 *October* 1980; *revised received* 9 *January* 1981

Suspended solids, *p*H, chlorides, DO, BOD, PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N were estimated at 12 stations along a 70 km stretch from the mouth of the river Narmada during March, May, June and August 1979. Tidal range of over 1 m observed at a point 52 km upstream was due to the piling up of fresh water, and some intrusion of sea water occurred at 44 km upstream in early June when riverine flow had decreased considerably. Significant penetration of saline water was observed only up to 20 km during March. The water column was well mixed vertically with the absence of any significant stratification. High *p*H of fresh water influenced the *p*H of the estuarine region which varied considerably over tidal cycles. The estuarine zone was characterized by high, tide dependant, suspended load which decreased appreciably in fresh water region. High overall DO and low BOD indicated the absence of gross organic pollution in the estuarine and riverine zones. NO_3^--N decreased in the downstream direction while PO_4^{3-}-P showed an increase; NH_4^+-N concentration indicated natural background levels.

Narmada, one of the major rivers of India, has a high fishery potential[1]. After entering Gujarat State, it follows more or less a westerly course to the Gulf of Cambay, southward of Luwara Point (lat. 21°39′N; long. 72°33′E). Extensive sand banks, which get exposed during the low tide, are present in the estuarine as well as the riverine zones. Rapid industrialization of South Gujarat region has resulted in the pollution of some rivers[2-4] due to the disposal of industrial wastes. The plans for the industrialization of Bharoch district necessitate evaluation of the base water quality of the river Narmada which is likely to receive industrial wastes. This information may help careful control and maintenance of ecological balance.

Materials and Methods

Flood and ebb collections during spring and neap tide at 12 locations along a 70 km stretch (Fig. 1) of the river from the mouth were made during March, May, June and August 1979. Since the flood and ebb values (except chlorinity) at the surface as well as at the bottom did not vary appreciably, the results for a particular station during a given month were averaged. Time series studies over complete tidal cycles of some physico-chemical parameters were also undertaken at sts 6, 8 and 10. Surface samples were collected with a clean polyethylene bucket, while, Niskin sampler was used to obtain bottom samples 1 m above the sediment. All parameters were determined by the procedures given earlier[5]. Direct method was used for the determination of BOD[6].

Results and Discussion

General characteristics—Tides, currents and flushing characteristics of Narmada river have been studied in some detail[1]. The tidal streams on the eastern side of Gulf of Cambay, set in a N-E direction with the flood and in the S-W direction with the ebb tide. Tidal effects in Narmada river are observed even up to st 12 (Fig. 1). Tidal range of about 3.5 m at st 6 is decreased to 1.7 m at st 10 during spring tide and from 2.6 to 1.2 m during neap tide.

Chlorinity—Perennial fresh water flow, which decreased substantially from maximum in August to minimum during early June, influenced the intrusion and distribution of sea water within the estuary (Fig. 2). Chlorinity at the ebb and flood tide often varied widely (Figs 2 and 3) with marked increase in May. Although considerable tidal influence was observed at st 10, the surface and the bottom chlorinities remained nearly constant (0.02 to 0.03‰) over the tidal cycle in March (Fig. 3a) indicating the absence of sea water incursion at this point. Similar results were obtained during May and early June. The rise in water level beyond st 10 during high tide is, therefore, merely due to the piling-up of fresh water due to the advancing tidal front in the downstream regions of the estuary. St 8

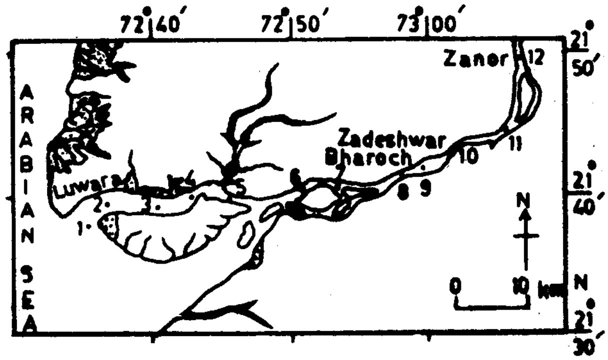
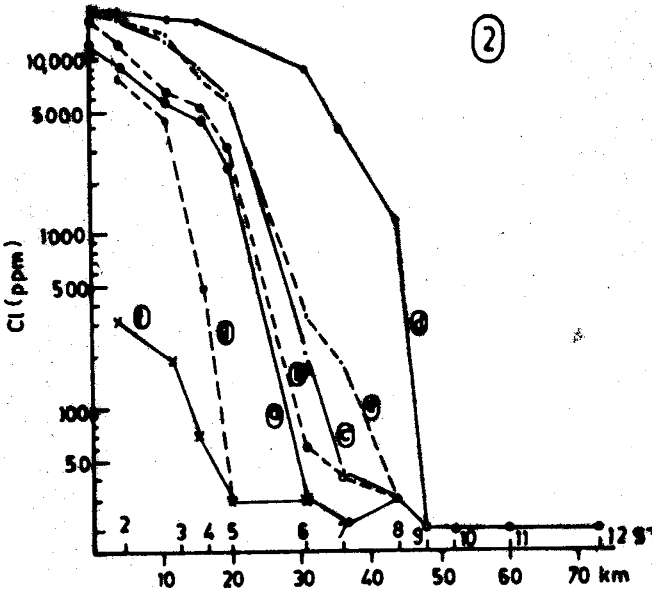
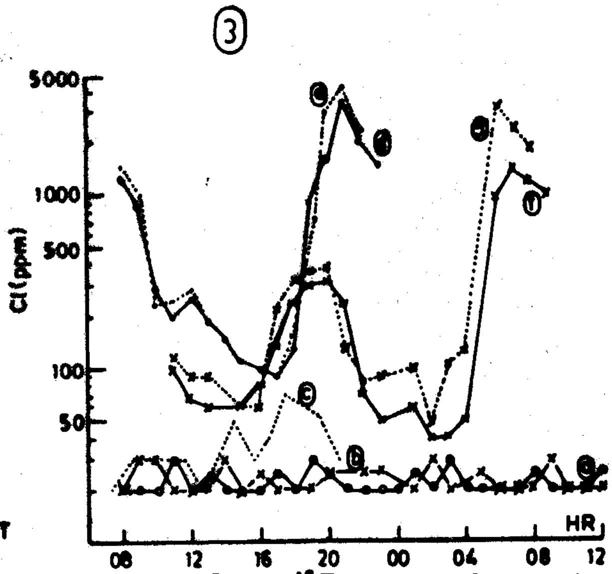
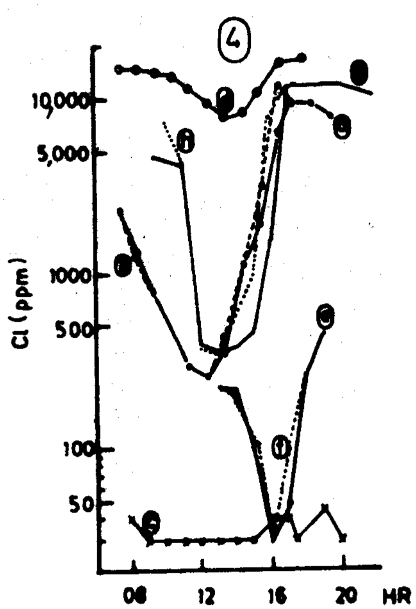


Fig. 1—Locations of sampling stations







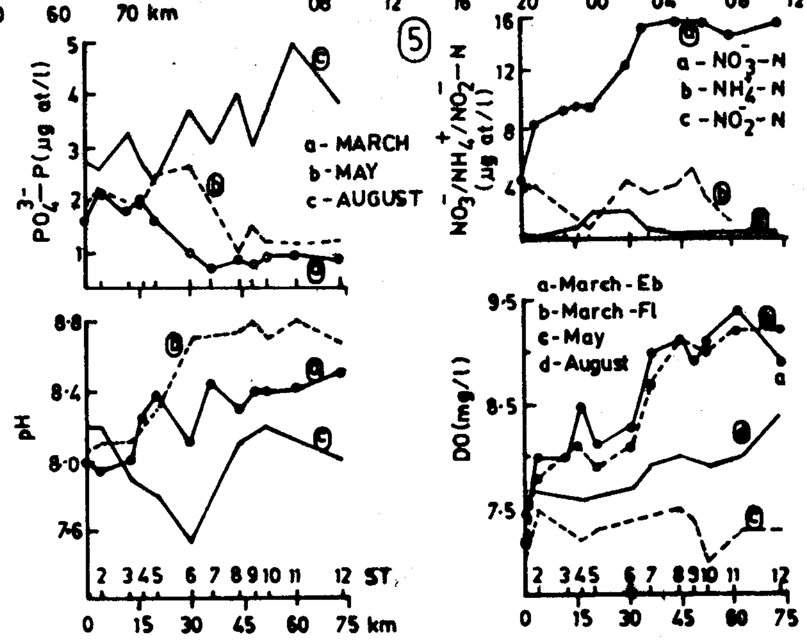


Fig. 2—Longitudinal variation of chlorinity on different days. [(a) 12.3.79, ebb, surface; (b) 12.3.79, ebb, bottom; (c) 21.3.79, flood, surface; (d) 26.5.79, flood, surface; (e) 26.5.79, ebb, surface; (f) 24.8.79, ebb, surface; and (g) 24.8.79, flood, surface]

Fig. 3—Variation of chlorinity with time at different stations. [(a) st 10, 12-13.3.79, surface; (b) st 8, 12-13.3.79, surface; (c) st 8, 22.5.79, surface; (d) st 8, 12.6.79, surface; (e) st 8, 12.6.79, bottom; (f) st 6, 12-13.3.79, surface; and (g) st 6, 12-13.3.79, bottom]

Fig. 4—Variation of chlorinity with time at different stations. [(a) st 6, 23.5.79, surface; (b) st 6, 23.5.79, bottom; (c) st 6, 26.8.79, surface; (d) st 4, 26.5.79, surface; (e) st 4, 26.8.79, surface; (f) st 4, 26.8.79, bottom; (g) st 2, 25.8.79, surface; and (h) st 2, 25.8.79, bottom]

Fig. 5—Longitudinal variation of *p*H, DO, PO_4^{3-}-P, NO_3^--N, NO_2^--N and NH_4^+-N

was the most extreme point where some sea water incursion was observed during late May (Fig. 3c); the maximum recorded chlorinity being 0.07‰ at the neap flood tide. The spring flood value was 1.2‰ (Fig. 2d). During early June the chlorinity increased to 4.5‰ at high tide even during the neap period (Fig. 3d and e). Thus except for May-June the river up to st 8 retained only fresh water throughout the year. Significant intrusion of sea water occurred up to st 5 from March to June with the minimum chlorinity recorded being 2.5‰ during ebb tide in March (Fig. 2a). The incursion at st 6 was intermittent in March with the maximum high tide chlorinity of about 1.8‰ decreasing to nearly fresh water value at the ebb tide (Fig 3f and g). The intrusion was considerable in May with the chlorinity increase to 9.8 and 2.5‰ respectively, during flood and ebb tide (Fig. 4a and b). The fresh water flow declined considerably in May, however, its influence was noticeable at st 4 where chlorinity decreased from 16‰ at the flood to 8‰ at the ebb tide (Fig. 4d). Although there was considerable longitudinal chlorinity gradient, the water column was well mixed vertically at most stations (Figs 2 to 4) with the absence of any significant stratification.

The extensive use of riverine stretch up to st 7 for domestic needs and the weak sea water influence only during May-June indicate that the zone upstream of st 6 may be considered as fresh water zone for the purpose of waste water discharges, and the external releases up to this point should be very carefully considered. Guidelines for the release of waste water in coastal marine environment may be applicable for the release of waste water beyond st 6. However, appreciable upstream tidal excursion[1] should also be considered to protect the fresh water zone while allowing the release of waste water.

During August, the period of very high fresh water flow, all traces of sea water are completely flushed out up to st 5 but considerable intrusion of saline water with wide variation in chlorinity over the tidal cycle occurred in the lower 15-20 km (Figs 2 to 4) of the estuary.

*p*H-*p*H of fresh water zone during March-June generally varied from 7.9 to 8.8 and decreased from 7.5 to 8.2 in August (Fig. 5). Abnormal values ranging up to 9 were sometimes observed in June at fresh water stations. Temporal changes at sts 8 and 10 indicated a variation from 8.4 to 8.8 and from 8.3 to 8.8 respectively, during June although the change was irregular and was not tide dependant. Such large variation is unusual in the absence of external waste water discharge and lack of appreciable sea water intrusion. Primary production, respiration and mineralization are able to alter the redox potential (Eh) and *p*H of the aqueous systems due to the changes in oxygen and carbonate concentrations. This may be predominant in Narmada river because of high turnover rates. Natural turbulence with concomitant aeration can also influence the *p*H though to a limited extent. Alkaline *p*H and its tendency to increase from March to June (Fig. 5) is perhaps related to the limestone deposits through which the river is known to flow in its upper reaches. The concentrations of carbonate and bicarbonate are therefore, expected to be more in Narmada river and high *p*H during May can result from substantial evaporation or greater base addition at higher temperature.

*p*H decreased marginally in the estuarine zone though the tendency to increase in May was still evident. Temporal variations in May indicated decrease

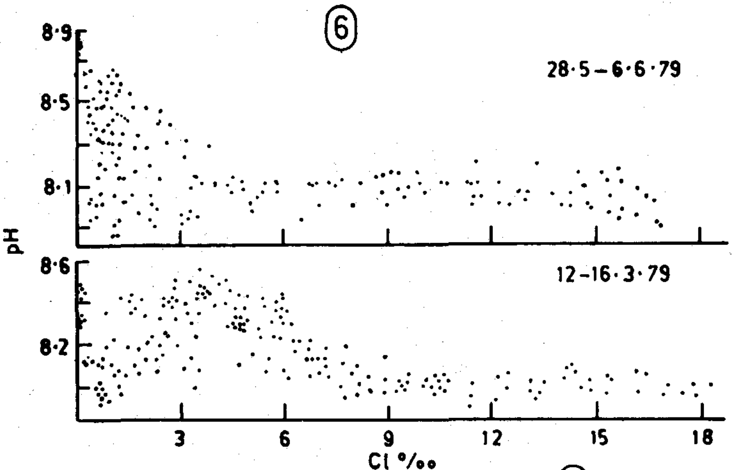


Fig. 6—Variation of *p*H with chlorinity

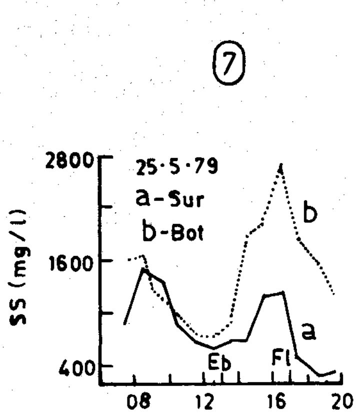


Fig. 7—Variation of suspended solids with time at st 6

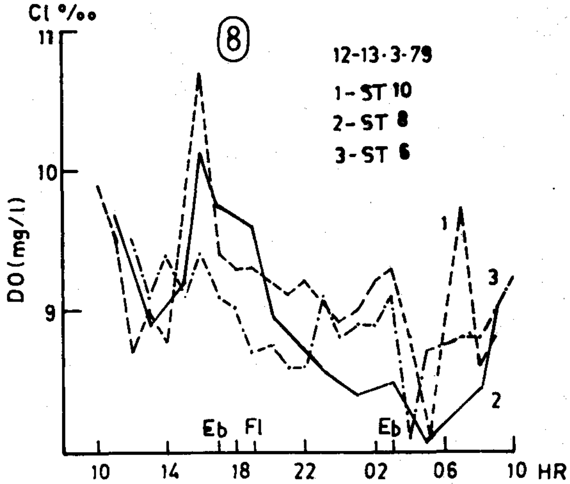


Fig. 8—Variation of DO with time at some stations

from 8.7 at the ebb tide to 8 at the flood tide at st 6. This decrease was from 8.6 to 8 at st 4 revealing the influence of fresh water on *p*H. From the plot of the variation of *p*H against chlorinity (Fig. 6) it is evident that the *p*H varied in a narrow range between chlorinities 7 and 18‰ while considerable scatter occurred at low chlorinities indicating greater chemical interactions leading to changes in *p*H at low chlorinities when fresh water and sea water mixed.

Suspended solids—The average suspended load up to st 10 was 45 mg/litre during March and increased to 560 mg/litre during August due to the load associated with the land drainage. There was marked increase in the estuarine region and the values of the order of 250 mg/litre were quite common during March/May. The increase during monsoons was about 1500 mg/litre. The tidal dependance of suspended solids (Fig. 7) with increase of bottom value from 860 at the ebb to 2650 mg/litre at the flood tide is due to the strong but variable currents[1] which dispersed the bottom sediment into the overlying water column.

DO and BOD—Although low values (4-5 mg/litre) were occasionally observed, the general variation in 7 to 10 mg/litre range indicated good oxidising conditions. The increase in the upstream direction (Fig. 5) may be due to the greater solubility of oxygen in fresh water. The levels decreased in May which could be due to the rise in temperature from 22-26°C in March to 28-32°C in May. Increase in temperature not only decreases the dissolution rate of gaseous oxygen but increases the rate of oxidation of organic matter and hence the rate of oxygen consumption.

Measurement over the tidal cycle indicated random variations with no definite relation with the tidal state (Fig. 8). Higher values observed during the day with overall decrease during the night indicated that the biological influence of photosynthesis and respiration were more pronounced than the influence of temperature, since, decrease in temperature in the night (25.5 to 22.5 at st 10, 26.5 to 22.5 at st 8 and 24 to 22 at st 6) would result in higher DO levels. Highest DO at these stations (Fig. 8) was observed around 1500 hrs and minimum was centered around 0500 hrs.

Water bodies having BOD exceeding 8 mg/litre are considered to be moderately polluted[6]. BOD in Narmada river varied from 0.5-4.8 mg/litre over the study period. There was no regular vertical or lateral variation and values fluctuated randomly over the tidal cycle. The low values immediately reveal the absence of organic pollution in the riverine as well as the estuarine zones.

Nutrients—Under good oxidizing conditions prevailing in Narmada river the most important forms of nitrogen are nitrate, nitrite and ammonia. The river water having high concentration of NO_3^--N is the major source of nitrogen supply to the estuary (Fig. 5). Evidently, levels of the order of 15 μg-at NO_3^--N/litre at sts 7 to 12 decreased to about 5 μg-at NO_3^--N/litre in the mouth region. NO_2^--N was low in line with the oxidising conditions in the river. NH_4^+-N varied considerably from 1 to 5 μg-at/litre and indicate only natural levels. In absence of external waste discharges chief source of nitrogen appears to be from land drainage. On the contrary PO_4^{3-}-P was relatively low in fresh water and hence increase in the downstream regions is apparent (Fig. 5). The longitudinal PO_4^{3-}-P profiles indicate an increase up to st 2 and then decrease at the mouth. A few samples collected outside the mouth of the estuary indicated that PO_4^{3-}-P concentration in the coastal region was around 1.5 μg-at PO_4^{3-}-P/litre. This suggests that estuary acts a sink for PO_4^{3-}-P and perhaps greater release of the element occurs in this region. Considering NO_3^--N and PO_4^{3-}-P concentrations it appears that phosphorus is the growth limiting factor in the fresh water region while it is nitrogen in the estuarine zone.

Acknowledgement

The authors thank Dr S Z Qasim, Director, for his keen interest and for suggesting valuable improvements. Thanks are also due to the Gujarat Narmada Valley Fertilizers Company Ltd for financial support.

References

1 *Feasibility of disposal of effluent from the GNFC Plant into the river Narmada* (Report submitted to the Gujarat Narmada Valley Fertilizers Company Limited, Bombay Regional Centre, NIO) 1980.
2 Zingde M D, Narvekar P V, Sarma R V & Desai B N, *Indian J mar Sci*, **9** (1980) 94.
3 Zingde M D, Sabnis M M, Mandalia A V & Desai B N, *Mahasagar—Bull natn Inst Oceanogr*, **13** (1980) 99.
4 Zingde M D, Sarma R V & Desai B N, *Indian J mar Sci*, **8** (1979) 266.
5 *Methods of sea water analysis* edited by K Grasshoff (Verlag Chemie, Weinheim, New York) 1976.
6 Martin D F, *Marine chemistry*, Vol. 1 (Marcel Dekker, INC; New York) 1970, 271.