

SPECTRAL CHARACTERISTICS OF THE COASTAL CURRENTS OFF THAL,  
BOMBAY DURING A FAIR DAY

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A typical one-day record of currents measured every 20 min with a direct reading current meter at an anchored station of mean water depth about 8 m off Thal (Bombay coast) during a fair day was subjected to spectral analysis to identify the characteristics of the alongshore and on/offshore components of the coastal current. The spectra for the surface, mid-depth and the bottom levels exhibited tidal harmonic effect more on the on/offshore components whereas the alongshore currents at the surface were prominently influenced by winds. The net drift during the day at these three levels was largely towards south ( $3\text{ cm s}^{-1}$ ) and towards the coast ( $6.5\text{ cm s}^{-1}$ ). The implications of some of these features in the effluent disposal through a submarine pipeline are indicated.

This work was carried out as part of a preliminary study to identify problems related to the release of wastewater through a submarine pipeline from a fertilizer factory located at Thal near Bombay (Fig. 1). Spectral methods have been found useful in interpreting coastal current structure. Winant & Olson (1976) for instance, considered long-period oscillations to evaluate the vertical current structure in 18 m of water off San Diego. Varkey (1980) studied the power spectra of currents in the continental shelf off Bombay (water depth ranging from 8 m to 40 m) and found that the spectral energy in this area was predominantly contributed by tidal frequencies. During windy periods however, oscillations (of frequency 0.1 cpm) were induced by the movements of the anchored ship.

The circulation characteristics of the Thal area, including tides, currents, bathymetry, etc., are discussed elsewhere (Swamy, Sarma, Suryanarayana & Desai, 1986). A typical record of currents measured every 20 min with a Direct Reading Current Meter (NIO make) at one of the anchored stations of mean water depth about 8 m (N3, Fig. 1) during a fair day of winds 2-4 knots (30 November/1 December, 1980) was subjected to spectral analysis (Gouveia & Mahadevan, 1983) to find out the gross characteristics of the currents in this coast interspersed with creeks, sandbars and islets. It is appreciated that 20 min

interval for sampling would filter off smaller frequencies and the results presented here are limited to that extent, but the conditions on a fair day are indicative of minimal (crucial) ambient dilution. The alongshore (North, positive) and on/offshore (Onshore, east, positive) components of the currents at the surface (1 m below), mid-depth and the bottom (1 m above), alongwith the day's tide, are presented in Fig.3. Fig.2 gives the spectral distribution of these componential currents.

The present results corroborated that the tidal contributions were predominant at 0.001-0.002 cpm range on the alongshore component of the current at this shallow station. Fig.2 shows that the maximum spectral density<sub>1</sub> of the alongshore currents (of the order of  $10^2$  (cm/sec)<sup>2</sup> (cpm)) at semi-diurnal frequency at the three depths, which is the major contribution of the semi-diurnal tides. The contribution of the wind was also seen at the frequency between 0.01 and 0.02 cpm on the alongshore component at the surface. On the contrary, the spectra of on/offshore currents exhibit the dominance of tidal harmonics at the lowest frequency level. At the same time, between the frequencies 0.01 and 0.025 cpm, the secondary peaks are observed on the spectra of alongshore currents. These peaks indicate the contribution of wind energy and also the oscillation due to the movements of the anchored boat. These secondary peaks are negligibly low on the spectra of the on/offshore components. The net drift at the surface, mid-depth and the bottom levels during the day was largely towards south ( $3 \text{ cm s}^{-1}$ ) and towards the coast ( $6.5 \text{ cm s}^{-1}$ ) (Table 1).

Table 1. Net drift ( $\text{cm s}^{-1}$ ) at Station N3 on 30.11.80/01.12.80

| Depth     | Alongshore | On/offshore |
|-----------|------------|-------------|
| Surface   | -3.1       | -6.6        |
| Mid-depth | 0.7        | -4.7        |
| Bottom    | -0.7       | -4.8        |

The absence of well-defined peaks at the lower frequency side of the spectra is due to the fact that the low-frequency trend has not been filtered from the original data and also due to scanty data.

There is no significant phase difference between surface to mid-depth and to the bottom in the case of both on/offshore and alongshore components (Fig.3). But some fluctuations are observed at the surface alongshore currents, owing to the prevailing winds.

In Fig.3 it is noticed that the on/offshore currents are maximum when the alongshore currents are minimum, and vice versa. This behaviour of currents indicating the to and fro oscillations of the current vector in the horizontal plane is also observed by Antony, Murty, Reddy & Rao (1985).

The tides in this area set towards north during high, and withdraw towards south during low. However offshore components are associated with flood tide and the onshore components are associated with ebb tide. It is assumed that this pattern is contributed by the islets interspersing the tidal set up.

Very significant coherence was noted between the alongshore currents at all depths, and the surface tides.

These qualitative results are significant in the context of the disposal of effluents through a submarine pipeline into shallow waters. Large shear developed across small span of depth leads to instabilities and turbulence. Winant & Olson (1976) have highlighted, inter alia, the question whether there may be sufficient shear across the water column to overcome the stabilizing influence of the thermocline and thus enhance the vertical mixing. Currents associated with tidal displacements of the thermocline should be out of phase by  $\pi$  across the thermocline, at least in the case of the lowest mode of oscillation. Semidiurnal onshore fluctuations are caused by internal tide. Longshore currents show evidence of strong semi-diurnal periodicity, but no phase difference between surface and bottom currents; these are ascribed directly to the surface tides. Onshore currents result primarily from the incidence of internal modes that are in shoal water at the depth of the measurements, thereby directing their energy towards the shoreline. Winant & Olson (1976) have concluded that longshore currents are related to processes such as wind stress and the tides which are independent of the internal modes. Also in shallow waters, baroclinic fluctuations of semidiurnal frequency are enhanced, and the onshore currents are strongly affected by baroclinic 'noise'. This has been confirmed by Shenoi, Antony & Sundar (1986).

The net drift of the order of  $3-6 \text{ cm s}^{-1}$  during fair conditions calls for significant initial dilution. As long as the wastewater field is confined to the bottom level, which is not always the case, the flume will not be caught up in the regime directly influenced by the wind and its fate would not be determined by the changing wind conditions. The tidal and other effects then become the decisive factors. Predictive models for the effluent plume of this disposal site shall consider these factors delineated by this preliminary analysis.

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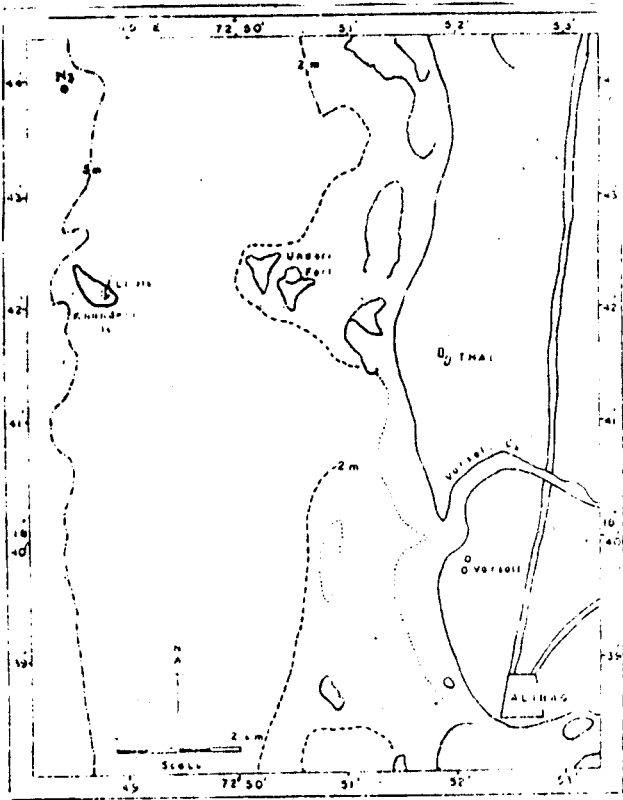


FIG. 1 STATION LOCATION MAP

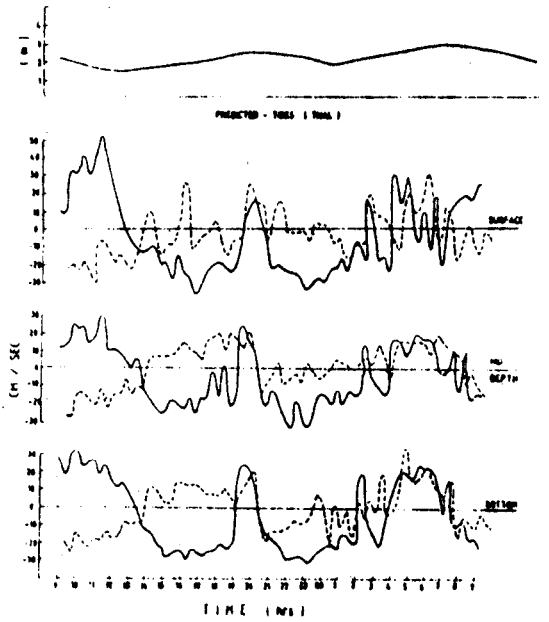


FIG. 2 ON/OFF SHORE (—) ALONG SHORE (---) CURRENTS AND TIDAL FLUCTUATIONS ON 00-11-68 TO 00-12-68

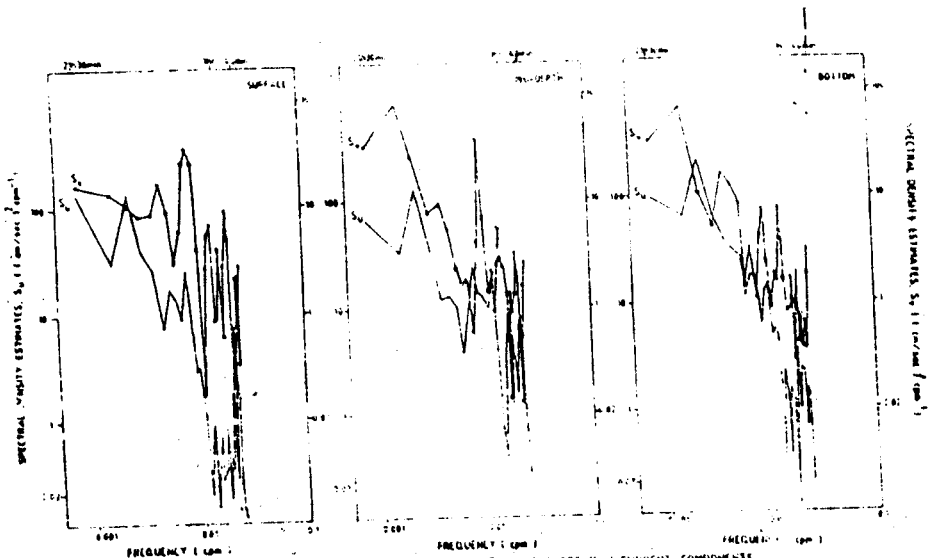


FIG. 3 SPECTRAL DENSITY ESTIMATES OF THE ON/OFF SHORE (S<sub>11</sub>) AND ALONG SHORE (S<sub>22</sub>) CURRENT COMPONENTS