

Light Transmission Characteristics of the Northern Arabian Sea During December-May

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Light transmission characteristics were studied from data collected on board *INS Darshak* during December 1973 to May 1974. Values of attenuation coefficient were computed for layers of 5 m thickness. Mean attenuation coefficient (E_D) for the euphotic zone, from surface to 1% illumination level had been computed separately for each station. A minimum value of 0.067 was observed off Port Dabol south of Bombay corresponding to a 1% level of 68 m. In the very turbid Gulf of Cambay the 1% level occurred very close to the surface and a high E_D value of 4.6 was noted corresponding to a 1% level of 1 m. Based on the values of (E_D) the marine environment could be divided into 3 categories, (i) oceanic ($E_D \leq 0.15$), (ii) coastal ($0.15 < E_D < 0.46$), and (iii) very turbid ($E_D \geq 0.46$). Transmission properties of the water column got greatly modified by suspended matter of both biogenic and minerogenic nature. Off Oman and Okha, regions of relatively high attenuation were noticed and the concentration of the suspended organic matter was inferred to be the main factor responsible for the high values. Thermal structure seemed to affect the transmission properties of the water column as the distribution of suspended matter was partly controlled by the gradient in temperature. In the Gulf of Cambay and nearby areas transparency was greatly affected by sediment churned up by strong tidal currents.

IN the sea photosynthetic production plays a vital role being at the base of the food pyramid and depends largely on the availability of sunlight. Production at the successive higher trophic levels depends both directly and indirectly on the photosynthetic production. Knowledge of the light transmission characteristics in the sea is, therefore, very much important for understanding the marine ecosystem.

The sun's energy reaching the sea surface is partly reflected and partly absorbed. With depth the energy spectrum is modified due to selective absorption and scattering, as a result, its intensity and range are much reduced. The decrease in intensity with depth has been found to be exponential. The mean attenuation for a particular layer is the net effect of absorption and scattering in that layer. In pure sea water only the water molecules and the ions affect attenuation. Distilled water and filtered sea water do not show any difference in attenuation properties within the precision of measurements. However, the sea is normally rich in suspended matter of both organogenic and minerogenic nature. In some regions the presence of 'yellow matter' considerably affects the transmission properties of the medium.

Earlier studies on the transparency of the Bay of Bengal and the Arabian Sea are mostly confined to coastal regions²⁻⁴. More recently the light penetration in the Cochin Backwater along the southwest coast of India has been studied extensively⁵. Raman and Murthy⁶ have made comparative studies on the transparency between the Malabar and Coromandal coasts. These studies indicate that river discharge, coastal upwelling,

monsoon circulation and suspended organic matter are some of the important factors affecting the transmission of light. Clarke and Kelly⁷ have studied the variation in transparency and bioluminescence in the western Indian Ocean. More extensive investigations have been carried out during International Indian Ocean Expedition. McGill⁸ gives a comprehensive account of transparency studies in the Indian Ocean with special reference to nutrients. The present study has been undertaken with a view to obtaining some features of the transparency characteristics of the Northern Arabian Sea.

Methods

Observations were made on board *INS Darshak* from December 1973 to May 1974 using a submarine photometer (Model No. 268, WA 300, G. H. Mfg & Instrument Corp.). The instrument consists of a deck photocell, an under water photocell and a deck meter. The photocells are matched pair of Weston barrier layer cells. Each photocell has 50% sensitivity within the spectral range of 4000 to 6400 Å. The long brass stabilizer fin keeps the seacell in line with the current, thereby reducing twisting and bobbing. The underwater cell is connected to the deckmeter by a 100 m long cable which was graduated for measuring the depth.

In total 98 stations were worked out in the region covering very shallow coastal and deep oceanic stations. Both the deck cell and the sea cell were read simultaneously on board the ship before each lowering. At each station the light intensity was measured at intervals of 5 m generally up to the depth of occurrence of 1% of the incident illumina-

tion. Utmost care was taken to see that no shadow of the ship's superstructure affects the sea cell readings. Observations of doubtful nature when patches of clouds were present in the sky were discarded. Temperature and phosphate data were collected simultaneously in the same cruise.

For analysis of the data, the entire survey area was divided into 4 zones (Fig. 1) in which the hydrographic conditions were assumed to be more or less steady. In zones I and II the data were collected during December-February. Zone III was covered during March-April. Observations in Zone IV were carried out in the first half of May.

Attenuation coefficients for each station were computed for layers of 5 m thickness using the formula

$$I_z = I_s \cdot e^{-EZ}$$

where I_z is illumination at depth z ; I_s , illumination at surface; E , mean attenuation coefficient for the layer; and Z , thickness of the layer.

Results and Discussion

Fig. 2 shows that along transect B the depth of 1% illumination varies from 17 m (at B₁) to 55 m (at B₁₅). In the central part of the section relatively high values of attenuation coefficient are found up to a depth of about 35 to 40 m. El-Sayed and Jitts⁹ have shown this area to have high inorganic phosphate concentrations (1-2 $\mu\text{g-at/litre}$) at the surface and they further indicate that

a high standing stock of phytoplankton is associated with high surface phosphate. For all stations along this transect the integrated mean $\text{PO}_4\text{-P}$ concentrations for the layer 0 to 100 m are found to lie between 1.2 and 1.9 $\mu\text{g-at/litre}$ (Fig. 3). The mean potential primary production for this area during December-March has been shown as 5 $\text{mg C/m}^3 \text{h}^{-1}$ for the surface layer (0-50 m)¹⁰.

In Fig. 4 vertical temperature structure along transect B is contoured to bring out variations in the isothermal zone. At B₁₁ the well developed thermocline limits the suspension to be concentrated above 60 m giving relatively high attenuation

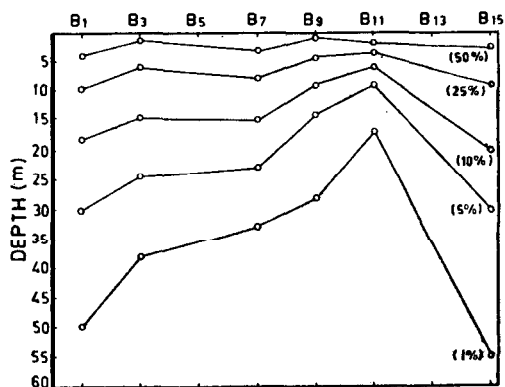


Fig. 2 — Distribution of percentage illumination along transect B off Muscat and Oman

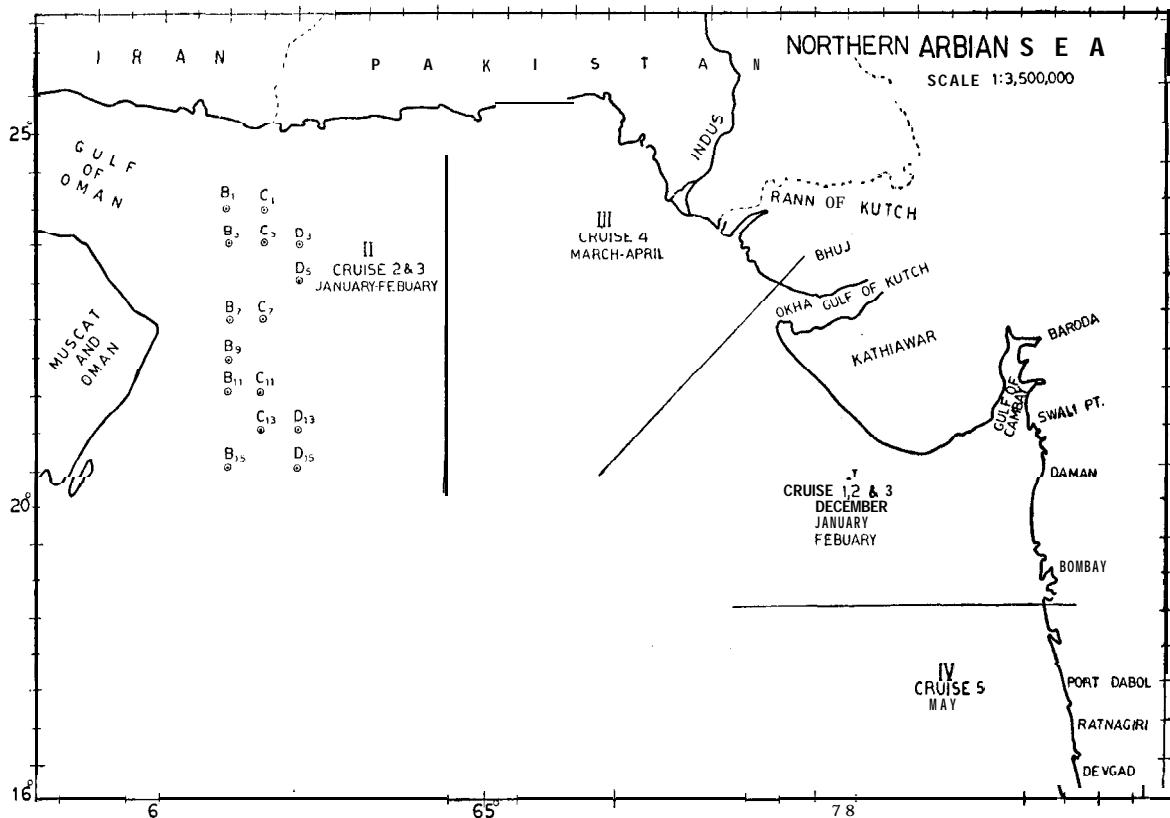


Fig. 1 — Northern Arabian Sea — survey area

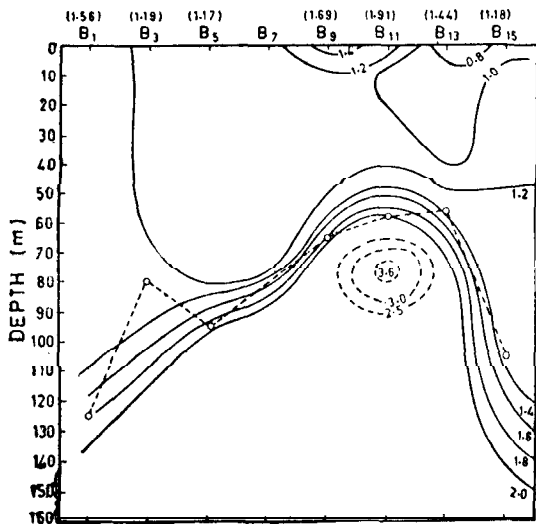


Fig 3 — Vertical section along transect B off Muscat and Oman showing the distribution of inorganic phosphate ($\mu\text{g-at/litre}$) [Integrated mean value from 100 m to surface is given in brackets at the top. - - - \circ - - -, depth of isothermal layer]

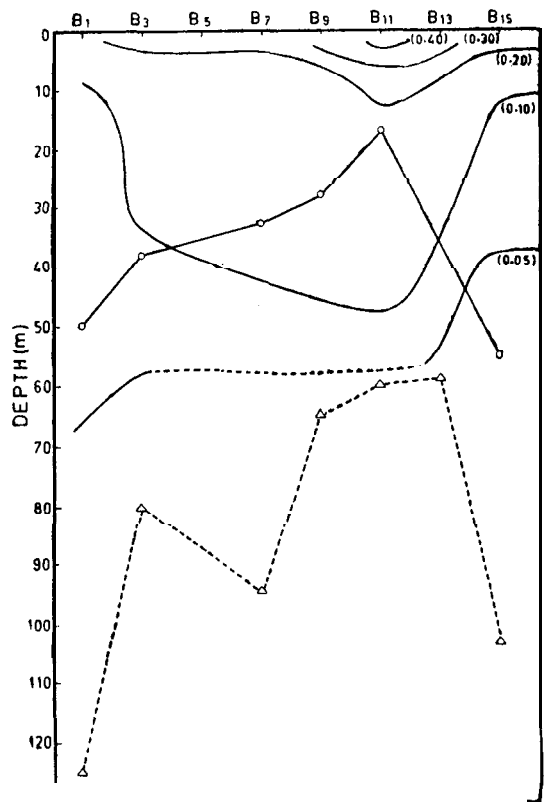


Fig 5 — Vertical section along transect B off Muscat and Oman showing the distribution of attenuation coefficient [— \circ —, depth of 1% illumination level; and - - - Δ - - -, depth of isothermal layer]

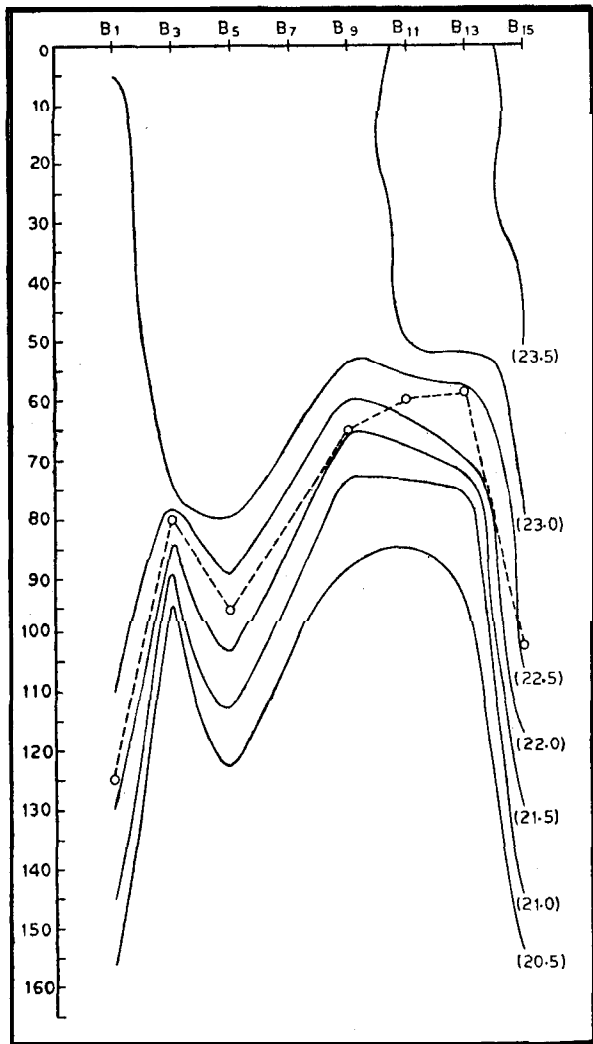


Fig. 4 — Vertical temperature section along transect B off Muscat and Oman [- - - \circ - - -, depth of isothermal layer]

coefficients at depths below the 1% illumination level also (Fig. 5). Towards north from B_8 the isothermal layer deepens and at B_1 , it extends to 125 m and below that, only weak thermal gradient (0.02°C/m) exists up to a depth of 150 m. Similar conditions prevail at the extreme south station B_{15} where the isothermal layer extends up to 102 m and the gradient down to a depth of 150 m is 0.04°C/m . Since the thermocline is located much deeper at these stations, it is possible that the resulting low concentrations of suspended matter could give rise to low values of attenuation coefficient as shown in Fig. 5. Hence, suspended organic matter, the abundance of which is indicated by the high values of potential primary productivity and inorganic phosphate, can be the decisive factor controlling the transmission characteristics in this area.

Fig. 6 shows the relationship between depth of 1% illumination (D) and the mean attenuation coefficient (E_D). The curve may be divided into 3 parts, (i) areas with D values greater than 30 m ($E_D \leq 0.15$) and could be termed as oceanic, (ii) regions with D values between 30 and 10 m ($0.15 < E_D < 0.46$) representing coastal conditions and (iii) areas with D values less than 10 m ($E_D \geq 0.46$) and may be termed very turbid. Clarke and Denton¹¹ also define the coastal zone within the same limits. Some of the deep (>3000 m) stations (Nos. 1 to 4 in Fig. 6) off the Oman coast show coastal transmission characteristics mainly due to suspended organic matter as illustrated before.

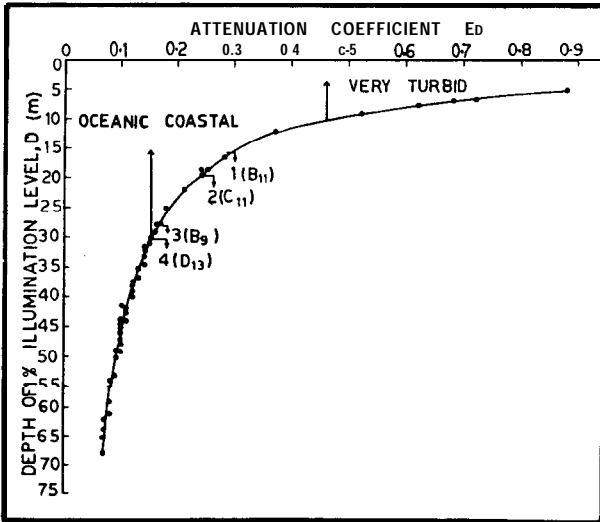


Fig. 6 — Relationship between depth of 1 % illumination level, D and the corresponding mean attenuation coefficient for the euphotic layer, E_D

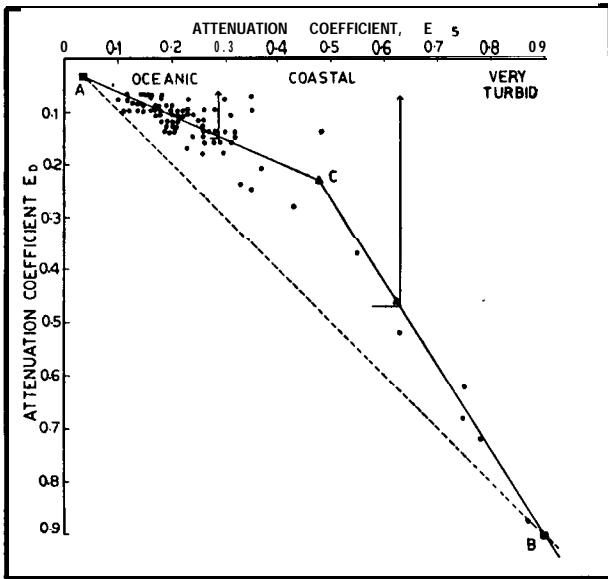


Fig. 7 — Relationship between the mean attenuation coefficient for the euphotic layer, E_D and the attenuation coefficient for the surface 5 m layer, E_s

The very turbid environment is generally observed only in estuaries and in nearshore areas. The Gulf of Cambay and coastal regions are found to belong to the very turbid group.

The attenuation coefficient for the upper 5 m layer is found to be significantly higher than the values at lower layers. Fig. 7 relates between values of E_s and E_D for all stations. The dashed line AB shows the ideal condition when the water column up to 1% illumination level is uniformly turbid. 'A' represents the ideally clear oceanic water with an attenuation value of 0.033 (ref. 11). Again 'B' shows the conditions when the 1% illumination level occurs at 5 m depth. This point is read from Fig. 6. The 2 straight lines AC and BC are visual mean-fits. The scatter is very narrow

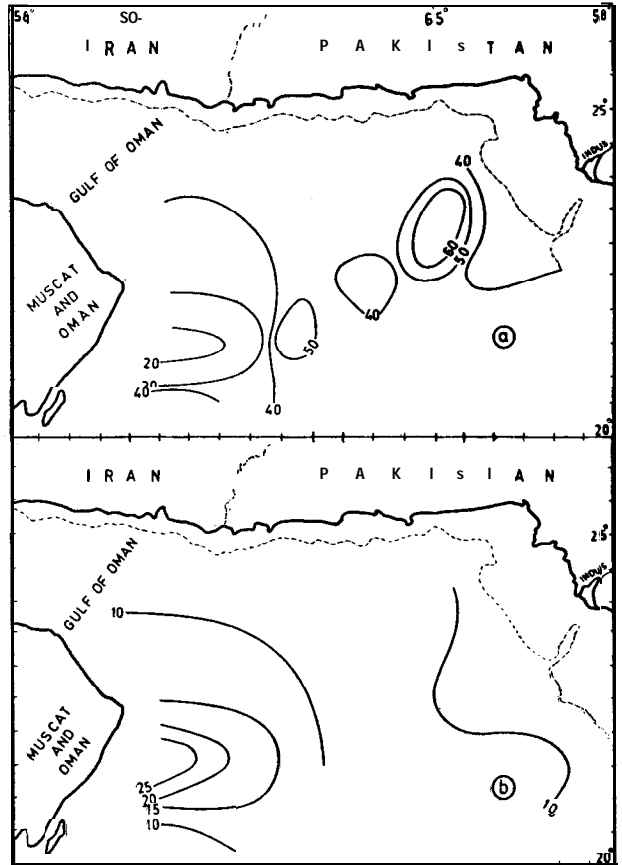


Fig. 8 — Distributions of (a) 1 % illumination level and (b) the corresponding mean attenuation coefficient ($E_D \times 10^3$) for the northwestern Arabian Sea

for the very turbid part and widest for the coastal condition. This shows that the surface-layer attenuation (E_s) is at variance more in coastal condition than in oceanic or very turbid environments with the mean attenuation (E_D) for the whole layer.

Fig. 8 shows the distributions of (a) 1% illumination level and (b) the corresponding mean attenuation coefficient for the north-western Arabian Sea. The low values of 1% illumination level off Muscat and Oman bring out the prevalence of turbid conditions and as already explained is due to suspended matter of biogenic nature. The transparency of the sea south of Bombay increases with distance from the coast. As there is no evidence of any large scale land drainage in this region bringing in suspended matter, it could be inferred that the transparency characteristics are decided by organic suspension and also in shallow waters by bottom sediments churned up by turbulence. In the Gulf of Cambay area the 1% illumination level occurs at 1 m depth with a corresponding E_D value of 4.6. This area is largely influenced by the bottom materials brought in suspension by turbulence caused by strong tidal currents in shallow depths. Off the Indus river the 40 m 1% illumination contour occurs at a distance of about 270 km showing the possible effect of river discharge. Relatively high attenuation might be due to increased biological activity or

high concentration of terrigenous suspended matter brought in by the river or both.

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