

The most important question concerning ecological monitoring has yet to be posed and that is what do we understand and mean by ecological monitoring? I have used monitoring here as goal orientated towards measuring effects of pollution along a known gradient. This is a very common form of monitoring but is relatively simple since the spatial extent of the monitoring programme is governed by the dispersion of the effluent(s). A more difficult form of monitoring is that concerned with chronic effects over long time periods where one has to be concerned with natural variability in the data. If one is interested in long-term variability over many years then with benthic monitoring it may well be quite sufficient to sample merely once per year. In north temperate latitudes with the massive recruitment in summer (leading to the departure from an equilibrium community indicated by the log-normal plots) monitoring can reasonably be confined to the winter period only. A programme of this type is being done in Northumberland by Dr Buchanan (Buchanan *et al.*, 1978) and has produced excellent results for relatively little effort. This is only possible if one is interested in year-to-year variations and in this case counting and identifying all the newly settled spat in summer would be pointless in relation to the overall aim. Thus the monitoring strategy must be related to the question being asked. Too often the aim of the monitoring is not clearly defined and results in the waste of time and money mentioned at the beginning of this article.

Ecological monitoring does not have to be extremely costly if the strategy outlined here is followed. The questions

being asked must be clearly defined and then after an initial investigation a rationalized programme can be followed. Such a programme is likely to be based on intensive studies of a few species from an ecological standpoint measuring growth rates, fecundity, recruitment and general life-table data. On these same species a suite of biochemical and physiological techniques could be applied. The important and new data on stress physiology could then be applied to the ecologically important species and the best of all combinations found. Physiological and biochemical approaches are based on the individual and it is the effects of the population that are important ecologically. Whereas the physiological and biochemical approaches predict effects on populations it is the ecological monitoring that is the only test of whether these predictions are correct. Here, then, is the answer to the question posed in the title. Ecological monitoring is thus essential but the ideal is a combination of biochemical, physiological and ecological monitoring on the same species not the fragmented and competing approaches that seem to be the rule today.

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REPORTS

Dissolved Petroleum Hydrocarbons in some Regions of the Northern Indian Ocean

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Dissolved petroleum hydrocarbons were measured in some parts of the Northern Indian Ocean using UV absorbance technique with a clean up step. The concentration of oil ranged from 0.6 to 26.5 $\mu\text{g l}^{-1}$. Higher values were recorded along the oil tanker route compared with the coastal region. From surface to about 10 m depth the oil appeared to be well mixed with water.

According to the reports of NAS (1975), the total global oil (petroleum and its products) shipped in 1971 was 1355 million tonnes (MT). Of this, 755 MT or 55.7% of the total was shipped across the Arabian Sea. From the Gulf countries, there are two main oil tanker routes through the Arabian Sea - one across the Mozambique Channel via the

South African waters to the western hemisphere and the other across the Laccadive Sea (Lakshadweep), via Sri Lanka (Ceylon), the southern Bay of Bengal and through The Malacca Strait to Far Eastern countries and Japan. The bulk of the crude is carried along the former route whereas through the latter only about 295 MT oil has been reported to be transported in 1971.

In 1977, the global marine transport of oil increased to 1724 MT (B.P. Statistical Review of the World Oil Industry, 1977), thus recording an increase of 27% from 1971. In the same way, the total quantity of oil shipped across the Arabian Sea increased to 1024 MT; of which the transport to the countries in the eastern hemisphere was 334 MT.

The two oil tanker routes in the Arabian Sea are of direct concern to India, as about 750-1000 tonnes of tar-like

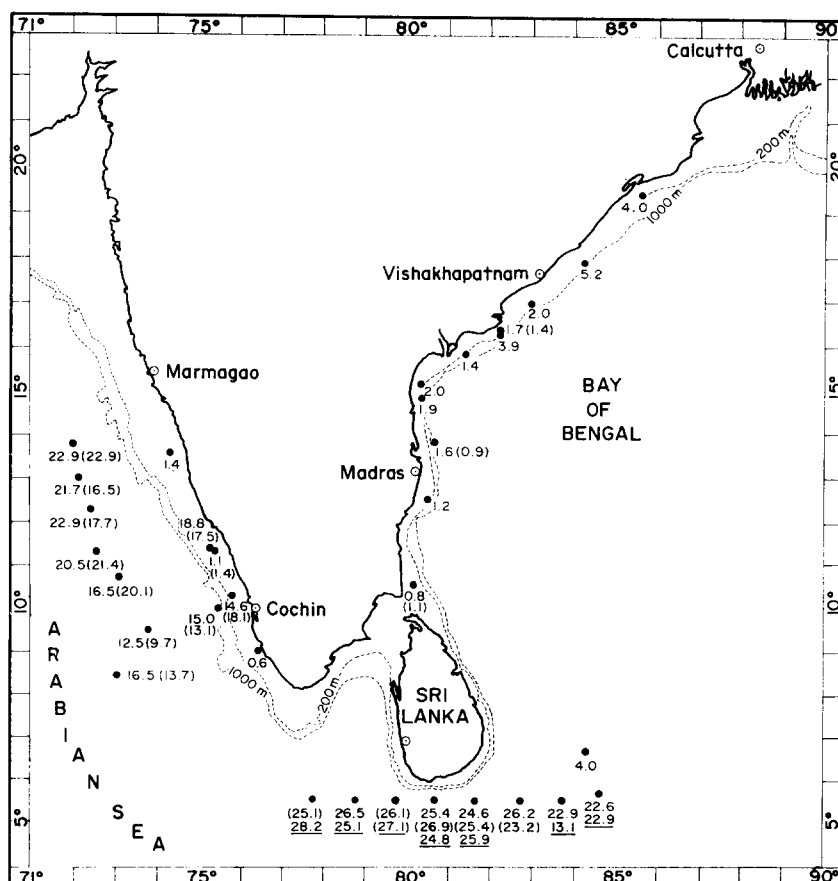


Fig. 1 Network of observation stations showing concentrations of petroleum hydrocarbons in $\mu\text{g l}^{-1}$ (Free numbers are concentrations at the surface, numbers in parentheses are concentrations at 10 m; and underlined numbers are concentrations at 20 m.)

residue is deposited every year on the beaches of the west coast of India (Dhargalkar *et al.*, 1977) during the south-west monsoon (June to September).

There are different estimates available of the oil spilled annually at sea from different sources and the reports indicate that the total quantity of spilled oil in the world ranges from 2.2 MT to 6.113 MT (Revelle *et al.*, 1971; Goldberg & Grant-Gross, 1971; Brummage, 1971; NAS, 1975). If the oil spill has any relationship with the total oil shipped then the Arabian Sea must have a high contamination of oil.

Fortunately, only a few tanker disasters have occurred along the Arabian Sea routes so far. In 1974, the oil tanker *Transhuron* ran aground on one of the atolls of the Laccadives spilling 5000 tonnes of Navy special fuel oil (Qasim *et al.*, 1974). In 1976, a Greek tanker sank off the Gulf of Kutch leaving behind a long patch of oil floating for several days in rough sea. In 1978, the tanker *Sealift Mediterranean* ran aground on an island off the northern tip of Sumatra, spilling 1000 tonnes of crude oil. These few accidents indicate that disasters along this route are not uncommon. It was, therefore, felt that periodic monitoring of petroleum hydrocarbons will be useful in determining the extent of oil pollution occurring along the shipping routes.

No measurements of petroleum hydrocarbons have so far been reported from the seas around India. This communication gives the results of the study carried out during three cruises of *R. V. Gaveshani* during the periods September–October, 1977; March–April, 1978; and June, 1978. The study formed a part of the Marine Pollution

(Petroleum) Monitoring Pilot Project (MAPMOPP) of the Integrated Global Ocean Station System (IGOSS).

Materials and Methods

Surface samples were collected using a hexane-cleaned stainless steel bucket before the ship came to a halt at the stations so as to avoid contamination from the oil discharge of the ship when it is stationary. A glass bottle fitted with a sinker and a rubber bung tied to nylon lines, was used to collect samples at depth. This latter device did not work below 20 m depth, because the bottle could not be opened by pulling the nylon line from the ship, under increased hydrostatic pressure.

All gears and glassware used for the collection and analyses of the samples were thoroughly washed with doubly-distilled hexane before use.

After collection, a 400 ml aliquot of the sample was transferred to a 0.5 l. glass bottle provided with a ground glass stopper. To the aliquot, 10 ml hexane was added and shaken in a mechanical stirrer for 30 min. The sample was then stored on board at -5°C .

In the shore laboratory, after thawing, each sample was shaken again before it was transferred to a separatory funnel. After separation, the sample was extracted with hexane for a second time. The combined hexane extract was freed from the residual water by treatment with anhydrous sodium sulphate. It was then concentrated to about 20 ml by evaporation at 50°C on a thermostatically controlled water bath.

The hexane extract was then passed through a column of silica gel (60–120 mesh) which had been treated and deactivated before use. This clean-up operation for the removal of non-petroleum material was undertaken as suggested by UNESCO (1976). The column was then washed with 30–40 ml hexane. The combined hexane extract was evaporated and the final volume made up to 10 ml. Hexane was used as a blank and a Saudi Arabian crude oil was taken as a standard. Both these were treated by the same way as the samples.

Concentrations of oil were measured by UV Absorption Spectrophotometry as suggested by Levy (1971, 1972). The absorption spectra of the samples relative to the blank were obtained by scanning in the region 350–190 nm with a Beckman ACTA C-III double-beam recording spectrophotometer. As an example, Fig. 2 shows the curve in which the second peak at 256 nm present in the (a) part of the curve has almost disappeared in the (b) part of the curve after the column chromatographic treatment of the samples. This peak must be due to the absorbance of non-petroleum material. No well-marked peak was obtained at 256 nm with the standard. Hence, the concentrations were measured by integrating the area enclosed within the curve at 205 nm using a planimeter. With the instruments and reagents at our disposal, several replicate runs of the same samples gave a coefficient of variation as $\pm 0.6\%$.

Results and Discussion

Before attempting to interpret the results, the following comments are noteworthy:

(i) UV absorbance was measured in the absence of a suitable instrument to measure UV fluorescence.

(ii) As mentioned by NAS (1975), any substance which possesses the necessary solubility characteristics and absorbs light at 256 nm is because of the petroleum source. It has also been mentioned by UNESCO (1976) that the silica gel column chromatography cleans up the hexane extract from the non-petroleum material. Applying the latter treatment to all of our samples, it can be deduced that the peak absorbance at 256 nm had totally disappeared while that at 205 nm became sharper (Fig. 2). From the consistency of the results obtained during the analyses it appears that the absorbance at this wavelength (205 nm) was

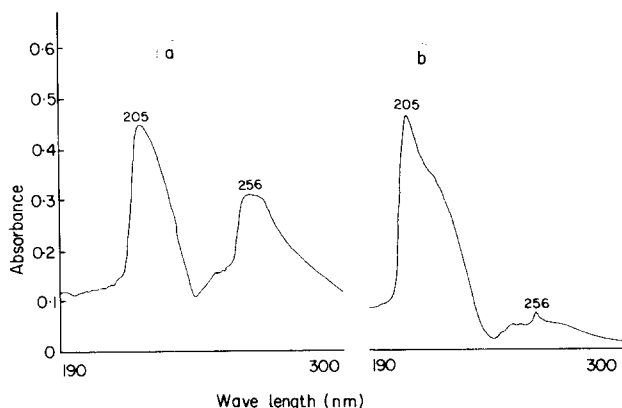


Fig. 2 Typical UV spectra of hexane-extract of sea water samples: (a) before silica-gel column chromatography, and (b) after chromatographic treatment (note the almost complete disappearance of the peak at 256 nm after chromatography).

entirely due to petroleum material. Normally, lighter fractions of the petroleum hydrocarbons are more soluble in sea water and hence the absorbance at 205 nm is because of fractions such as benzene, toluene, etc. Presumably this absorbance is the combined effect of the presence of lighter hydrocarbons originally present in the samples and the photo-oxidation and breakdown products of higher aromatics present in the oil.

(iii) We used the rubber bung to the glass bottle for sampling at depths. Although we used the same rubber bung throughout and kept it immersed in hexane for about a day before every cruise there might still be some error as rubber is known to pose problems in petroleum hydrocarbon analysis.

(iv) Considering all these limitations we do not claim our data as definitive. They may be interpreted as indicative of the petroleum hydrocarbon concentrations in the area surveyed.

The region covered during the three cruises was divided in three different parts: (i) the oil tanker route; (ii) coastal Arabian Sea; and (iii) coastal Bay of Bengal.

(i) Oil tanker route

Surface concentrations in this area varied from 12.5 to 26.5 $\mu\text{g l}^{-1}$ with an average of $21.7 \pm 1.0 \mu\text{g l}^{-1}$. The concentration at 10 m varied from 9.7 to 26.9 $\mu\text{g l}^{-1}$ (Fig. 1), with a mean value of $20.5 \pm 1.2 \mu\text{g l}^{-1}$. At 20 m depth, only a part of the oil tanker route in the Bay of Bengal was sampled. The values at seven stations varied from 13.1 to 28.2 $\mu\text{g l}^{-1}$ (Fig. 1) with a mean of $23.9 \pm 1.2 \mu\text{g l}^{-1}$.

It can, therefore, be concluded that the petroleum hydrocarbons up to 20 m depth in this region are fairly well mixed and there is no significant difference between 0 and 20 m.

(ii) Coastal Arabian Sea

Surface concentrations in this area ranged from 0.6 to 18.8 $\mu\text{g l}^{-1}$ with an average of $8.6 \pm 3.1 \mu\text{g l}^{-1}$. The values at 10 m depth ranged between 1.4 and 18.1 $\mu\text{g l}^{-1}$ (average 12.5 $\mu\text{g l}^{-1}$). Both at the surface and at 10 m, the concentrations were observed to be fairly high at those stations which were close to two busy ports on the west coast of India, namely, Cochin and Mangalore. Probably shipping traffic in the port area was the main factor contributing to the higher values of petroleum hydrocarbons. Lower concentrations at the other stations along this track, away from the ports, lend support to this view.

A comparison of the values obtained from the coastal area with those from the offshore regions in this part of the Arabian Sea, suggests that the concentrations of hydrocarbons increase offshore. This is in agreement with our earlier observations (Sen Gupta *et al.*, 1978).

(iii) Coastal Bay of Bengal

Surface concentrations in this part ranged from 0.8 to 5.2 $\mu\text{g l}^{-1}$, averaging $2.3 \pm 0.4 \mu\text{g l}^{-1}$ (Fig. 1). At 10 m, the values ranged between 0.9 and 1.4 $\mu\text{g l}^{-1}$ (average 1.1 $\mu\text{g l}^{-1}$). The range in the concentrations of petroleum at the surface and at 10 m depth in the Arabian Sea was greater from that in the Bay of Bengal by about an order of magnitude. Evidently, this is because of the oil tanker traffic along the shipping route in the Arabian Sea. The annual transport of oil and its products across the Bay of Bengal in 1971 was about 29 MT (Levy, 1977) compared with 951 MT across the Arabian Sea. The magnitude of shipping from the ports on the east

coast of India is also far less than that from the ports on the west coast.

Concentrations of petroleum hydrocarbons in the world oceans vary between 0 and 1 mg l⁻¹ (Farrington & Meyer, 1975). The values from the Indian Ocean are at present well within this range. The Arabian Sea is an area of negative water balance where evaporation exceeds precipitation and runoff by 7–10 km³ every year (Venkateswaran, 1956). This, together with the biodegradation of oil, might be the factors contributing to the low concentrations of dissolved petroleum hydrocarbons in this area in spite of the very large global oil transport which passes through the Northern Indian Ocean.

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Trace Element Content in Fish Otoliths in Relation to Age and Size

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Fish otoliths could serve as storage sites of certain elements of biological and/or radioecological importance.

The elements caesium, cobalt, iron, selenium and silver have been determined in otoliths of the pelagic fish *Scomber japonicus colias* collected from three sampling areas of the Aegean Sea, by neutron activation analysis and γ -spectroscopy.

The distribution pattern of the elemental composition of the otoliths has been correlated with biometrical variables. It has been found that in general the content of the studied elements decreases with increasing age.

The necessity to investigate the physiological role of trace elements, in order to elucidate the mechanisms which are peculiar to the animal – besides their biological availability and their exchange – it has been pointed out in many marine pollution studies.

The work done on the concentration factors of essential trace elements and their nuclides in certain marine species showed that the rhythm of the replacement of elements in soft tissues is faster than in bones and shells. Therefore,

deposition of elements in skeletal parts might be chiefly performed in growing parts only (Saiki, 1968).

The localization of certain trace elements possessing long-lived radionuclides, correspondingly, may cause undesirable effects on certain physiological functions of marine species and especially at the earlier stages of the development cycle.

The knowledge of trace element content of hard tissues such as bones, scales and otoliths could support the study of the characterization of 'storage sites' for certain biologically, or radioecologically significant elements in the organism.

Studies on the elementary composition of fish bones as well as on the accumulation of certain radionuclides have been presented by several authors (Vinogradov, 1953; Saiki, 1968; Goldberg, 1965). However the research work concerning the presence of certain important elements in fish otoliths is limited.

The work done on the chemical composition of fish otoliths until 1953 has been summarized by Vinogradov (1953). The presence of calcium carbonate with organic