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Hydrocarbons in Seawater and Sediment from the West Coast of Peninsular Malaysia

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The Straits of Malacca, along the west coast of Peninsular Malaysia, is one of the busiest waterways in the world with about 2000 vessels passing through it per month, of which about 25 percent are oil tankers of varying sizes (Daud 1984). In the course of their passage, the practices of tanker ballasting and pumping of bilges by non-tanker vessels result in considerable pollution in these waters. Collisions and groundings also cause oil spills in Malaysian waters. Oil contaminants not only pollute the high seas but also affects the near-coastal waters. Marine oil pollution, in particular that of near-coastal waters, may also be attributed to land-based activities such as the utilisation of petroleum related products, the direct discharge of untreated municipal and industrial wastes containing refined and partly weathered oils to sewers and rivers, and the discharge of effluents from refineries and other similar sources.

There is, at present, little information available on the total hydrocarbon concentrations (THCs) in water and sediments in these waters. The present study was undertaken to determine the levels of hydrocarbons in water and sediments along the near-coastal areas of the Straits of Malacca.

MATERIALS AND METHODS

The locations of the sampling sites are shown in Figure 1. Sampling took place between the months of April 1992 and November 1992.

Water samples were collected from a depth of 1 metre using glass Winchester bottles held in a stainless-steel frame and operated by handline. The analysis of THC in water was carried out in accordance with established procedures (Keizer and Gordon 1973; Parsons et al. 1984). Briefly, water samples were extracted twice with dichloromethane, the extracts combined, and then dried over anhydrous sodium sulphate. Non-petrogenic polar materials were removed using a silica gel column.

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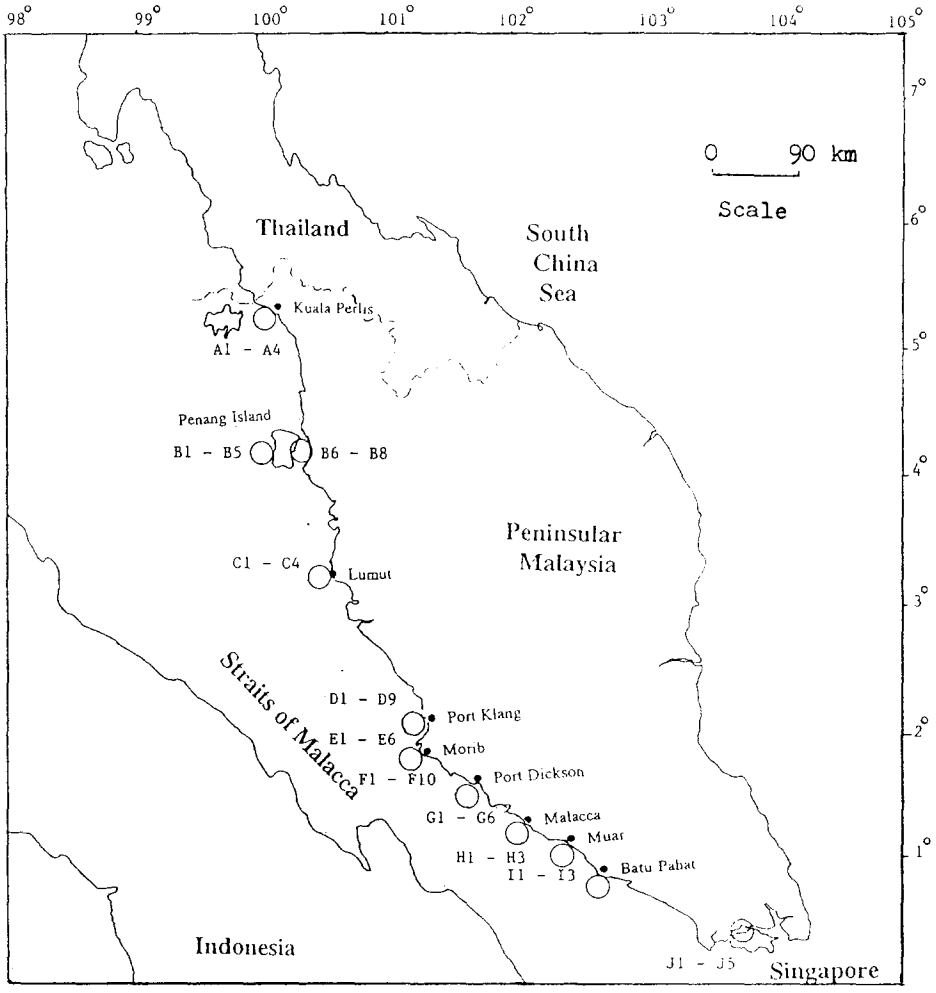

Figure 1. Location of the sampling sites

Samples of surface sediments were collected by means of a handcorer. The samples were wrapped with hexane-cleaned aluminium foil and stored at -20 C until analysis. The extraction and subsequent clean-up procedure for hydrocarbons from sediment samples is based on one of the methods reported by Hilpert and co-workers (1978). Thus, thawed sediments were digested under reflux with methanolic NaOH, followed by hexane extraction and column chromatography on silica.

THCs were determined by fluorescence spectroscopy (UVF) on a Shimadzu UV Spectrophotometer RF 5000. The fluorescence of the samples were measured at 310nm excitation and at 374nm emission wavelength respectively. Seligi crude oil, a light crude was chosen as the arbitary

standard. Solvent blanks were run with each batch of samples and one or more standard solutions of Seligi crude measured on each working day to verify the calibration program prior to the analysis of samples. Recoveries from fortified samples were not less than 90% and 80% from water and sediment samples respectively.

RESULTS AND DISCUSSION

The fluorospectrophotometric method of analysis is not specific for petrogenic hydrocarbons but is sensitive to any fluorescing compounds that are extractable with dichloromethane. While it may be possible to remove non-petrogenic polar organic materials that may possess fluorescing properties, by incorporating a chromatographic clean-up step on silica, the accuracy of this method is limited. This is because the aromatic composition of the samples and the chosen standard were not the same. The samples collected in this study were likely to contain hydrocarbons from a large number of sources.

The results of the water and sediment analysis, reported as the average of triplicate determinations, are given in Tables 1 and 2 respectively. Hydrocarbons were present at all the stations sampled. The range of THCs in water and sediments were 0.005 to 0.386 mg/L Seligi crude oil equivalents and 52.81 to 733.74 mg/kg dry weight Seligi crude oil equivalents respectively. The highest THC in water (0.386 mg/L) was recorded in the vicinity of the largest naval base in Malaysia, while the highest THC in sediment (733.74 mg/Kg) was found in Port Klang, the busiest commercial port in Peninsular Malaysia. Furthermore, in the latter case, the samples were collected in the vicinity of an oil depot where there is always the likelihood of oil spillages occurring during offloading operations.

In general, results obtained in the present study suggests that elevated THCs were found in waters with a higher concentration of maritime activities: stations A (0.018-0.031 mg/L) situated at a fishing village as well as being at a ferry route; sampling stations in port areas such as B6, B7 and B8 (0.024-0.031 mg/L) which comprised the main shipping lane for the north end of the straits, as well as being in the vicinity of the ferry route from the mainland to the island of Penang; all stations (0.314-0.386 mg/L) in Lumut, the site of Malaysia's largest naval base; all D stations (0.018-0.129 mg/L) in Port Klang; stations F1, F2, F3, F4, F5 ,F6 and F8 (0.018-0.112 mg/L) in Port Dickson. In the latter case, the transportation and off-loading operations of crude oil at the terminals of refineries located here are probably contributing factors to the level of contamination. High levels found in all H stations (0.018-0.048 mg/L) and all I stations (0.026-0.081 mg/L) were thought to be due to urban runoff, since both these stations are in the vicinity of urban areas.

Table 1. Total hydrocarbon concentrations in seawater (mg/L Seligi crude oil equivalents)

Sampling station	Concentration	Sampling station	Concentration
A1	0.025	E5	0.022
A2	0.031	E6	0.043
A3	0.029	F1	0.025
A4	0.018	F2	0.023
B1	0.007	F3	0.018
B2	0.005	F4	0.024
B3	0.014	F5	0.024
B4	0.009	F6	0.112
B5	0.007	F7	0.008
B6	0.030	F8	0.020
B7	0.024	F9	0.011
B8	0.031	F10	0.010
C1	0.339	G1	0.014
C2	0.335	G2	0.011
C3	0.386	G3	0.015
C4	0.314	G4	0.011
D1	0.027	G5	0.011
D2	0.023	G6	0.008
D3	0.029	H1	0.018
D4	0.039	H2	0.023
D5	0.045	H3	0.048
D6	0.018	I1	0.081
D7	0.129	I2	0.031
D8	0.068	I3	0.026
D9	0.087	J1	0.017
E1	0.035	J2	0.008
E2	0.009	J3	0.013
E3	0.043	J4	0.032
E4	0.017	J5	0.014

Coastal waters along recreational beaches, on the other hand, were found to have significantly lower concentrations of hydrocarbons particularly stations B1-B5 (0.005-0.014 mg/L) situated on the west coast of the island of Penang, as well as all G stations (0.008-0.015 mg/L) along a stretch of coastal waters in the vicinity of Malacca. However, there were exceptions: stations E1, E3, and E6 (0.035-0.043 mg/L), situated at a popular beach, were found to contain levels of hydrocarbons similar to the more polluted areas.

Table 2. Total hydrocarbon concentrations in samples of surface sediments (mg/Kg dry weight Seligi crude oil equivalents)

Sampling station	Sediment type	Concentration
A1	Mud	148.09
A3	Mud and sand	139.24
B1	Sand and shell	52.81
B4	Mud and sand	124.52
C2	Coarse sand	179.79
C4	Coarse sand	86.54
D4	Mud	145.66
D6	Mud and sand	733.74
D9	Mud and sand	276.09
E2	Sand and shell	82.89
E4	Sand and shell	75.99
F1	Mud and sand	62.33
F5	Mud and sand	114.46
F10	Mud and sand	71.16
G1	Coarse sand	93.55
G4	Coarse sand	151.22
H2	Mud	198.57
I1	Mud	82.43
I3	Mud	107.91
J1	Mud and sand	130.22
J3	Mud	90.81

All sediment samples were found to contain THCs in excess of 50 mg/Kg dry weight, the majority exceeding 100 mg/Kg dry weight. Stations such as B1, E2, E4, F10 and G1 with low levels of hydrocarbons in water also had relatively low concentrations in sediments. Similarly, stations C2 and D9 which had high levels of hydrocarbons in water, were also found to have polluted sediments. However this trend is not true for all stations. The highest level of contamination in sediments were found in station D6. This finding is not consistent with the relatively low levels in sea water collected from the same site. The same is true for station G4. Levels of hydrocarbons in seawater tend to fluctuate throughout the year, and are subjected to seasonal variations such as the monsoon season which effects tidal currents. Hydrocarbon content in the sediment is probably a better measure of oil pollution. Sediments containing fine particles tend to be good accumulators of organic pollutants presumably because of their greater effective surface area (Law 1981; Burns et al. 1982). Coarse-grained sands and sediments made up of stones or shell, on the other hand, can be

expected to have lower levels of hydrocarbon content, even though the corresponding levels in the seawater might be high. All samples in the present study contained varying proportions of mud and sand except for stations B1, C2, C4, E2, E4, G1 and G4 from which were collected coarse-grained sands, as well as sands and shell. Hence, although the THC in seawater at C4 was amongst the highest recorded in the present study, the corresponding level of hydrocarbons in the sediment was relatively low.

Hydrocarbons in water and sediments from Malaysian waters have been determined in previous surveys. Although, these have been largely limited to areas connected with exploration and exploitation of oil and gas reserves activities in the South China Sea, several isolated studies have been conducted along the west coast of Peninsular Malaysia. Phang and co-workers (1984) found levels of hydrocarbons in the range of 0.05-0.12 mg/L at several locations in the island of Penang, while waters off the coast of Port Dickson were found to contain hydrocarbons in the range 0.015-0.15 mg/L and 21.7-74.5 mg/Kg in water and sediment respectively (Law et al. 1991). These results are comparable to those found in the present study. Surveys in the South China Sea, in the vicinity of an oil field in 1985 (Law and Yusof 1986) showed THCs to be in the range 0.01-1.75 mg/L and 6.43-1332 mg/Kg for water and sediment samples respectively. Further south, levels of 0.010-0.066 mg/L in water and 10.73-73.97 mg/Kg in sediments were found (Law and Mahmood 1987) while surveys in the offshore waters off Sarawak in East Malaysia recorded concentrations in the range of 0.013-0.545 mg/L and 7.42-1089 mg/Kg for water and sediment samples respectively (Law and Libi 1988). Hence, the hydrocarbon levels measured in the present study, appear to be in the same order of magnitude to those observed in the South China Sea although the predominant sources of these hydrocarbons are likely to be quite different.

When compared to other areas in the region, such as in Manila Bay (1.25-6.98 mg/L) and the Indonesian waters (0.3-11.5 mg/L) (Bilal 1980), the levels of THCs recorded in the present study are significantly lower. In the Gulf of Thailand, however, THCs were found to be substantially lower than the present study: 0.0001-0.008 mg/L in water and 0.03-62 mg/Kg in sediments (Wattayakorn 1987a and 1987b). In the coastal areas of Hong Kong, THCs ranged between 0.004-0.012 mg/L (Cheung 1979). Recent studies from other areas of the world, comparable in terms of shipping activities, suggests that water and sediments in the Malacca Straits are grossly polluted. The range of THCs found in water and sediments from the English channel, for example, were 0.0003-0.014 mg/L and 0.3-560 mg/Kg dry weight respectively (Fileman and Law 1988). Faraco and Ros (1979) measured hydrocarbon concentrations ranging from 0.001-0.012 mg/L in the Western Mediterranean sea, while contamination levels in the range of 0.0016-0.033 mg/L in water and 3.1-40.35 mg/Kg dry weight in sediments were reported in the Omani coastal waters (Badawy and Al-Harthy

1991).The THCs in the sediments of the present study are comparable to the lower limits of those found in other polluted coastal sediments such as the N-W Atlantic coast (113-2900 mg/Kg) and the Bay of Narragansett, USA (350-5410 mg/Kg) (Marchand et al. 1982).

In general, the level of hydrocarbon content in surface seawater is higher in near-coastal waters than the open sea (Barbier et al. 1973). According to the Food and Agricultural Organization, (FAO 1982), seawater containing hydrocarbon levels less than 0.0025 mg/L can be classified as unpolluted. Unpolluted coastal sediments on the other hand, contains hydrocarbons less than 100 mg/Kg dry weight (Marchand et al. 1982). On these basis, and also when compared to hydrocarbon levels in seawater and sediments reported elsewhere in the world, comparable in terms of shipping activities, the levels found in the present study clearly shows that the coastal waters and sediments from the majority of the study areas in the Straits of Malacca are polluted.

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