Pertanika 13(3), 381 - 387 (1990)

Oil Pollution in the Coastal Waters off Port Dickson, Straits of Malacca

LAW, A.T., V. RAVINTHAR and C.H. YEONG
Faculty of Fisheries and Marine Science,
Universiti Pertanian Malaysia,
43400 UPM Serdang, Selangor Darul Ehsan, Malaysia.

Key words : oil pollution, petroleum hydrocarbons, coastal waters.

ABSTRAK

Taburan hidrokarbon petroleum di perairan persisiran Port Dickson telah dikaji selama tiga tahun iaitu daripada tahun 1986 hingga 1989. Secara amnya, tidak terdapat perbezaan yang bererti (P > 0.05) untuk tahap hidrokarbon dalam air di antara stesen pensampelan pada setiap hari pensampelan yang sama. Walau bagaimanapun, keadaan turun-naik tahap hidrokarbon telah didapati pada hari pensampelan yang lain. Keadaan turun-naik yang nyata juga didapati untuk kandungan hidrokarbon dalam endapan yang disampel pada hari yang berlainan. Kepekatan min hidrokarbon dalam air didapati berjulat di antara 14.69 ppb hingga 150.28 ppb setara minyak mentah ESSO Tapis A (atau di antara 0.77 ppb dan 7.87 ppb setara krisen). Kepekatan min kandungan hidrokarbon di dalam endapan pula didapati di antara 21.73 mg/kg hingga 74.50 mg/kg endapan kering setara minyak mentah ESSO Tapis A (atau di antara 1.12 mg/kg dan 3.90 mg/kg endapan kering setara krisen). Tahap pencemaran hidrokarbon di perairan persisiran Port Dickson adalah hampir sama ataupun lebih tinggi daripada perairan Zon Ekonomi Ekslusif Pahang dan Sabah tetapi agak lebih rendah daripada perairan Terengganu dan Sarawak. Sumber pencemaran hidrokarbon di perairan persisiran Port Dickson berkemungkinan datangnya daripada laut luas, pelabuhan dan juga terminal penapisan minyak yang berhampiran dan bukannya daripada hasil buangan darat.

ABSTRACT

The petroleum hydrocarbon distribution in the Port Dickson coastal waters was studied over a period of three years from 1986 to 1989. Generally, there was no significant difference (P > 0.05) of hydrocarbon levels in water among the sampling stations on each of the sampling dates. However, a pronounced fluctuation was found at different sampling dates. Similarly, a pronounced fluctuation of hydrocarbon content in the sediment with different sampling dates was also detected. The mean hydrocarbon level in the water ranged between 14.69 ppb and 150.28 ppb, ESSO Tapis A crude oil equivalent (or between 0.77 ppb and 7.87 ppb, chrysene equivalent), while for the sediment it ranged between 21.73 mg/kg and 74.50 mg/kg dry sediment, Esso Tapis A crude oil equivalent (or between 1.12 mg/kg and 3.90 mg/kg dry sediment, chrysene equivalent). The oil pollution level in the Port Dickson coastal waters was comparable or higher than that found in the Exclusive Economic Zone waters off Pahang and Sabah, but was lower than that detected in the Terengganu and Sarawak waters. The source of hydrocarbon pollution in the Port Dickson coastal waters was probably from the open sea and the nearby harbour and oil refineries rather than from land runoff.

INTRODUCTION

Oil pollution of Malaysian coastal waters largely arises from vessel operation, tanker accidents, oil exploration and production activities, and to a lesser extent from municipal and industrial discharges (UNEP 1987a). During the period between 1975 and 1987, there were not less than ten cases of shipping accidents in Malaysian waters

resulting in the release of 23,000 tons of crude oil into the marine environment (UNEP 1987b). An average of 150 ships/day comprising of 90 cargo ships, 40 tankers and other vessels go through the Straits of Malacca (Finn et al. 1979). There are five oil refineries in operation in Malaysia and two of them are located on the coast of Port Dickson. Extensive exploration and production activities are being conducted in the off-shore waters of the South China Sea where there are more than 45 oil fields and 47 gas fields (UNEP 1987b). All these activities have made the Malaysian coastal waters more susceptible to oil pollution.

Port Dickson is located on the west coast of Peninsular Malaysia adjacent to the Straits of Malacca. Routine handling of crude oil and refined oil at the terminals and at the port as well as heavy maritime tanker transportation in the Straits of Malacca would undoubtedly have an impact on the water quality of the Port Dickson coastal waters. Comprehensive studies on petroleum hydrocarbon pollution have not been reported in this area except that of Law and Ravinthar (1989) who studied the hydrocarbon distribution in the near-shore waters and beach sand. This project was undertaken to study the distribution of petroleum hydrocarbons in the coastal waters and sediments off Port Dickson.

MATERIALS AND METHODS

Study Area.

FIfteen sampling stations were established and their locations are the same as described in the previous report (Law & Azahar, 1990). Stations A_1 to A_6 were about 3 to 5 m away from the shoreline and had a depth of 1 m. Stations B_1 to B_3 were 1 km, stations C_1 to C_3 were 3 km and stations D_1 to D_3 were 5 km away respectively from the shoreline.

Sampling Techniques.

Water samples close to the shore were collected with a 4 l clean amber-glass bottle which had been thoroughly cleaned with detergent, hot distilled water and dichloromethane prior to use. For coastal waters, water samples were collected at a depth of half a meter below the sea surface with a 4 l clean amber-glass bottle and approximately 1 m above the sea floor with a 5 l Van Dorn Sampler. The samples were kept cool in the dark and extraction was conducted within 3-6 h after sampling. Sediment samples were collected with a McIntyre grab. The surface sediment samples (0-3 cm) were taken by using a stainless steel spatula and transferred into wide-mouth glass specimen bottles. The samples were kept cool in an ice box on board and frozen at −20°C in the laboratory until further analysis.

Analytical Techniques.

Petroleum hydrocarbon concentrations in the water samples were determined according to the fluorospectrometric method of Parsons et at. (1984). One l of the water sample was extracted three times with dichloromethane (40ml: 40 ml: 20 ml). The extracts were combined and stored in glass reagent bottles which had been cleaned with dichloromethane and brought to the laboratory for analysis. The residual water and polar organic substances were removed from the extract with anhydrous sodium sulfate and silica gel (60-120 mesh), respectively. The solvent was evaporated to dryness in a rotary evaporator at 35°C under partial vacuum. The concentrate was taken up in 10.0 ml n-hexane. Fluorescence of the sample was measured at 310 nm excitation and 374 nm emission wavelength, respectively. A Kontron Fluorospectrometer (SFM 23) was used for the analysis. Chrysene and ESSO Tapis A crude oil were used for the calibration. A conversion factor of 19.1 for the ESSO Tapis A crude oil/chrysene fluorescene responses was established. Triplicate analyses were performed on each water sample. A 93 ± 3.6% recovery was achieved from synthetic sea water containing 81.29 ppb of ESSO Tapis A crude oil.

The petroleum hydrocarbon content in the sediments was estimated according to the method of USEPA (1979). The frozen sample was dried in the freeze dryer. Five g of the dried sample was extracted with 150 ml of dichloromethane for 8 h in a Soxhlet apparatus. The temperature for the Soxhlet extraction was set at 40°C. After extraction, the extract was depolarized and the solvent was evaporized. The residual oil was concentrated in 10 ml of n-hexane. The petroleum hydrocarbon content in the samples was then determined by the fluroescence method as described for the water sample. A 96% ± 4.9% recovery was obtained from the hydrocarbon free

TABLE 1

Petroleum hydrocarbon distribution in the water and sediment off Port Dickson coastal waters with distance away from the shoreline (in chrysene equivalent)

Sampling date	17/11/86		17/12/86		24/4/87		24/8/87		26/3/88		21/6/88		24/8/88		18/1/89			
Stations[1]	Water[2]	Sediment[3]	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment
A (1-6)	0.72[4] (0.20-1.41)	–[5]	0.61 (0.21-1.27)	-	-	-	5.42 (3.05-7.06)	-	-	-	-	-	5.42 (3.05-7.06)	-	-	-	2.88 (1.04-5.29)	-
B (1-3)	0.86 (0.47-1.45)	2.91 (1.23-4.99)	2.08 (1.26-3.02)	0.72 (0.50-0.94)	3.04 (1.67-4.13)	4.20 (1.30-7.01)	5.96 (3.98-7.90)	2.59 (1.45-3.71)	6.53 (4.14-10.30)	5.15 (3.77-6.53)	3.06 (1.33-5.47)	3.18 (1.05-4.97)	5.96 (3.98-7.90)	-	4.84 (2.64-6.45)	-	2.41 (0.44-4.19)	2.08 (1.19-2.88)
C (1-3)	0.78 (0.23-1.58)	0.72 (0.19-1.69)	1.38 (0.42-2.58)	1.38 (0.73—1.93)	4.78 (1.06-8.28)	1.71 (1.11-3.66)	6.15 (3.68-7.80)	-	7.59 (5.40-10.86)	2.66 (0.88-6.08)	2.62 (0.48-4.48)	4.38 (1.42-8.22)	6.15 (3.68-7.80)	-	4.76 (2.41-8.46	-	1.63 (1.08-2.56)	1.66 (0.38-2.89)
D (1-3)	-	-	1.43 (0.56-2.08)	-	3.32 (1.95-5.88)	-	5.88 (2.05-7.80)	1.78 (1.24-2.24)	9.50 (5.47-11.40)	-	3.72 (2.05-9.03)	2.47 (1.08-4.19)	6.41 (2.05-7.90)	-	3.36 (2.16-5.05)	-	1.60 (0.86-3.22)	-
Mean	0.77 (0.20-1.58)	1.60 (0.19-4.99)	1.20 (0.21-3.02)	1.12 (0.50-1.93)	3.71 (1.06-8.28)	2.71 (1.11-7.01)	5.77 (2.05-7.90)	2.27 (1.24-3.71)	7.87 (4.14-11.40)	3.90 (0.88-6.53)	3.14 (0.48-9.03)	3.34 (1.05-8.22)	5.74 (2.05-7.90)	-	4.45 (2.16-8.46)	-	2.28 (0.44-5.29)	1.97 (0.38-2.89)

1 Distance away from the shoreline; Stations A, 3-5 meters, Stations B, 1 km; Stations C, 3 km; Stations D, 5 km.

2 µg/1 chrysene equivalent

3 mg/kg dry sediment chrysene equivalent

4 Mean and range

5 Not determined

sediment containing 81.29 ug of ESSO Tapis A crude oil.

RESULTS AND DISCUSSION

The distribution of petroleum hydrocarbons in the water and sediment of Port Dickson coastal waters are presented in Table 1. The results indicated that on each sampling date, except on 26 March 1988, 21 June 1988 and 8 January 1989, there was no significant difference of petroleum hydrocarbon concentrations in the waters between the shore and 5 km away from the coast ($P > 0.05$). However, there was a significant difference of petroleum hydrocarbon content in the sediments ($P<0.05$). The mean concentration of petroleum hydrocarbon in the water ranged between 0.77 ppb and 7.87 ppb, chrysene equivalent (or between 14.69 ppb and 150.28 ppb Esso Tapis A crude oil equivalent), while for the sediment, it ranged between 1.12 mg/kg and 3.90 mg/kg dry sediment, chrysene equivalent (or 21.73 mg/kg and 74.50 mg/kg dry sediment, ESSO Tapis A crude oil equivalent). The results also indicated that there was a pronounced fluctuation of hydrocarbon levels in the water and sediment on the sampling dates, with a 10-fold fluctuation in the water and 3.5-fold fluctuation in the sedimen (Fig 1a). These findings were consistent with the findings of Law and Ravinthar (1989) that petroleum hydrocarbon residue levels fluctuate in the near-shore waters and in the beach sand of Port Dickson.

The petroleum hydrocarbon concentration in the near-shore waters was found to be not significantly different and comparatively lower than that detected in the coastal waters ($P>0.05$). This indicates that hydrocarbons that originate from the municipal effluents from Port Dickson do not contribute significantly to oil pollution in the coastal waters. The possible sources of oil contamination are the discharge of oily waste water by vessels passing through the Straits of Malacca and through the routine handling of crude oil at the terminals of the refineries. The oily waste water can reach the coastal waters off Port Dickson through transportation by tidal current, especially during the south-west monsoon season. Even though there was no correlation between the hydrocarbon level in the water and

TABLE 2
Comparison of petroleum hydrocarbon levels in Port Dickson coastal waters with values reported in other seas (in crude oil equivalent)

Location	Water (µg/1)	Sediment (mg/kg dry weight)	Sources
South China Sea			
Terengganu coastal waters	980 (10 - 1750)	(6.43 - 1332.13)	Law and Rahimi (1986)
Pahang coastal waters	36.9 (9.49 - 65.56)	(10.73 - 85.26)	Law and Zulkifli (1987)
Sarawak coastal waters	133.96 (13.11 - 545.10)	(2.92-1153.53)	Law and Saili (1988)
Sabah coastal waters	76.09 (31.61-163.66)	102.54(19.84-226.42)	Law (unpublished data)
Hong Kong Harbour	8.56 (3.67-11.98)	–	Cheung *et al* (1979)
Boston Harbour, U.S.A.	292	–	Ahmad *et al.* (1974)
Egyption Red Sea	36.8 (10-105)	–	Hanna (1983)
Jakarta Bay	6.11 (0.5-46)	85.5 (9-331)	UNEP (1987b)
Gulf of Thailand	1.77 (0.07-8.30)	12.98(0.03-62.0)	Wattayakorn (1987a & 1987b)
Straits of Malacca			
Penang coastal waters	(10-120)	–	Phang *et al.* (1980)
Present study, Port Dickson coastal waters	(14.69-150.28)	(21.73-74.50)	

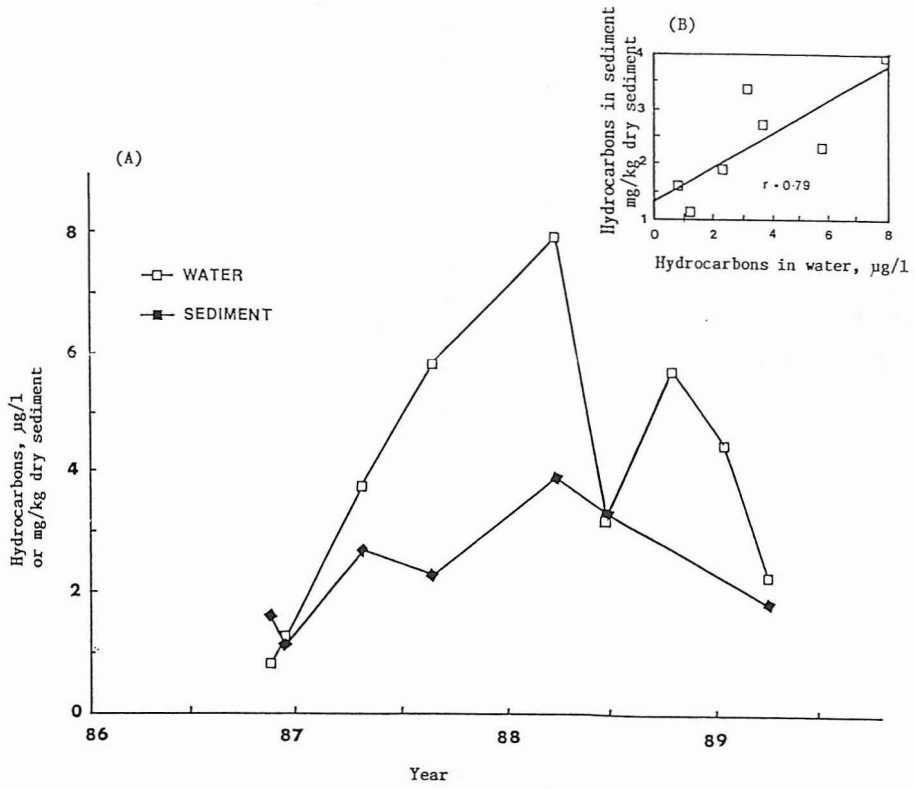

Fig. 1. Mean petroleum hydrocarbon levels in the water and sediment of Port Dickson coastal waters (in chrysene equivalent). (A): with different sampling dates; (B): the linear regression)

sampling time of the year, there was a tendency of higher hydrocarbon levels in the water at the stations located 5 km away from the coastline during the south-west monsoon season. In general, a significantly higher level of hydrocarbons in the water was detected at stations B1 and C1 ($P < 0.05$). These stations were situated near the anchoring site of vessels as well as the terminals of refineries and the Port Dickson harbour. It is possible that oil terminal activities have contributed to some extent to oil pollution in this area. Further studies are required for the assessment of the impact of oil on the water quality of the Port Dickson coastal waters.

The hydrocarbon content in the sediment would probably reflect the status of oil pollution in the area better than the level of hydrocarbon present in the water, especially in the Port Dickson coastal waters, where the hydrocarbon levels fluctuate throughout the year. A close relationship between the hydrocarbon content in the sediment and that in the water was inferred in this study because the correlation coefficient was 0.79 (fig 1b). The gas liquid chromatographic analyses of the hydrocarbon residues in the sediment, collected from stations C1, C2 and C3, revealed that the samples contained mainly oil of the heave fraction (Fig 2). This indicates that active biodegradation of hydrocarbons occurs in this area. Studies on the biodegradation of crude oil are being conducted to verify this aspect.

A comparison of the petroleum hydrocarbon levels in the water and sediment of the present study with values reported for other seas are presented in Table 2. The hydrocarbon level in the waters off Port Dickson was lower than that found in the Boston Harbour waters, the Terenganu and the Sarawak coastal waters of the South China Sea. However, the levels were comparable to that detected in the Egyptian Red Sea, Sabah and Penang coastal waters but higher than that found in the Gulf of Thailand, Hong Kong Harbour and Pahang coastal waters. In the case of sediments, the petroleum hydrocarbon

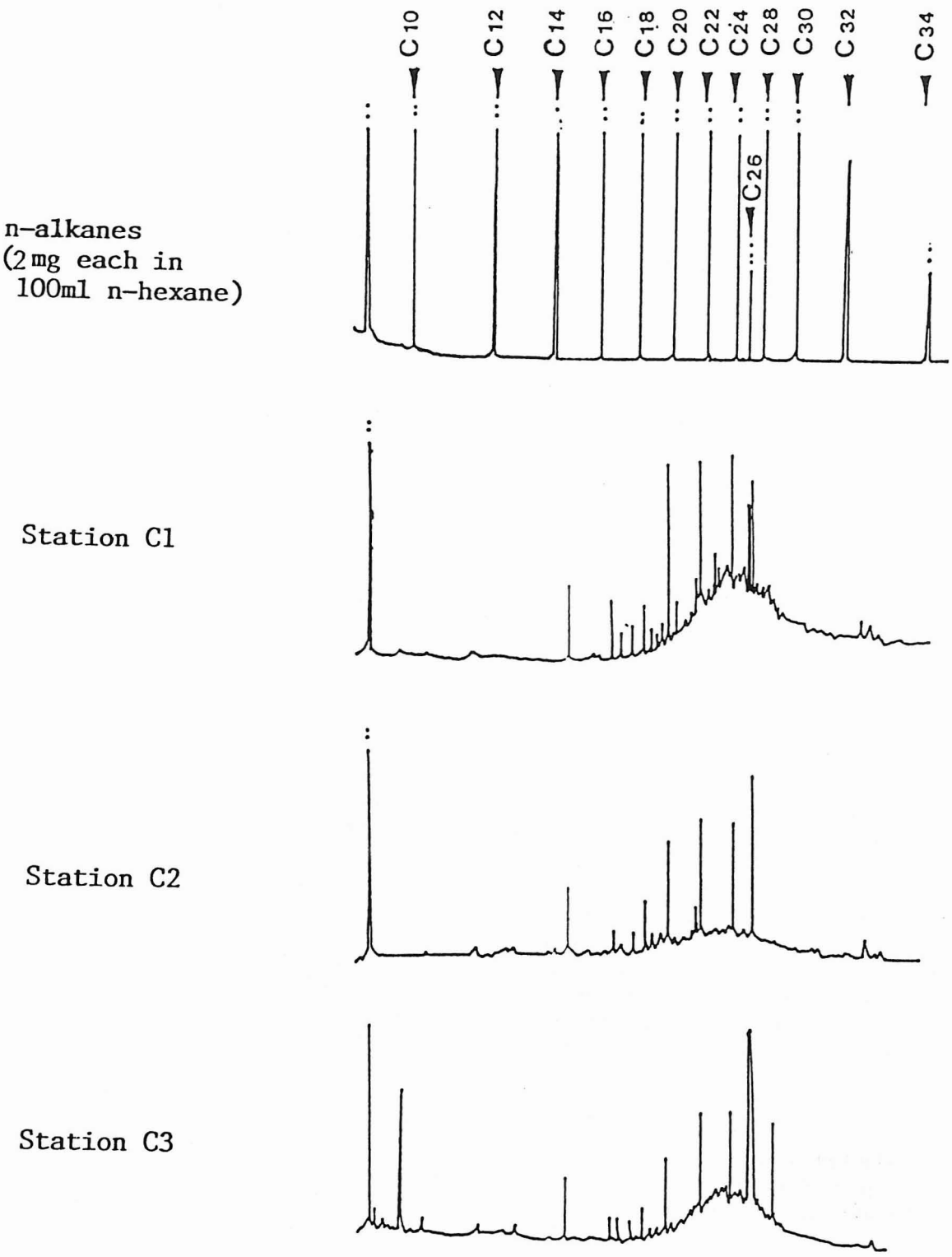

Fig. 3. Gas chromatographic spectra of oil residues in the sediments at Station C1, C2 and C3.

content was higher than that detected in the Gulf of Thailand, but lower than those found in Sabah, Sarawak, Pahang and Terengganu coastal waters. Marchand et al. (1982) employed an index of 100 mg hydrocarbon per kilogram of dry sediment as an indicator for oil pollution. The hydrocarbon content in the sediments of this study ranged between 21.33 mg/kg and 74.50 mg/kg dry sediment, ESSO Tapis A crude oil equivalent, thus indicating that the petroleum hydrocarbon contamination in the study area was still low and may not be detriment to living organisms.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Cheah Sin Hock and Dr. Hishamuddin bin Omar for their comments and suggestions and Puan Normala bte Abu Samah for typing the manuscript. This project was funded by Universiti Pertanian Malaysia and IRPA (4-07-05-06).

REFERENCES

AHMAD, A.H., M.D. BEASLY, A.C. EFROMSON, and R.A. HITES. 1974. Marine Pollution Monitoring (petroleum). *Proceedings of a Symposium and Workshop* held at NBS Gaitersburg, Maryland, 13-17 May, 1974. *NBS Spec. publ.* **409**:109.

CHEUNG, M.T., T.Y. CHENG, S.W. LEUNG, C.C. LO and L.M. MAK.1979. Oil pollution along Coastal Areas of Hong Kong. *Mar. Pollut. Bull.* **10**:228-231.

FINN, D.P.,Y. HANAYAMA, M.J. MEINANDI NEJAD, T. PIYAKARNCHANA, and J.N. REEVES. 1979. Oil Pollution from Tankers in the Straits of Malacca: a Policy and Legal Analysis. 153 p. East-west Centre, Open Grants Office, Honolulu, Hawaii. Mimeo.

HANNA, R.G.M. 1983. Oil pollution on the Egyptian Red Sea Coast. *Mar. Pollut. Bull.* **14**:268-271.

LAW, A.T. and Y. RAHIMI. 1986. Hydrocarbon Distribution in the South China Sea. Matahari Expedition '85. A Study on the Offshore Waters of the Malaysian EEZ, ed. A.K.M. Mohsin, Mohd. Ibrahim and Mohd. Azmi Ambak. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia, Occasional Publication. **3**: 93-100.

LAW, A.T. and M. ZULKIFLI. 1987. Distribution of Petroleum Hydrocarbon in the South-western Portion of the South China Sea. Matahari Expedition '86. A Study on the Offshore Waters of the Malaysian EEZ, ed A.K.M, Mohsin, Ridzwan Abd. Rahman and M.A. Ambak. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia, Occasional Publication **4**: 53-60.

LAW, A.T. and L. SAILI. 1988. Petroleum Hydrocarbon Distribution in the Coastal Waters off Sarawak. Matahari Expedition '87. A Study on the Offshore Waters of the Malaysian EEZ, ed. A.K.M. Mohsin, and Mohd Ibrahim. Faculty of Fisheries and Marine Science, Universiti Pertanian Malaysia, Occasional Publication **8**: 61-67.

LAW, A.T. and V. RAVINTHAR. 1989. Petroleum Hydrocarbon along the Coastal Areas of Port Dickson. *Pertanika* **12**:345-348.

LAW A. T. and AZAHAR OTHMAN . 1990 Sewage pollution in the Coastal waters off Port Dickson, Straits of Malacca. *Pertanika* **13 (3)**: 375 - 380.

MARCHAND, M.,G. BODENNEC, J.-C. CAPRAIS and P. PIGNET. 1982. The Amoco Cadiz Oil Spill, Distribution and Evolution of Oil Pollution in Marine Sediments. Ecological Study of the AMOCO CADIZ Oil Spill. Report of the NOAA-CNEXO Joint Scientific Commission, p. 143-157.

PARSONS. T.R.,Y. MAITA and C.M. LALLI, 1984. A Manual of Chemical and Biological Methods for Sea Water Analysis. 173 p. Frankfurt: Pergamon Press.

PHANG, S., T.K. HWANG and T.T. ANG. 1980. A Study of the Hydrocarbon Content in the Coastal Waters along the East Coast of Peninsular Malaysia. Coastal Resources of East Coast Peninsular Malaysia, ed T.E. Chua, and K.C. Joseph. Pulau Pinang: Universiti Sains Malaysia, 306 p.

UNEP. 1987a. Oil Pollution Control Measures and Arrangements in Malaysia. UNEP (OCA)/EAS WG. 1/11. Mimeo 38 p.

UNEP. 1987b. Oceanographic Features and Meterological Phenomena of the East Asian Seas Region Relevent to Oil Pollution and its Control. UNEP(OCA)/EAS WG. 1/3. Mimeo, 378 p.

USEPA. 1979. EPA method 625 (sample concentration),44, U.S. Registrar **(233)**: 69540.

WATTAYAKORN, G., 1987a. Dissolved/Dispersed Hydrocarbons in the Gulf of Thailand. *4th Seminar on Water* Quality and the *Quality of Living Resources in Thai Waters,* 7-9 July, Surat Thani, Thailand. Preprint, 10 p.

WATTAYAKORN, G. 1987b. Distribution of Petroleum Residues in Surficial Sediments from the Gulf of Thailand. *Conf. on Coastal and Estuarine Pollution,* 18-21 Oct. 1987, Fukuoka, Japan. Preprint, 7 p.

(Received 21 February, 1990)