



CHAPTER IV

RESULTS

4.1 Circulation Pattern of the Study Area

To determine the dispersion characteristics of petroleum hydrocarbons in seawater around ship-breaking industry area, twenty-five consecutively sampling hours of current measurements were conducted at the periods of scraping activity in June and November 1989. Wind speed and directions, integrating as a major factor controlling dispersion of oil slick were obtained from the Meteorological recorded. The results are as follows:-

Based on predicted tides at Sattahip and Chong Samed stations, the current measurement in June, Figure 4-1, was carried out a few hours after low water slack while in November the first sampling was taken after the high water slack. Notice that tide at Sattahip which is to the west of the study area and at Chong Samed to the east are in phase.

The hourly recorded surface current, Figure 4-2(a), was mainly in the second and fourth quadrants indicating flow parallel to the shore. The current rotated clockwise as tide changed from flood to ebb but counter-clockwise during the turn from ebb to flood tide. The progressive vector diagram, Figure 4-2(b) reveals the net tidal drift of about 264 m in the SE direction.

Figure 4-2(c) shows hourly recorded surface current measured in November. A longshore flow was less obvious than those recorded in June. However, rotation of currents associated with shifting between flood-ebb cycle followed that observed in June. The net tidal drifted for this period was approximately 173 m in the SSW direction.

Current speed and direction in June and November were observed as shown in Appendix A (Tables A-1 and A-2).

Wind speed and direction are considered as the major factor controlling dispersion of oil slick floating on sea surface. The effects of wind are two folds, i) directly drifted the oil a way from the point source, and ii) distorting current driven by tide. Wind speeds and directions data recorded by the Meteorological Department in the vicinity of the study site for the month of June and November 1989 are shown in Table A-3 in Appendix A.

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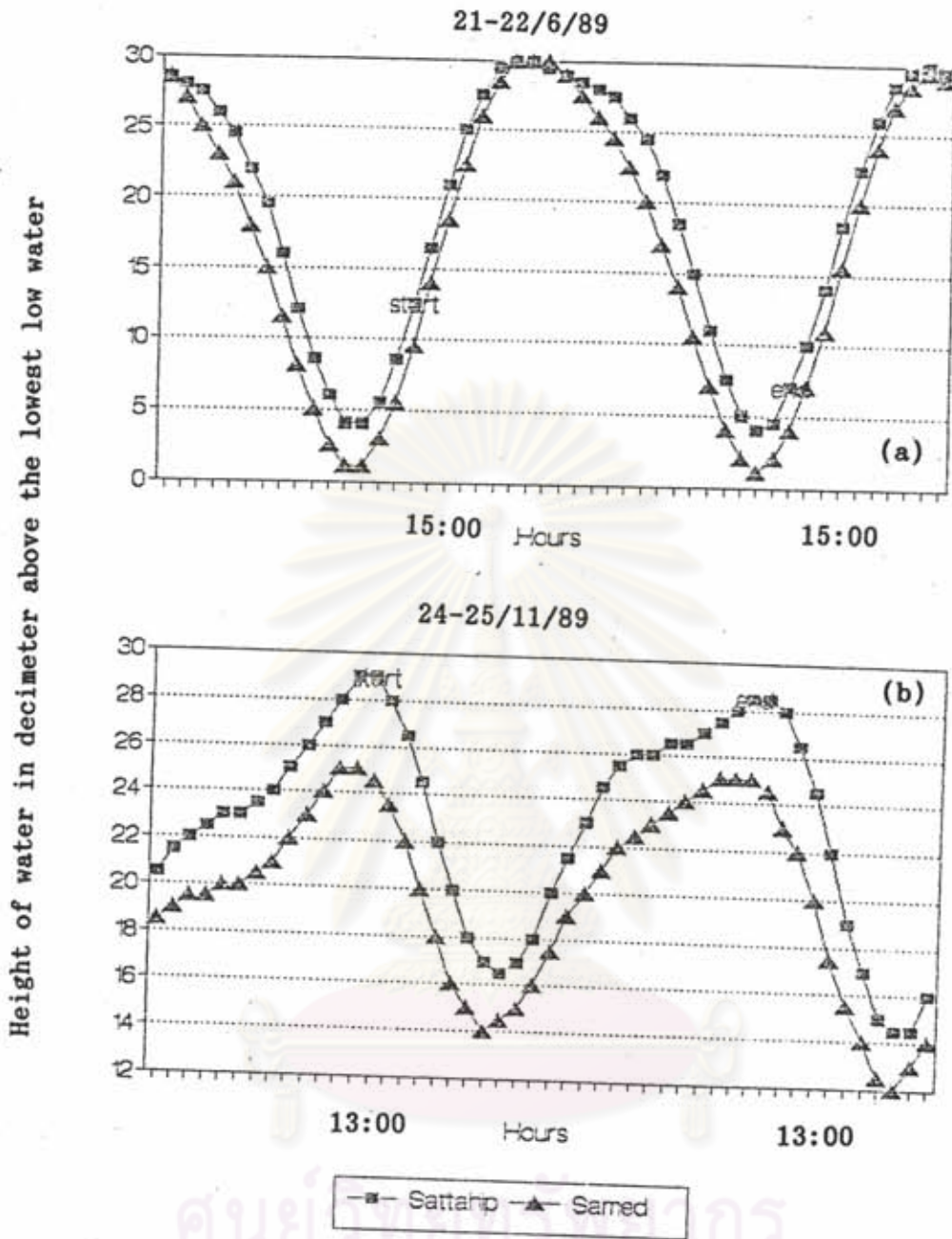


Figure 4-1 Plotting predicted tide from tidetable at Sattahp and Chong Samed which cover the Map Ta Phut area.
 a) 21-22 June, 1989
 b) 24-25 November, 1989

START : Starting current measurement
 END : Ending current measurement

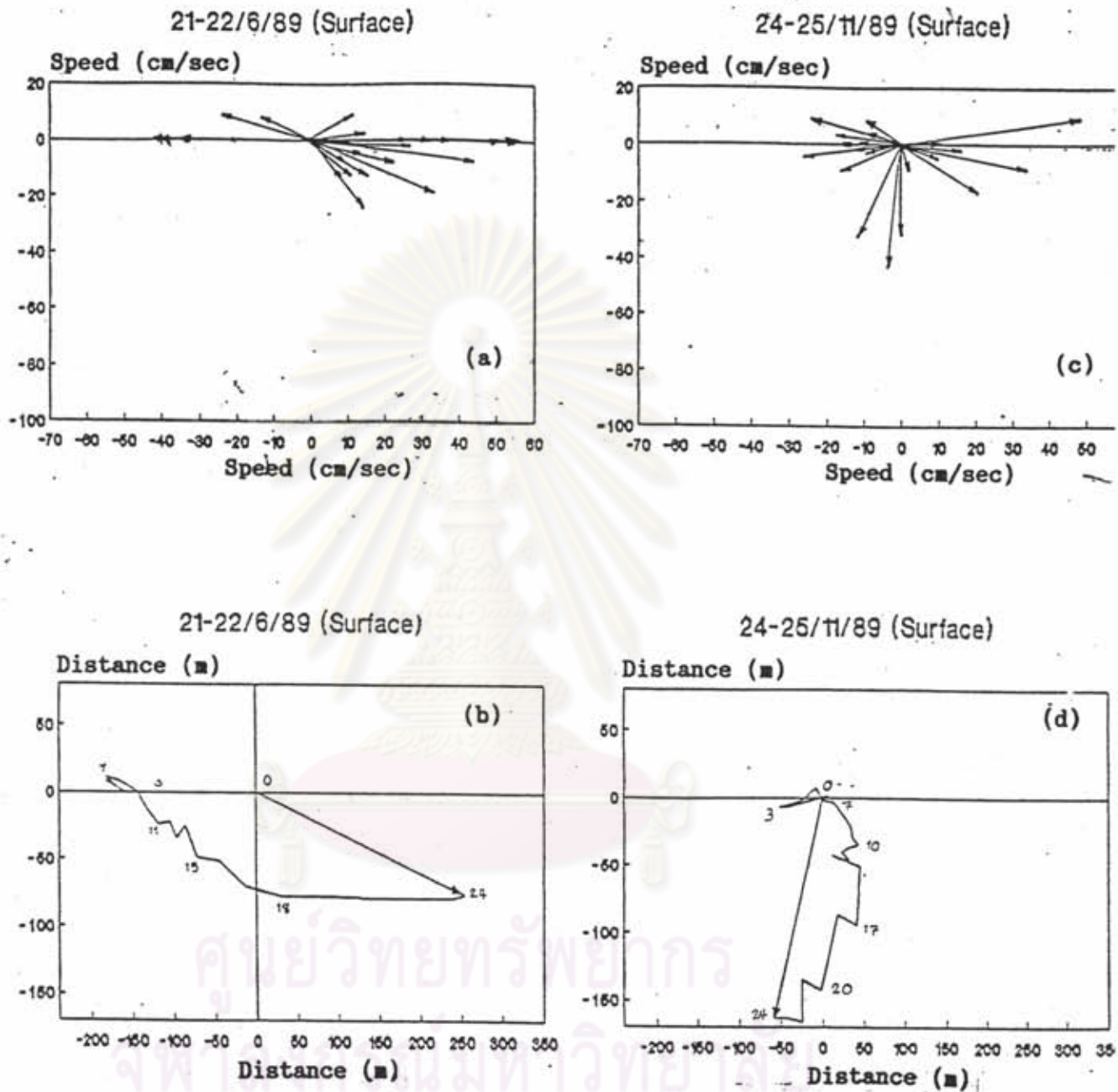


Figure 4-2 The hourly recorded surface current and the progressive vector diagram.
 a) The hourly recorded surface current in June
 b) The progressive vector diagram in June
 c) The hourly recorded surface current in November
 d) The progressive vector diagram in November

4.2.1 Concentrations of Petroleum Hydrocarbons in Seawater

The dissolved / dispersed petroleum hydrocarbon concentrations of water samples are shown in Table 4-1 and Figures 4-3 to 4-5. Figure 4-3 presents the concentration of water samples collected at 1-m depth. For the periods of October 1988 and May 1990, most of the samples contained low hydrocarbon concentrations (less than 1 $\mu\text{g}/\text{l}$). The exception, are samples from station N6 (1.05 $\mu\text{g}/\text{l}$) and station N1 (1.29 $\mu\text{g}/\text{l}$) for October and Station N1, N8, and N9 (1.00, 1.50 and 1.80 $\mu\text{g}/\text{l}$) for May which are the periods when the ship-breaking activity has already been finished. Concentrations range from 0.27-1.29 $\mu\text{g}/\text{l}$ was found in October and 0.14-1.80 $\mu\text{g}/\text{l}$ was found in May.

The hydrocarbon concentrations for the second (June) and the third (November) sampling periods show higher value with much more variation when compared to the first and the last sampling periods. For the second period, the average concentration of 5.03 $\mu\text{g}/\text{l}$ was found in the outer area (stations N1, N2, N14, N15 AND N16 for westwards and stations N7, N8, N9, N10 and N20 for eastwards of the scraping site). This concentration was higher than the concentrations of 1.82 and 0.59 $\mu\text{g}/\text{l}$ found in the inner (stations N, N3, N4, N5, N6, N11, N12, N13, N17, N18 and N19) and the offshore waters (stations O1, O2, O3, O4, O5 and O6), respectively. High concentrations were found at stations N7, N8, N9 and N10, eastwards of the scraping area. For the third sampling period, the average concentration found in the inner area was the highest when compared

Table 4-1 Concentration of dissolved/dispersed petroleum hydrocarbons in seawaters and creek water .

ST.	1-M DEPTH				SURFACE MICROLAYER				
	OCT88	JUNE89	NOV89	MAY90	OCT88	JUNE89	NOV89	MAY90	
N	-	7.49	-	-	-	-	-	-	
N3	0.75	0.89	2.57	-	-	-	-	-	
N4	0.97	0.74	1.04	0.22	6.67	14.88	1.19	4.52	
N5	0.85	0.75	2.74	0.16	2.73	1.06	-	2.40	
I R N6	1.05	7.47	2.28	-	-	-	-	-	
N E N11	0.79	0.76	0.61	-	5.05	10.69	-	-	
N G N12	0.47	0.25	0.69	0.24	4.91	1.84	10.01	1.32	
E I N13	0.34	0.41	1.21	-	2.29	1.18	22.08	-	
R O N17	0.48	0.54	0.43	0.16	4.36	1.83	27.98	1.00	
N N18	0.48	0.48	0.70	-	3.93	1.54	30.14	-	
N19	0.69	0.20	0.22	0.18	5.44	1.85	6.99	1.28	
Min	0.34	0.20	0.22	0.16	2.29	1.06	1.19	1.00	
Max	1.05	7.47	2.57	2.57	6.67	10.69	30.14	4.52	
Mean	0.69	1.82	1.25	0.19	4.42	4.36	16.40	2.10	
S.D.	0.22	2.68	0.88	0.03	1.34	4.98	10.92	1.30	
N1	1.29	0.58	1.15	1.00	-	-	-	-	
N2	0.43	0.89	0.41	-	-	-	-	-	
N7	0.35	5.72	0.29	-	-	-	-	-	
N8	0.49	10.07	0.25	1.50	5.87	7.28	5.13	5.84	
O R N9	0.42	19.37	0.13	1.80	6.15	30.96	4.00	7.60	
U E N10	0.60	6.25	0.99	-	0.95	22.25	1.74	-	
T G N14	0.44	0.36	0.62	-	4.71	0.99	2.54	-	
E I N15	0.40	0.25	0.44	0.22	1.68	14.45	21.17	1.26	
R O N16	0.74	5.65	0.42	0.14	2.42	0.88	8.85	1.22	
N N20	-	1.16	0.09	0.20	1.20	7.70	1.69	1.64	
Min	0.35	0.36	0.09	0.14	0.95	0.88	1.69	1.22	
Max	1.29	19.37	1.15	1.80	6.15	30.96	21.17	7.60	
Mean	0.57	5.03	0.48	0.81	3.28	12.07	6.45	3.51	
S.D.	0.28	5.74	0.33	0.67	2.07	10.39	6.44	2.68	
O O1	0.35	0.07	1.38	0.34	0.52	12.22	13.90	1.22	
F R O2	0.34	0.02	0.16	-	1.11	8.63	13.82	-	
F E O3	0.27	1.09	0.35	0.27	0.49	13.74	14.20	1.58	
S G O4	0.51	1.43	0.13	0.29	1.69	17.47	11.52	1.42	
H I O5	0.53	0.68	0.29	-	2.69	4.13	12.87	-	
O O O6	0.53	0.22	0.53	0.35	2.06	31.82	20.56	1.28	
R N E	Min	0.27	0.02	0.13	0.27	0.52	4.13	11.52	1.22
	Max	0.53	1.43	1.38	0.35	2.69	31.82	20.56	1.58
	Mean	0.42	0.59	0.47	0.31	1.43	14.67	14.48	1.38
	S.D.	0.10	0.53	0.43	0.03	0.80	8.72	2.86	0.14
C					4.97	3.00	2.88	2.64	
C R C1					0.54	2.73	0.57	0.33	
R E C2					0.83	1.33	0.84	0.30	
E G C3					0.53	1.14	0.85	*	
E I C4					0.42	*	*	*	
K O C5					0.53	*	1.12	1.45	
S N C6					0.34	0.58	1.73	0.34	
Min					0.34	0.58	0.57	0.30	
Max					4.97	3.00	2.88	2.64	
Mean					1.17	1.76	1.33	1.01	
S.D.					1.56	0.94	0.78	0.96	

Note: * = Samples were not available.

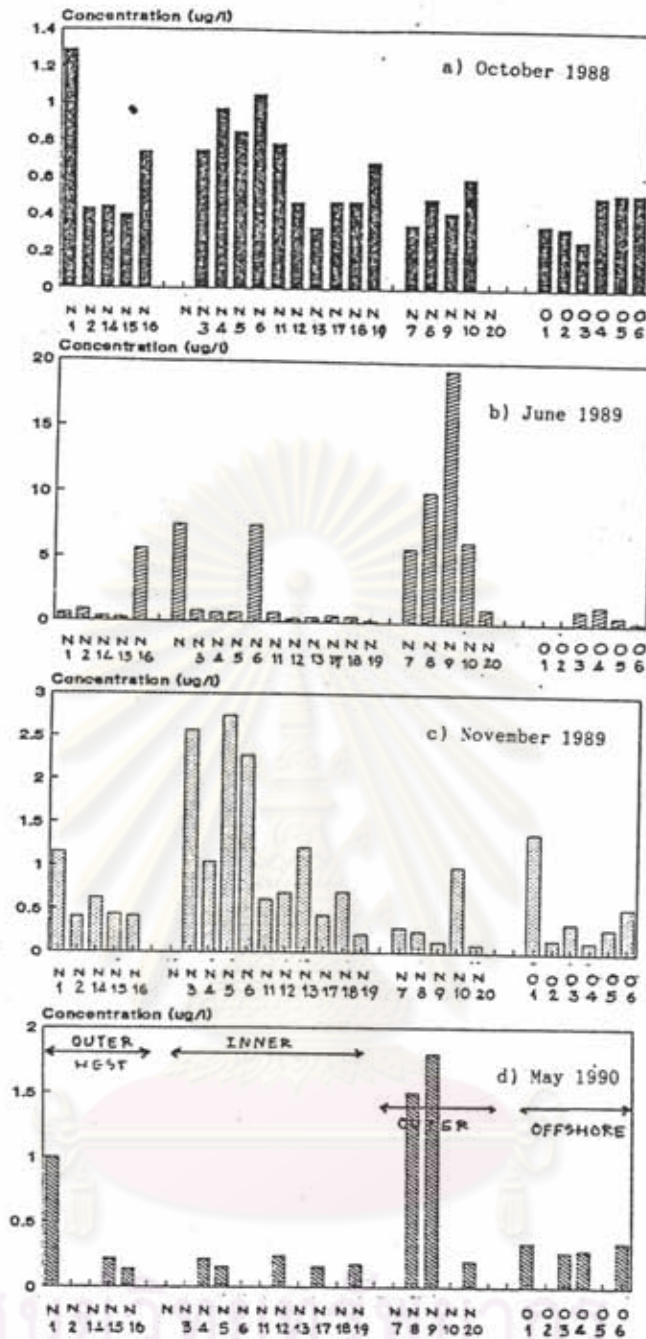


Figure 4-3 Petroleum hydrocarbon concentration in seawater samples collected at 1-m depth in 4 study periods.
 a) October 1988 b) June 1989
 c) November 1989 c) May 1990

Inner region = Station N, N3, N4, N5, N6, N11, N12, N13, N17, N18, N19
 Outer region = Station N1, N2, N14, N15, N16 (eastwards) and N7, N8, N9, N10 and N20 westwards of scraping fractorioes).
 Offshore region = Station 01, 02, 03, 04, 05, and Station 06.

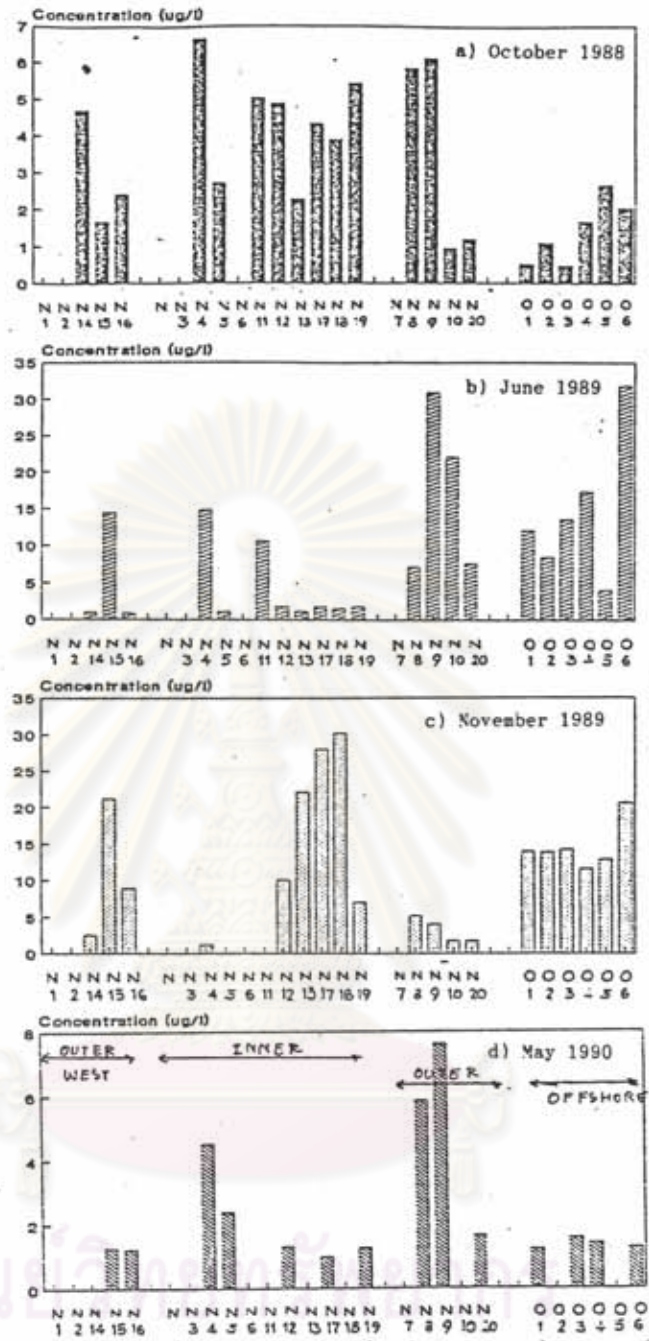


Figure 4-4 Petroleum hydrocarbon concentration in seawater samples collected at surface microlayer in 4 study periods.

a) October 1988 b) June 1989
 c) November 1989 d) May 1990

- Inner region = Station N, N3, N4, N5, N6, N11, N12, N13, N17, N18, N19
- Outer region = Station N1, N2, N14, N15, N16 (eastwards) and N7, N8, N9, N10 and N20 westwards of scraping fractorioes).
- Offshore region = Station 01, 02, 03, 04, 05, and Station 06.

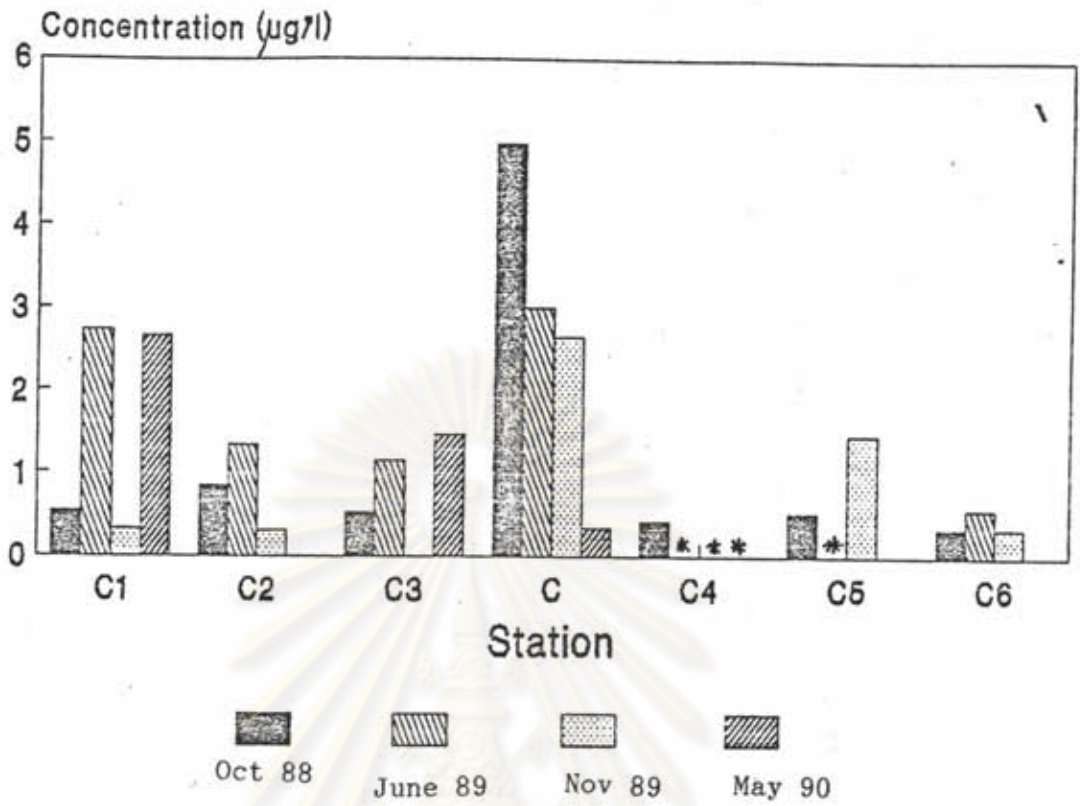


Figure 4-5 Petroleum hydrocarbon concentration in creek water samples collected in 4 study periods

Note : * = not obtained

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to other stations and was 1.25 $\mu\text{g/l}$, whereas the means of the outer and the offshore areas were only 0.48 and 0.47 $\mu\text{g/l}$, respectively.

Figure 4-4 shows the hydrocarbon concentrations in the surface microlayer. The concentrations were higher in June and November 1989 of scraping periods when compared to those found in October 1988 and May 1990. In the second period, however, the mean concentration in the outer area (12.07 $\mu\text{g/l}$), especially for the eastwards of the scraping site, was higher than those in the inner area (4.36 $\mu\text{g/l}$) but almost the same value as in the offshore areas (14.67 $\mu\text{g/l}$). High concentrations were found at station N9, eastwards of the factories in the outer area. For the third period, however, the highest mean concentration was found in the inner area (16.40 $\mu\text{g/l}$) and offshore water (14.48 $\mu\text{g/l}$) while the outer are found as low as 6.45 $\mu\text{g/l}$.

Average hydrocarbon concentrations from the outlet water region for the four sampling periods appears to be on the same order of magnitude, being 1.07, 1.76, 1.33 and 1.01 $\mu\text{g/l}$, respectively. High concentrations were observed at Klong C, C1 and C5 (Figure 4-5).

4.2.2 Enrichment Factors

An attempt to compare hydrocarbon concentrations in the surface microlayer and in the water (1 m below the surface) indicates an enrichment of hydrocarbon in the surface microlayer (Table 4-2). The ratios of those concentrations varied from 1.49-10.70 and 3.59-20.55 for no activity periods in October 1988 and May 1990. Higher enrichment occurred in the surface microlayer of the offshore area during ship-breaking periods, being 0.16-431.5 and

1.44-88.62 in June and November 1988, respectively.

4.2.3 Distribution Patterns of Petroleum Hydrocarbons

The concentrations of petroleum hydrocarbons in surface water found at the first scraping period in June were remarkably higher in those nearshore stations to the east of the cutting site than those on the west (Figure 4-6). Results from November observation reveal that concentrations of petroleum hydrocarbon were found to be higher in both nearshore and offshore stations, in front of the ship-breaking site in relation to those on the east and west (Figure 4-6). The distribution tendency of petroleum hydrocarbon concentrations in water samples collected at 1 m-depth were found to be similar. The concentrations of petroleum hydrocarbons in bulk water found in June were remarkably higher in those nearshore stations to the east of the cutting site than those on the west (Figure 4-7). In November observation, the distribution pattern implied that the higher concentrations of petroleum hydrocarbons was found on the east of scraping point in both nearshore and offshore stations (Figure 4-7).

4.2.3 Fluorescence Spectra

The emission spectra of most samples are presented in Figure 4-8. Fluorescence peaks in addition to the normal hexane when compare to hexane (extracted solvent) peak were observed in all samples.

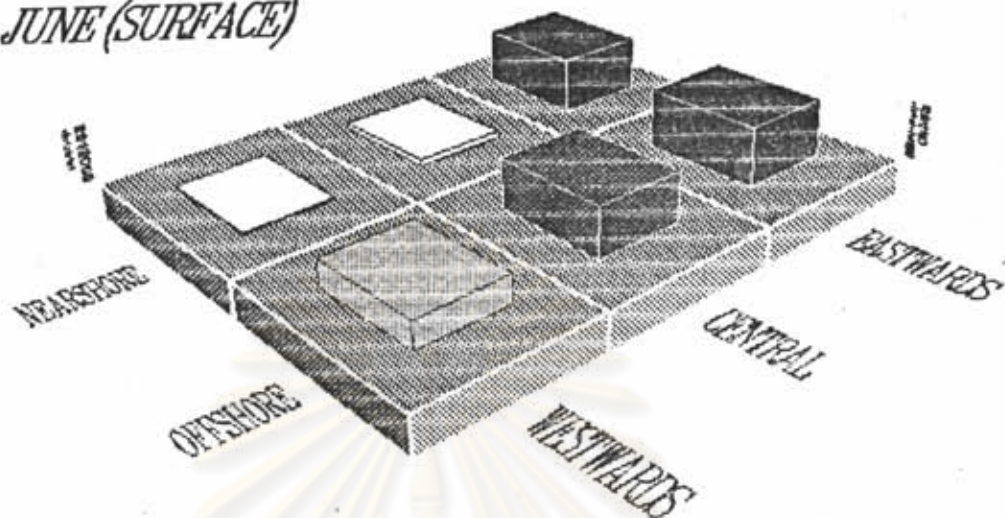
Further experiment shows that the synchronous spectra could be divided into 3 types according to the maximum emission peaks exhibited from the compounds with different numbers of fused aromatic

Table 4-2 Enrichment factor of hydrocarbon concentration between bulk water and sea surface water.

STATION	OCT88	JUNE89	NOV89	MAY90
N14	10.70	2.75	4.10	-
N15	4.20	57.80	48.11	5.73
N16	3.27	0.16	21.07	8.71
N4	6.88	20.11	1.14	20.55
N5	3.21	1.41	-	15.00
N11	6.39	14.07	-	-
N12	10.45	7.36	14.51	5.50
N13	6.74	2.88	18.25	-
N17	9.08	3.39	65.07	6.25
N18	8.19	3.21	43.06	-
N19	7.88	9.25	31.77	7.11
N8	11.98	0.72	20.52	3.89
N9	14.64	1.60	30.77	4.22
N10	1.58	3.56	1.76	-
N20	-	6.64	18.78	8.20
O1	1.49	174.57	10.07	3.59
O2	3.26	431.50	86.38	-
O3	1.81	12.61	40.57	5.85
O4	3.31	12.22	88.62	4.90
O5	5.08	6.07	44.38	-
O6	3.89	144.64	38.79	3.66
Min	1.49	0.16	1.14	3.59
Max	14.64	431.50	88.64	20.55

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JUNE (SURFACE)



NOVEMBER (SURFACE)

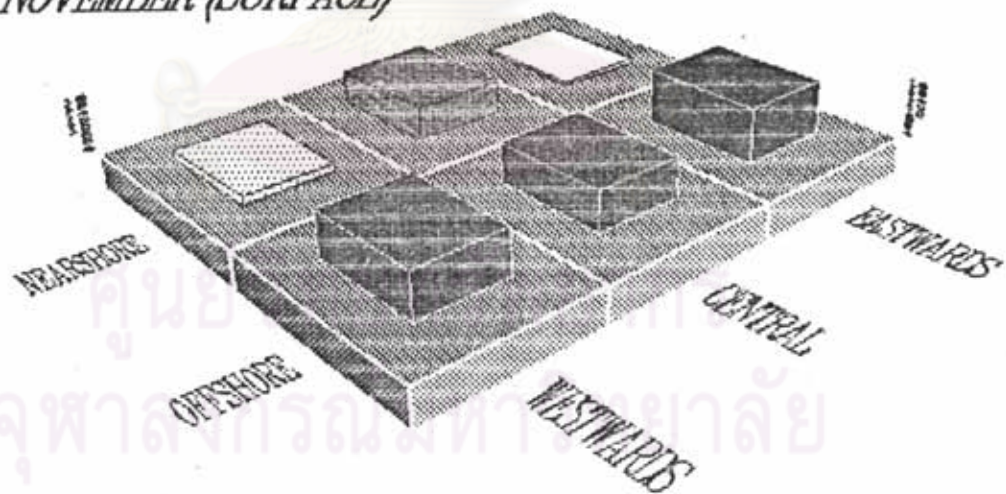


Figure 4-6 Distribution patterns of petroleum hydrocarbons at surface water in June 1989 (above) and November 1989 (below).

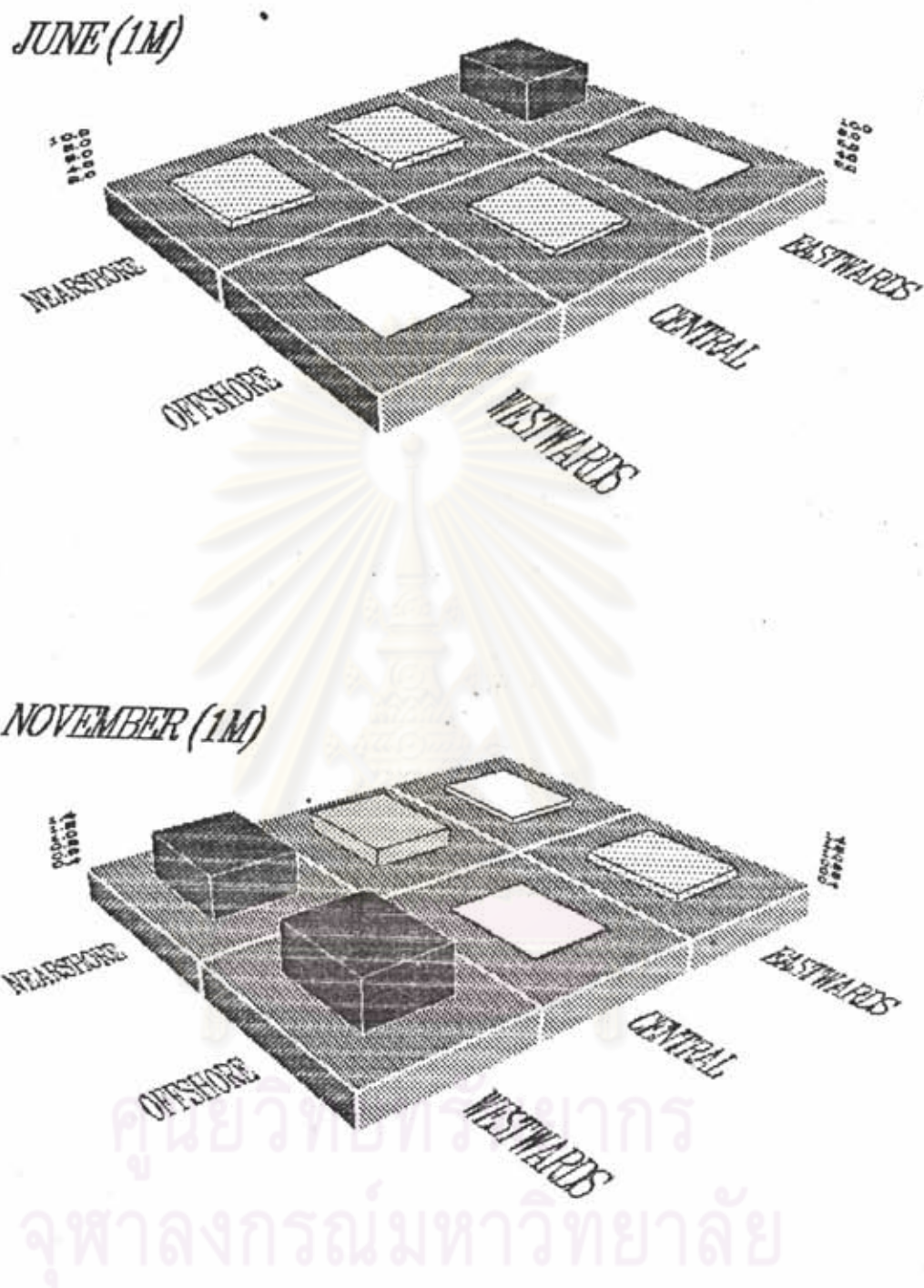


Figure 4-7 Distribution patterns of petroleum hydrocarbons in water column (1 m-depth) in June 1989 (above) and November 1989 (below).

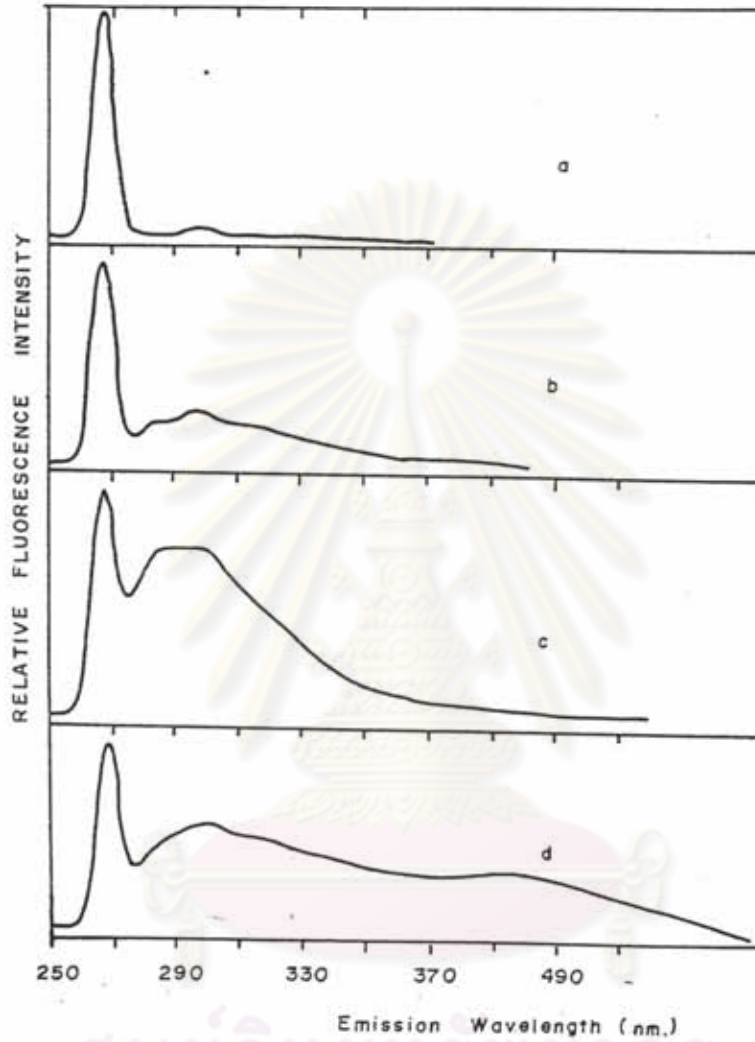


Figure 4-8 The fluorescence emission spectra of water samples.
(a) hexane solvent
(b,c,d) spectra of most samples

rings (Table 4-3, Figure 4-9). The details of these peak types are described below.

Type 1: Maximum fluorescence spectra is observed at 305-320 nm. Most seawater samples collected at the period of October 1988 and May 1990 exhibited this maximum peak. The peaks could be concluded as a representation of diesel oil, when compared to the synchronous spectra of different reference oils reported by Wattayakorn (1987), (Figure 4-10).

Type 2: The maximum emission peak occurred at 305-320 nm. and other small peak at about 380-400 nm.. This means that highly condensed aromatics from 2, 3 and 4 rings were present in the sample. Only one sample collected from station N5 at the first period exhibited this spectra.

Type 3: Peaks at 305-400 nm. and higher than 400 nm. were observed which indicate that highly condensed aromatics from 2 to 5+ rings are present in the samples. Most seawater samples collected in June and November 1989 exhibited this type of spectra.

The fluorescence spectra for most of the samples collected from the creek water exhibited this type 1 with an exception of klong C and C5 which showed type 3 spectra.

Table 4-3 Synchronous spectrum pattern of water samples collected in four study periods.

STATION	OCTOBER 1988		JUNE 1989		NOVEMBER 1989		MAY 1990	
	1m.	Surface microlayer	1m.	Surface microlayer	1m.	Surface microlayer	1m.	Surface microlayer
N	-	-	3	-	3	-	-	-
N1	1	-	3	-	3	-	1	1
N2	1	-	3	-	1	-	-	-
N3	1	-	3	-	3	-	-	-
N4	1	1	3	3	3	3	1	1
N5	2	1	3	3	3	3	1	1
N6	1	-	3	-	3	-	-	-
N7	1	-	3	-	1	-	-	-
N8	1	1	3	3	1	3	3	3
N9	1	1	3	3	1	3	3	3
N10	1	1	3	3	3	3	-	-
N11	1	1	3	3	1	3	-	-
N12	1	1	3	3	3	3	1	1
N13	1	1	3	3	3	3	-	-
N14	1	1	3	3	3	3	-	-
N15	1	1	3	3	3	3	1	1
N16	1	1	3	3	3	3	1	1
N17	1	1	3	3	3	3	1	1
N18	1	1	3	3	3	3	-	-
N19	1	1	3	3	3	3	1	1
N20	1	1	3	3	1	3	1	1
O1	1	1	3	3	1	3	1	1
O2	1	1	3	3	3	3	-	-
O3	1	1	3	3	3	3	1	1
O4	1	1	3	3	3	3	1	1
O5	1	1	3	3	3	3	-	-
O6	1	1	3	3	3	3	1	1
C	3	-	3	-	3	-	3	-
C1	1	-	1	-	1	-	1	-
C2	1	-	1	-	1	-	1	-
C3	1	-	1	-	1	-	-	-
C4	1	-	-	-	-	-	-	-
C5	1	-	-	-	3	-	3	-
C6	1	-	3	-	1	-	1	-

Type 1 : maximum fluorescence spectra at 305-320 nm.

Type 2 : maximum fluorescence spectra at 305-340 and small spectra at 380-400 nm.

Type 3 : maximum fluorescence spectra at 305-400 and higher than 400 nm.

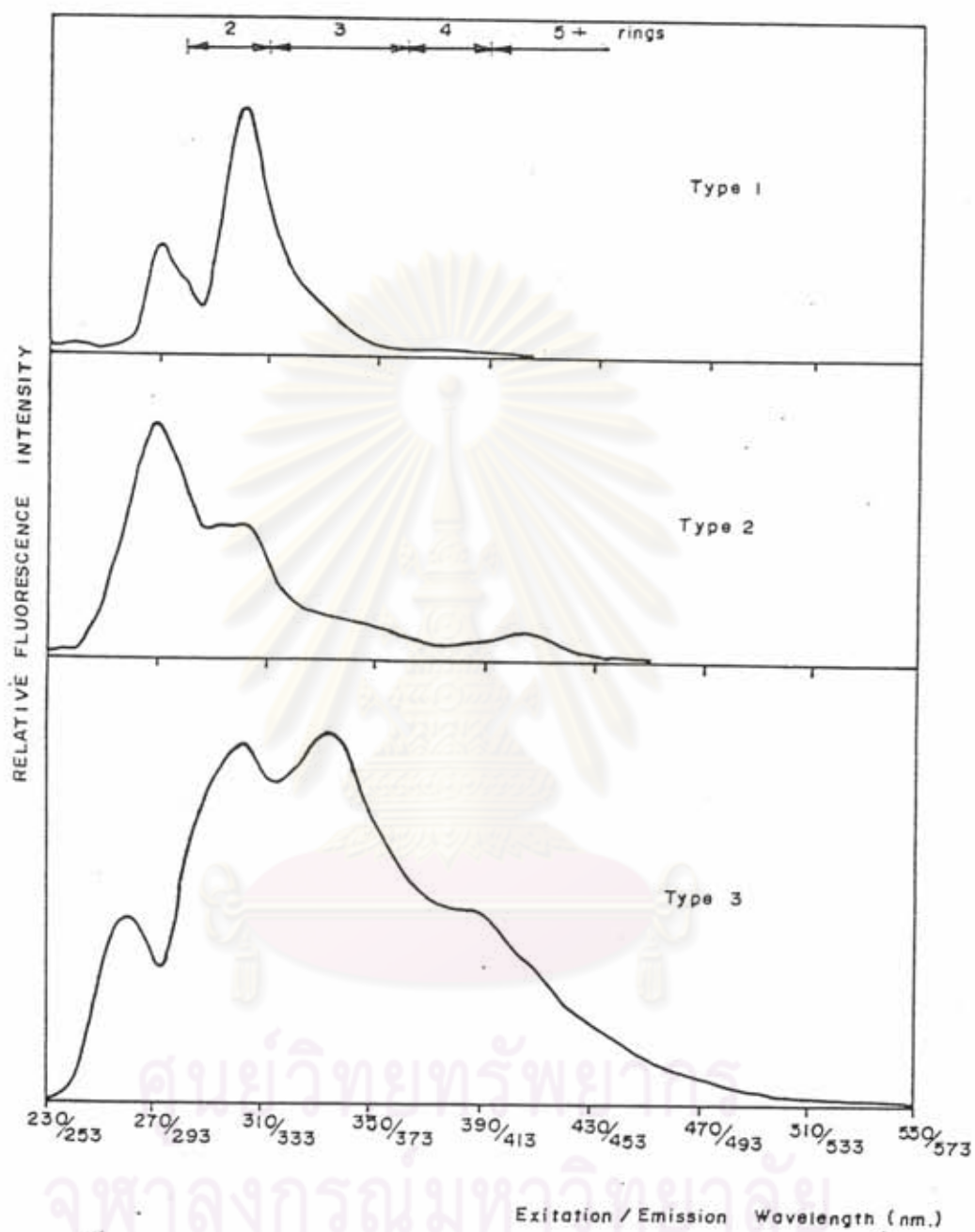


Figure 4-9 Three type of the representative fluorescence synchronous spectra.

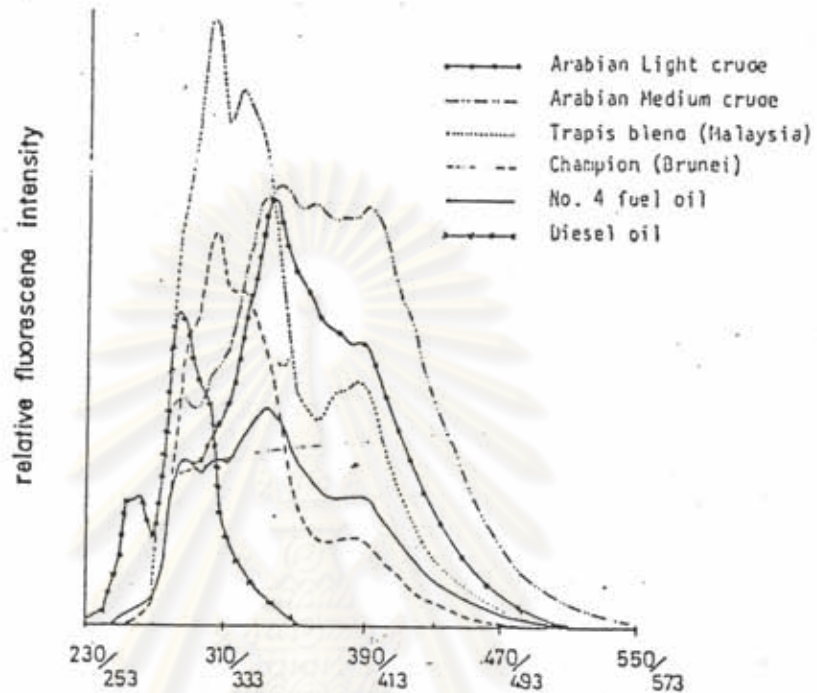


Figure 4-10 Fluorescences synchronous spectra of reference oils.

Source : Wattayakorn (1987).

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Deposition of beach tar in the area ranged from 0.62-20.83, 0.10-113.89, 0.47-209.11 and 0.85-69.11 g/m in October 1988, June and November 1989 and May 1990, respectively. Heavy tar deposition was observed at station N (Table 4-4). Concentrations of beach tar deposited at station N ranged from 69.11 g/m. in May 1990 to 209.11 g/m. in November 1989. Types of tar observed can be separated into fresh tar, sand coated tar and aged tar. Most tar at low and medium deposition accumulated in bands along the high tide mark. Large freshly and sticky tar balls at station N was found mostly in the intertidal area with small sandy coated and aged tar found at the high tide mark. Fresh tar predominated at heavy and medium deposition during June, November and May. The distribution of tar ball is shown in Figure 4-11.



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Table 4-4 Distribution of beach tar (g/m) deposited around ship-breaking factories on Map Ta Phut sea coast.

STATION	October 1988		June 1989		November 1989		May 1990	
	amount	type	amount	type	amount	type	amount	type
N1 Ban Phala	2.5	A>S	1.5	S>A	1.2	F>S	0.9	S
N2 Ban Payoon	0.6	S>A	0.1	A>S	0.8	F>S	5.4	S>F
N3 Ban Nam Tok	0.9	A>S	0.5	S>A	19.0	F>S	6.5	F>S
N Ship-breaking area	-	-	113.9	F	209.1	F	69.1	F
N6 Ban klong Pet	20.8	F>S	22.4	F>S	0.6	F>S	23.8	F
N7 Ban Aao Prdoo	0.6	A	26.1	F>S	0.5	S>A>F	1.6	A>S
N8 Ban Ta Kuan	0.7	A	24.5	F>S	0.5	S>F	1.1	S>F>A
Range	0.6-20.8		0.1-113.8		0.4-209.1		0.9-69.1	
Mean	4.4		27.0		33.1		15.47	

Note - = not measured
 F = Fresh tar is tar which is soft, sticky, almost free of sand and may be newly wash ashore.
 S = Sand coated is tar which relatively soft, coated with sand and may contain entrained sand since it has been exposed to and mixed with sand on beach for sometime.
 A = Aged tar is tar which is hard and brittle and may contain sand and shell fragments as it has been retained on the beach and exposed to air for a long period of time.

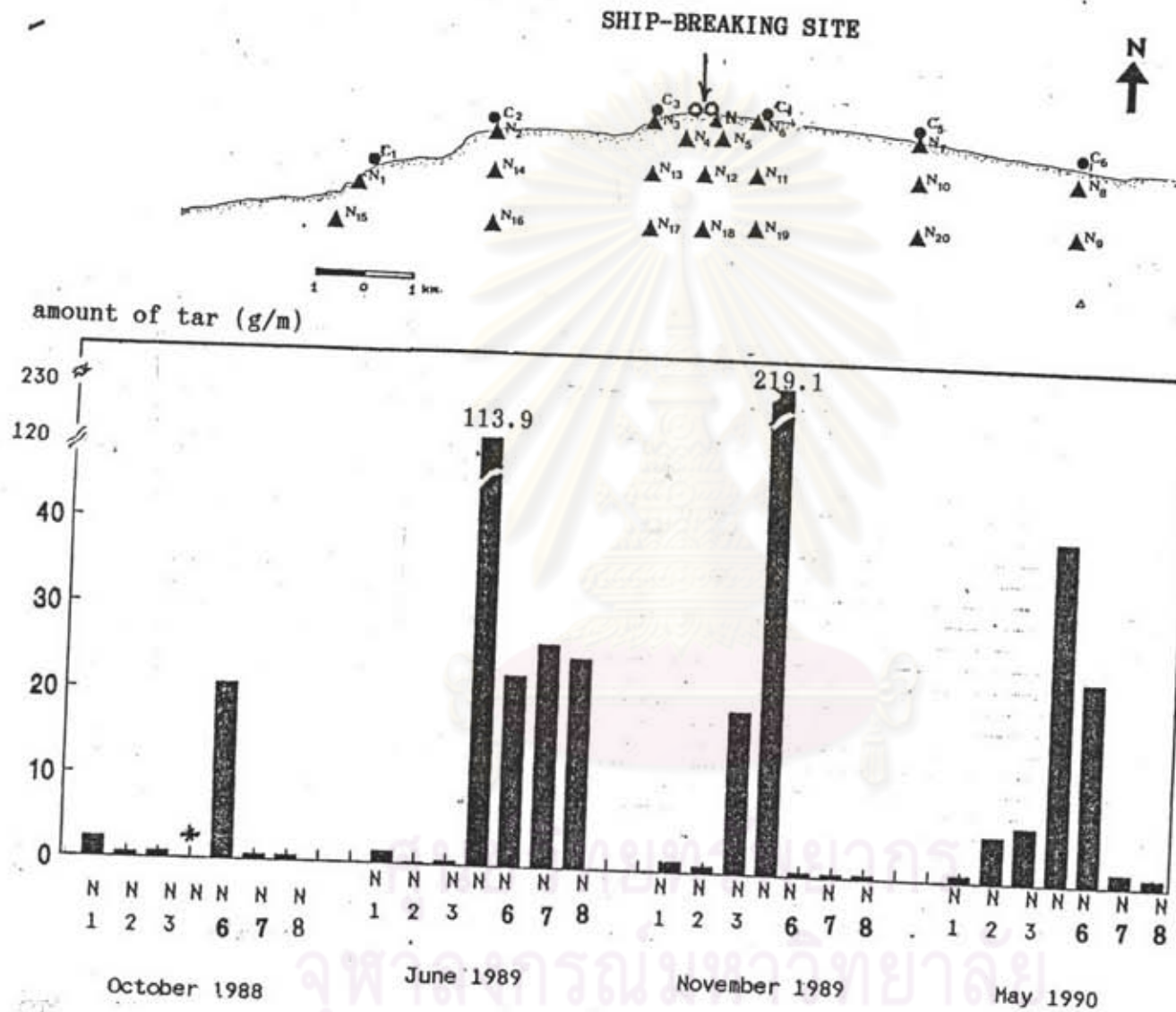


Figure 4-11 Distribution of beach tar around ship-breaking factories on the Map Ta Phut sea coast.

Note : * = not obtained

4.4 Distribution of Petroleum Hydrocarbons in sediment samples

Hydrocarbons in sediments were analyzed as base line information of the concentration level for petroleum hydrocarbons around the ship-breaking industry located in the Map Ta Phut area. Samples were collected before and during the scraping operations in October 1988 and June 1989, respectively. Samples were grouped according to nearshore (stations N to N20) and offshore (station O1 to O6) locations. Sediment from Klong C, most affected by the leaked oil from the upstream sources, was selected as a representative of a creeks sample.

4.4.1 Sediment Types and Organic Contents.

Visual observations suggest homogeneous distribution of sediment grain size for nearshore as well as offshore sediments in this area. Therefore, grain size analysis was performed on some selected sediment samples i.e. samples from Station N, N4, N16, N8 (October) and Stations N, N9, N12, N19, O2, O5 and C (June). The results are shown in Table 4-5 and 4-6. Nearshore sediments were found to be composed of more than 95 percent sand where as grain size of offshore sediments were finer particles of silt and clay as well as some shell debris.

Organic contents in sediment are shown in Table 4-7. Percentage of organic content found in October sediments ranged from 0.03 to 1.04 with an average of 0.28 in October sediments and ranged from 0.08 to 1.41 with an average of 0.41 in June sediments. Offshore sediment contained higher concentrations of organic matter than the

nearshore sediments. The average percentage of water content were observed to be 17.34 and 17.35 in October and June. The details are presented in Table 4-7. Percent water contents can be used for converting the unit of dry sediment to wet sediment in comparison to other previous reports.

Table 4-5 Grain size analysis for some selected sediment samples around the ship-breaking area at Map Ta Phut, Rayong Province (October, 1988)

Station	Grain Size Analysis		
	Sand (%)	Silt (%)	Clay (%)
N	98	0	2
N4	99	1	1
N16	99	0	1
N18	97	1	2

Table 4-6 Grain size analysis for some selected sediment samples around the ship-breaking area at Map Ta Phut, Rayong Province (June 1989).

Station	Grain Size Analysis		
	Sand (%)	Silt (%)	Clay (%)
N	98	0	2
N9	98	0	2
N12	98	1	1
N19	96	2	2
O2	83	9	8
O5	79	16	5
C	95	3	2

Table 4-7 Organic matter and water content in sediment samples collected at ship-breaking industry area at Map Ta Phut, Rayong Province, in October 1988 and June 1989.

Station	October, 1988		June, 1989	
	Organic Matter (%)	Water Content (%)	Organic Matter (%)	Water Content (%)
N	0.14	13.24	0.27	15.25
N1	0.14	17.61	0.10	17.65
N2	0.11	14.71	0.16	14.74
N3	0.17	16.23	0.13	19.16
N4	0.20	19.96	1.41	16.22
N5	0.11	17.62	1.11	14.18
N6	0.20	14.33	0.64	17.85
N7	0.22	12.17	0.67	19.92
N8	0.17	16.83	0.17	13.24
N9	0.08	14.22	0.19	16.55
N10	0.19	17.72	0.17	18.13
N11	0.14	15.14	0.22	13.76
N12	0.03	13.76	0.10	12.74
N13	0.17	17.92	0.14	15.11
N14	0.19	14.60	0.08	13.85
N15	0.08	20.08	0.08	17.66
N16	0.25	17.62	0.14	16.51
N17	0.38	15.11	0.17	12.29
N18	0.17	19.84	0.25	17.44
N19	0.22	12.26	0.22	16.58
N20	0.29	14.48	0.14	21.16
O1	0.89	22.40	0.64	21.45
O2	0.67	28.90	0.80	19.81
O3	0.40	16.40	0.67	23.26
O4	0.64	21.20	0.70	21.22
O5	1.04	20.40	1.11	26.17
O6	0.32	23.70	0.64	14.67
C	0.22	17.14	0.22	19.32
Min	0.03	12.17	0.08	12.29
Max	1.04	28.90	1.41	26.17
Mean	0.28	17.34	0.41	17.35

4.4.2 Distributions of Aliphatic Hydrocarbons (Fraction 1) in Sediments

Retention times and Kovats Indices of standard n-alkane mixture are presented in Table B-1 in Appendix B. The gas chromatograms of the mixture of standards n-alkane used in this study were presented in Figure 4-12 (a). Concentrations of n-alkane in sediments are listed in Table B-2 (October) and B-3 (June) in Appendix B. The homologous series of n-alkanes C₁₅ to C₃₀ were observed.

Total n-alkane ranged from 0.06 µg/g dry sediment to 1.79 µg/g dry sediment with an average of 0.35 µg/g dry sediment in October and ranged from 0.09 to 1.39 µg/g dry sediment with an average of 0.36 µg/g dry sediment in June. The recoveries for the aliphatic hydrocarbons were found to be 64.2-98.2 %.

Gas chromatograms of aliphatic hydrocarbons from the Map Ta Phut sediments can be divided into 3 types as follows:-

Type 1: Presence of several homologous series of odd-and even-numbered alkanes superimposed on the Unresolved Complex Mixtures (UCM). The concentrations of neighboring carbon numbers usually presents in nearly the same concentration. The odd-even predominance values unity are reflective of a petroleum source (Farrington , 1980). The representative chromatograms such as the chromatograms from station N and O revealed an obviously UCM as shown in Figures 4-12 (b and c)

An envelop of UCM of aliphatic hydrocarbon was presented above the baseline produced by blank samples in almost samples. This

is an indication of a very large number of compounds typical of petroleum (Farrington , 1980).

Type 2: Representation by n-alkanes where predominant at C_{17} , C_{19} and C_{21} in addition to the presence of the several homologous series of even-and odd-numbered alkanes superimposed on UCM. Normal alkanes in marine phytoplankton often exhibit this nature of the dominant of C_{17} , C_{19} and C_{21} . It indicates that the contamination impacts of biogenic and petroleum hydrocarbon were combined on the sediments. These sediments were collected in nearshore areas in two study periods. The representative chromatograms of this type depicted from station N8, N15, N18, are shown in Figures 4-12 d,e,f,g,h and i.


Type 3: Demonstration of the clear peaks dominance at retention times of C_{17} , C_{19} and C_{21} superimposed on the clearly present of UCM. The absence of normal alkane eluding after C_{21} was found. This indicated the degraded characteristic of oil and biogenic source. Most samples collected from offshore stations (01,02,03,04,05 and 06) in 2 study periods exhibited this type of chromatograms. The representative gas chromatograms shown in this type depicted from station 05 are shown in Figures 4-12 j.

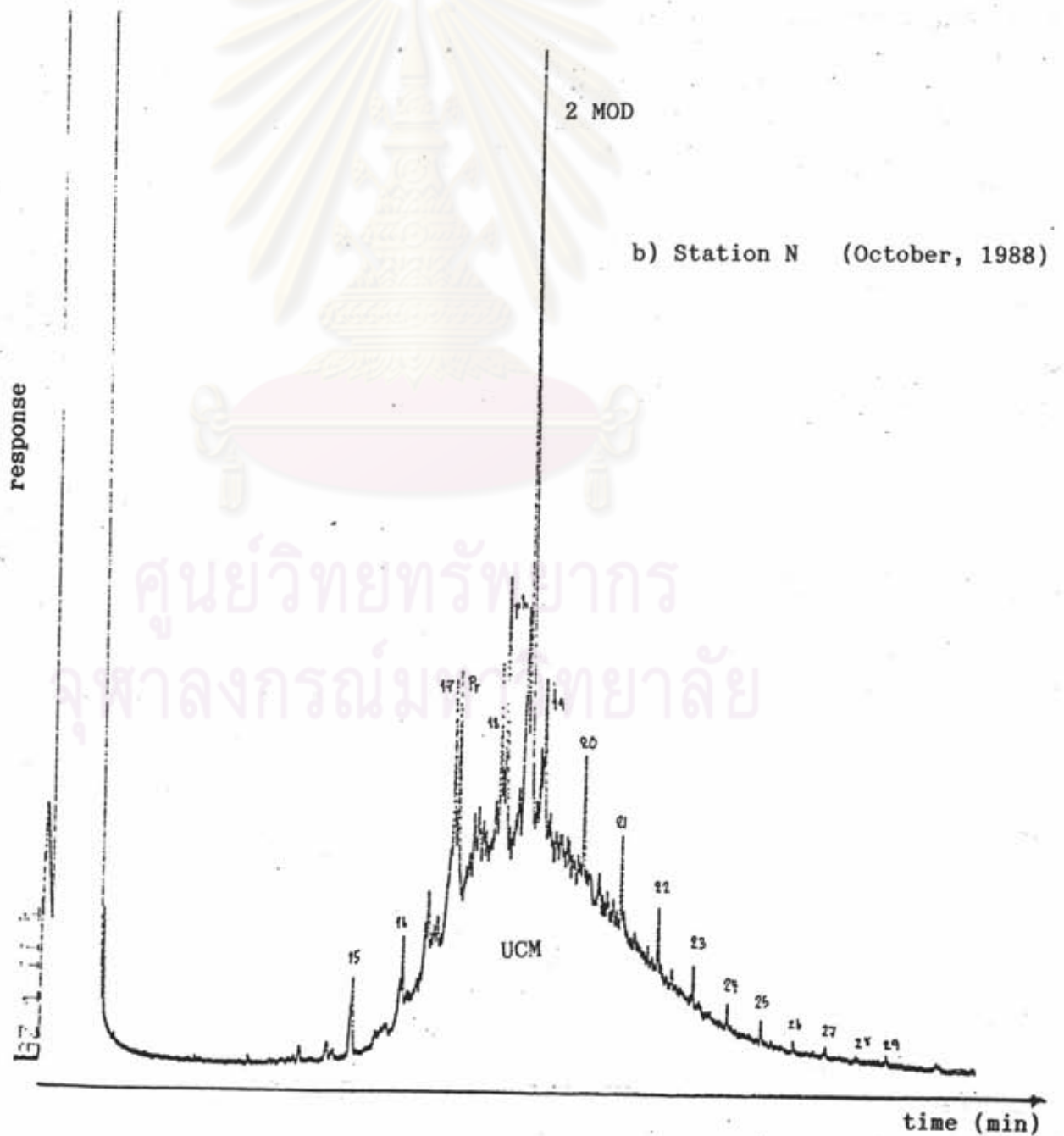
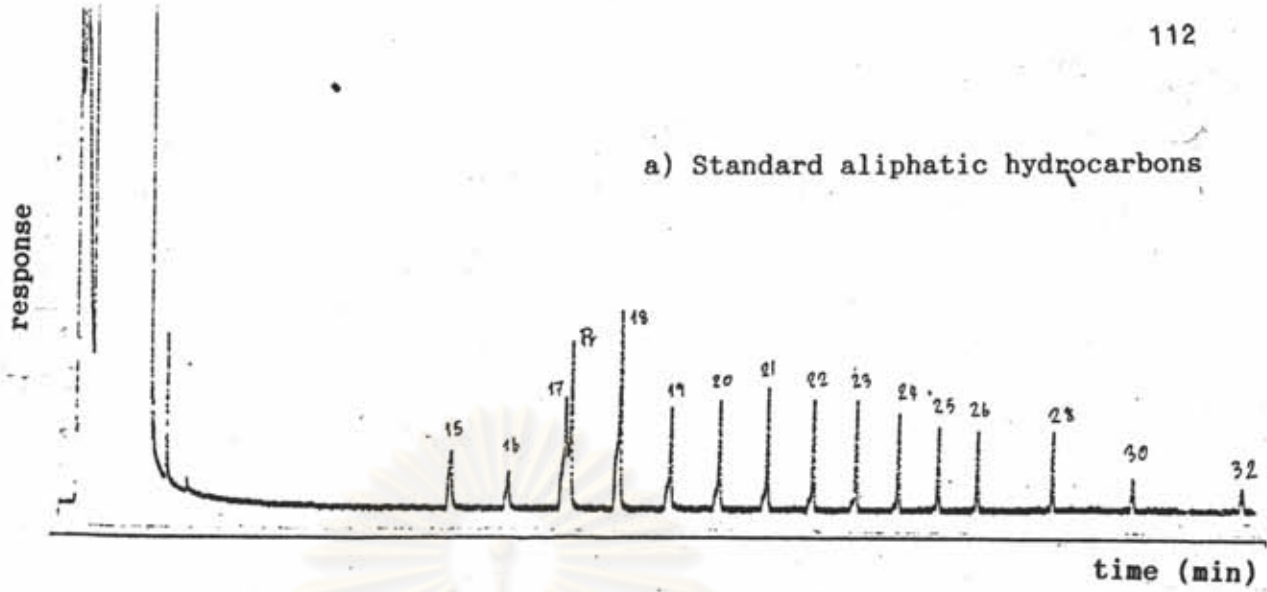
Carbon Preference Index (CPI) means the ratios between total weight of odd-carbon homologous and the weight of the even-carbon homologous (Yen, 1975 and Sleeter et.al., 1980). The CPI from 56 sediments studied in this 2 periods ranged from 1.1-9.6 in October and 1.0-4.0 in June.

The isoprenoid pristane and phytane were found in most gas chromatograms. Pristane was eluded after n-alkane C17 and phytane after C18. The ratio of C17/pristane ranged from 0.5-28.1 and 0.4-11.9 in October and June, respectively. The ratio of C18/phytane ranged from 0.5-6.8 and 0.9-7.0 while pristane/phytane ranged from 0.5-16.1 and 0.2-23.8 in October and June, respectively (Tables 4-8 and 4-9).

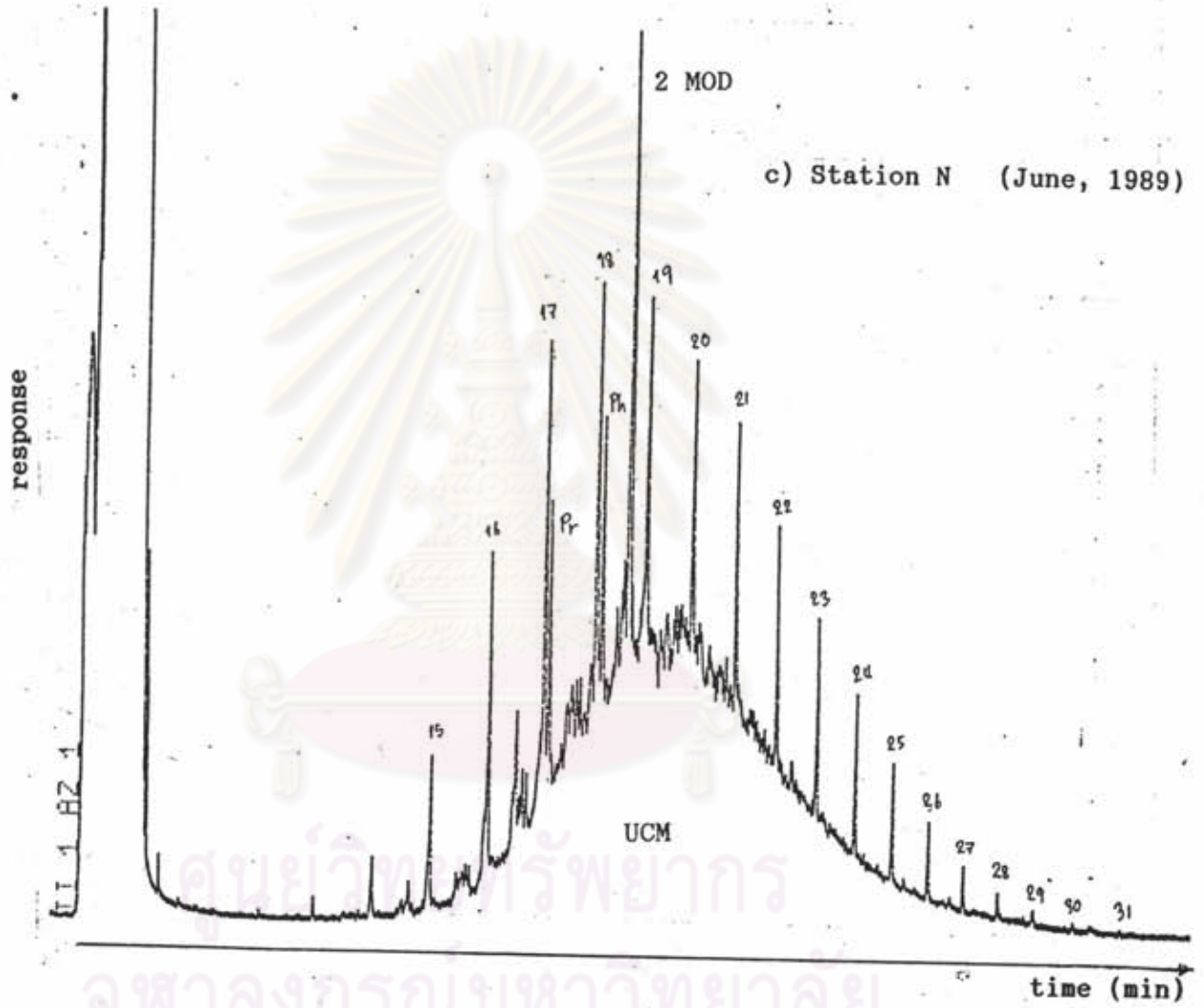
Distribution of total n-alkane were shown in Tables 4-8, 4-9 and Figure 4-13. Quantitative amount of aliphatic UCM found in October and June sediments were also presented in Tables 4-8, 4-9 and Figure 4-14. Total aliphatic hydrocarbons (UCM + total n-alkane) were presented in Figure 4-15.

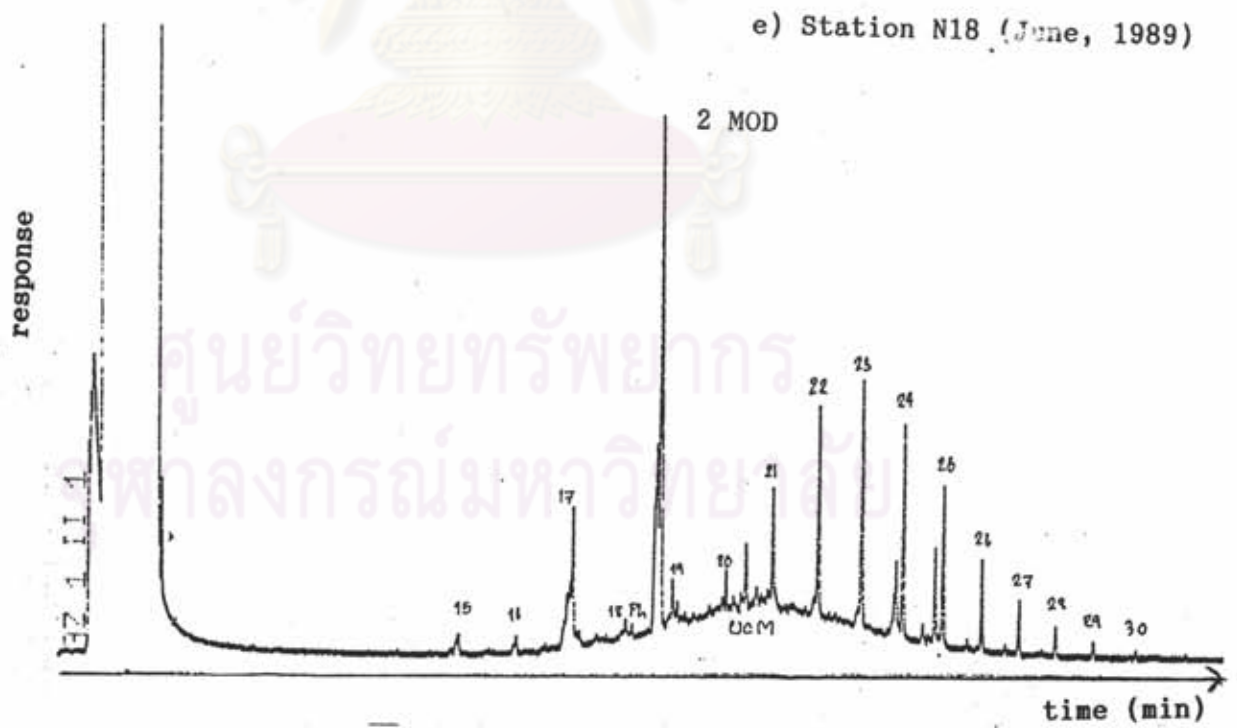
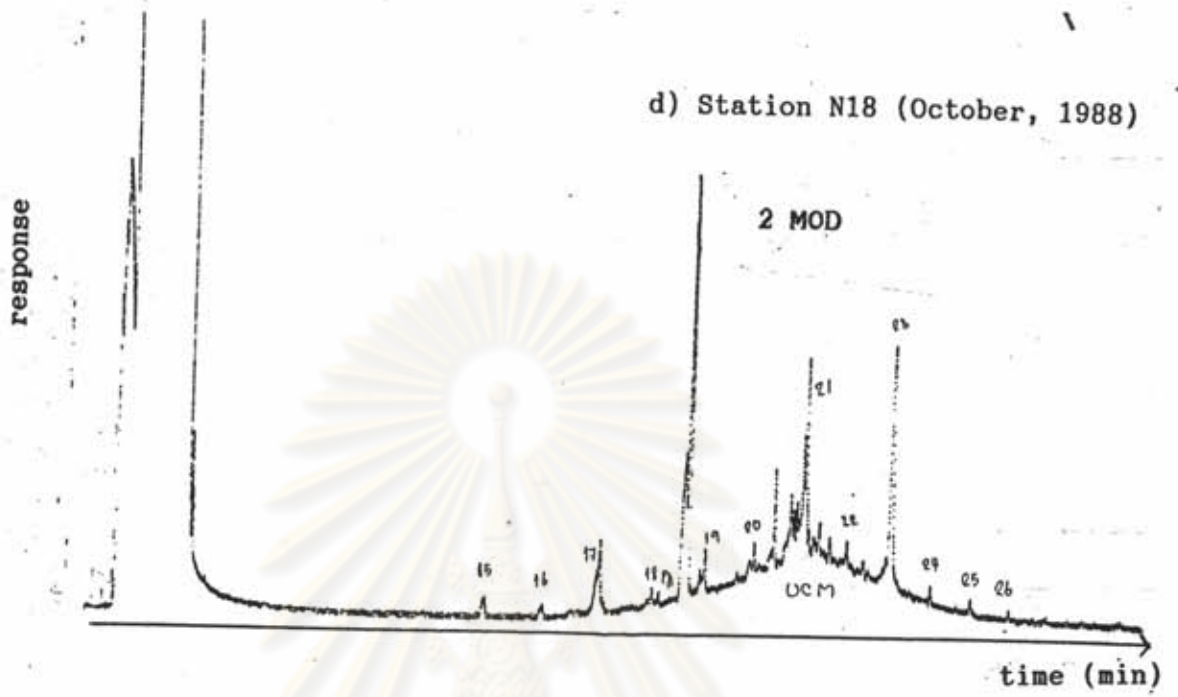
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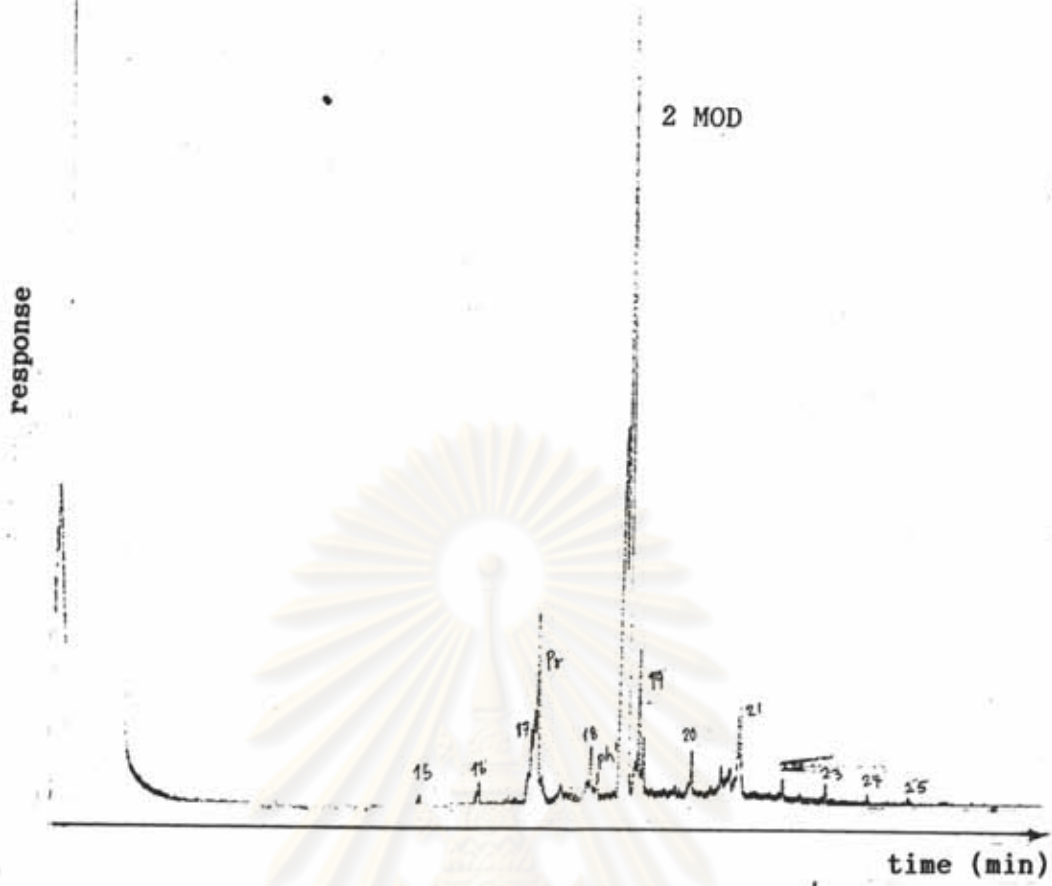
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- Figure 4-12 Gas chromatograms of aliphatic hydrocarbons in the sediments from the Map Ta Phut area. N-alkanes are numbered according to number of carbons in compound
- 2-MOD : 2-methyl octadecane (internal standard)
UCM : Unresolved Complex Mixture
Pr : Pristane
Phy : Phytane
- a) Standard aliphatic hydrocarbons
 - b) Station N (October, 1988)
 - c) Station N (June, 1989)
 - d) Station N18 (October, 1988)
 - e) Station N18 (June, 1989)
 - f) Station N8 (October, 1988)
 - g) Station N8 (June, 1989)
 - h) Station N15 (October, 1988)
 - i) Station N15 (June, 1989)
 - j) Station 09 (October, 1988)



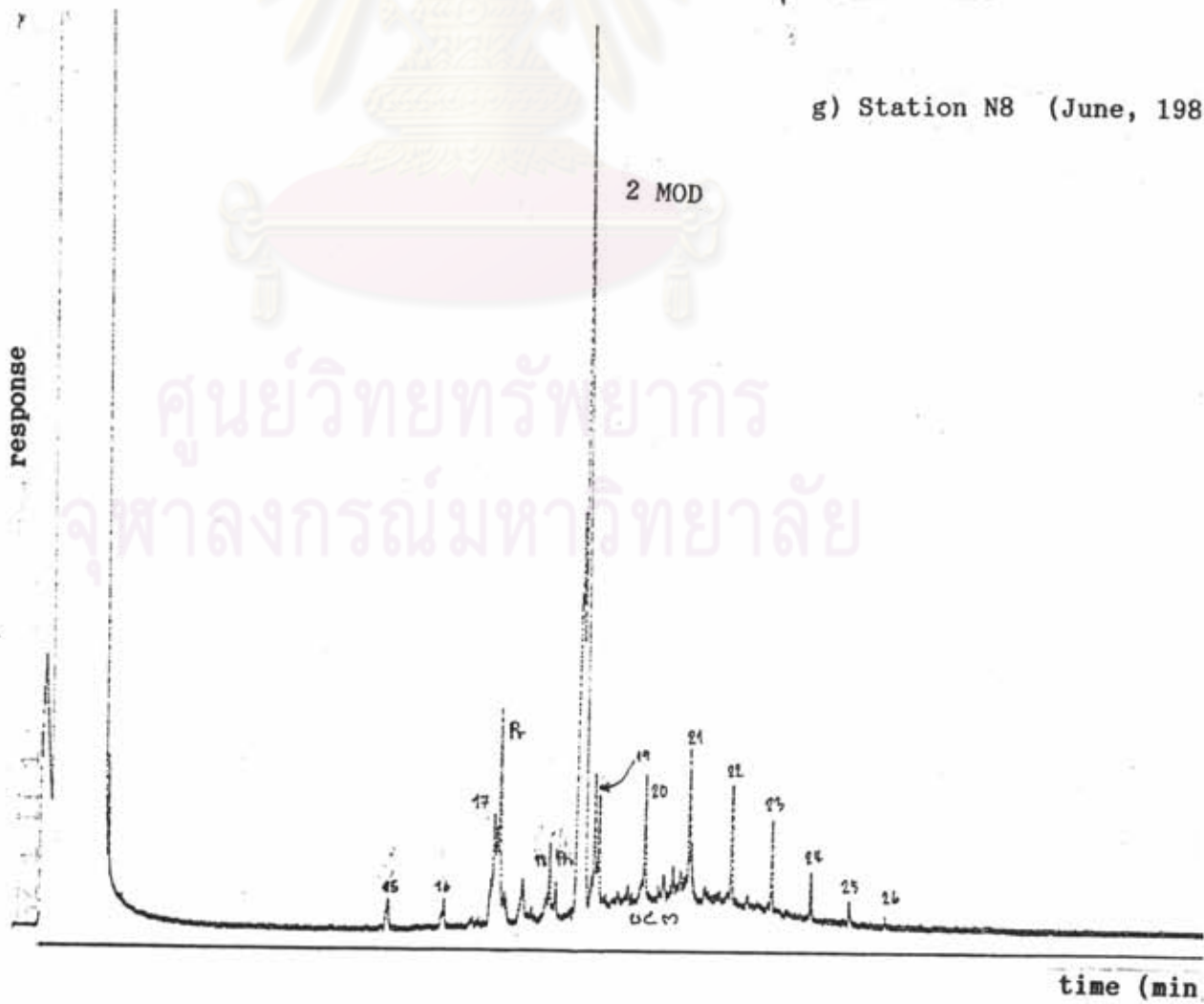
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g) Station N8 (June, 1988)

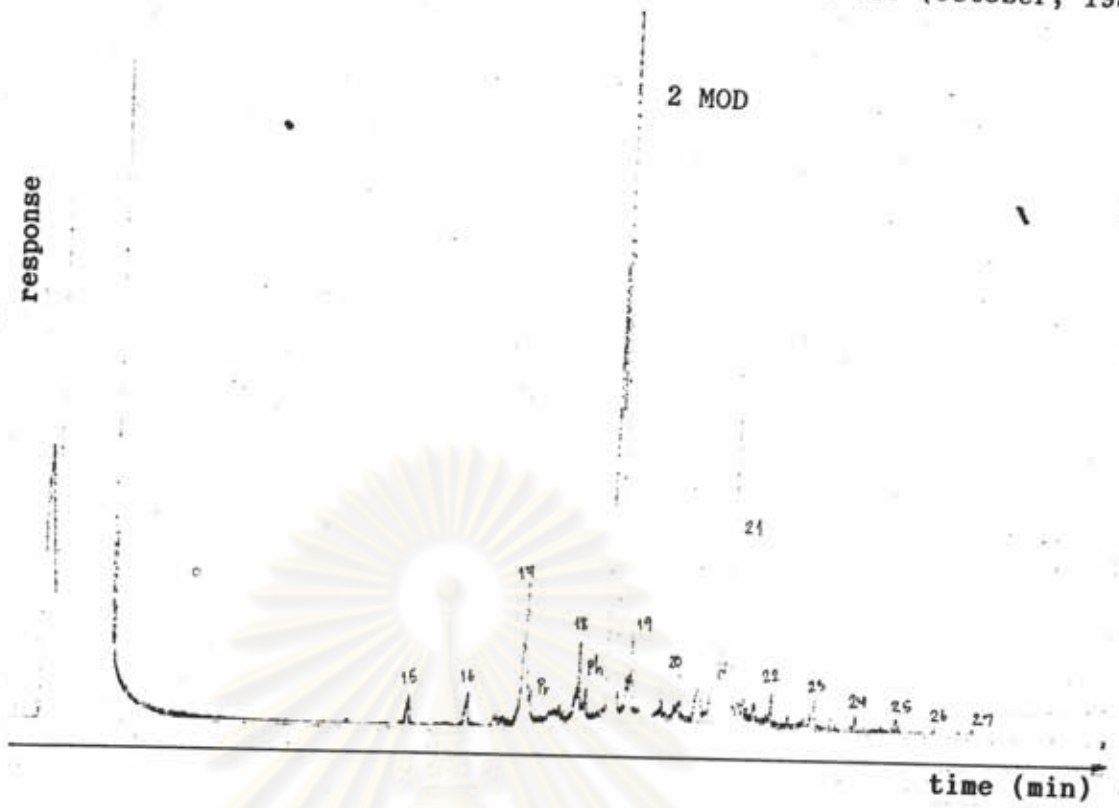


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h) Station N15 (October, 1988)

response

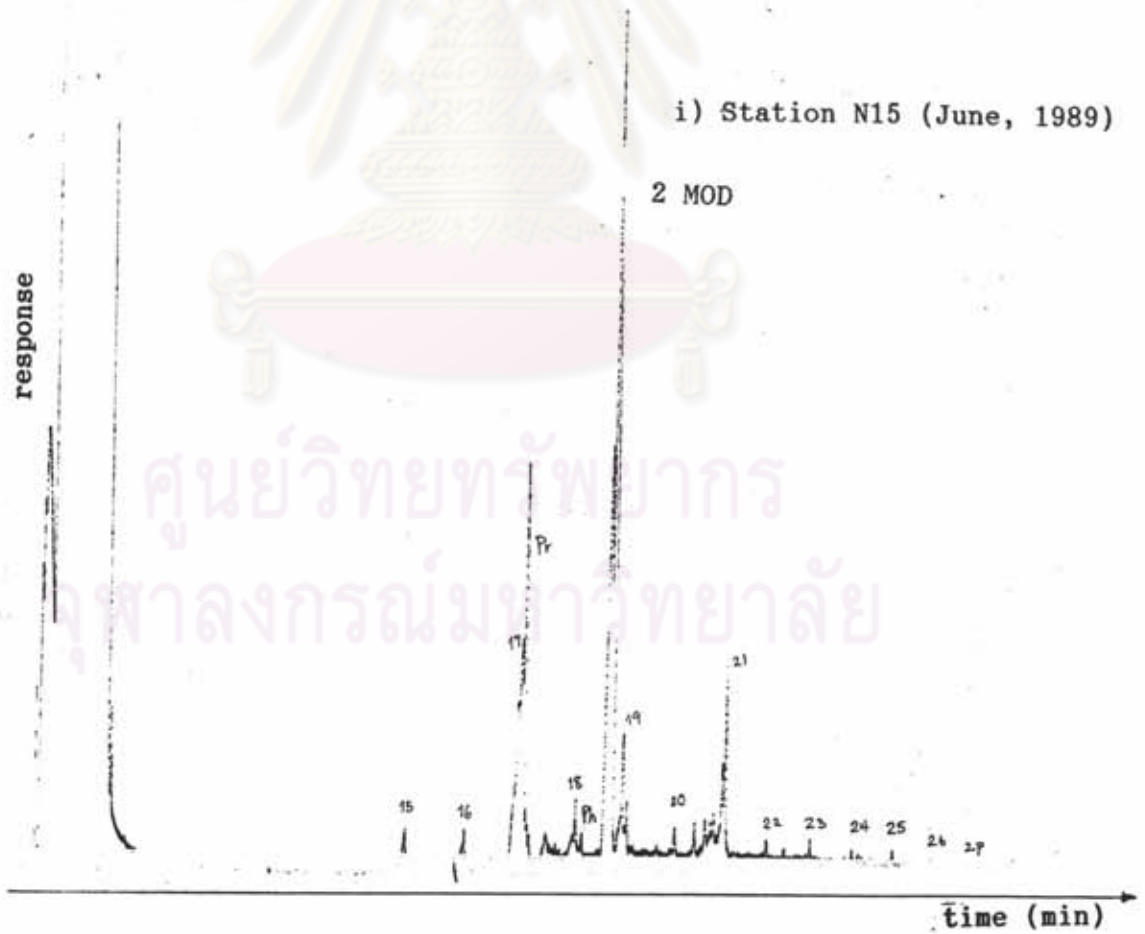
2 MOD



i) Station N15 (June, 1989)

response

2 MOD



j) Station 05 (October, 1988)

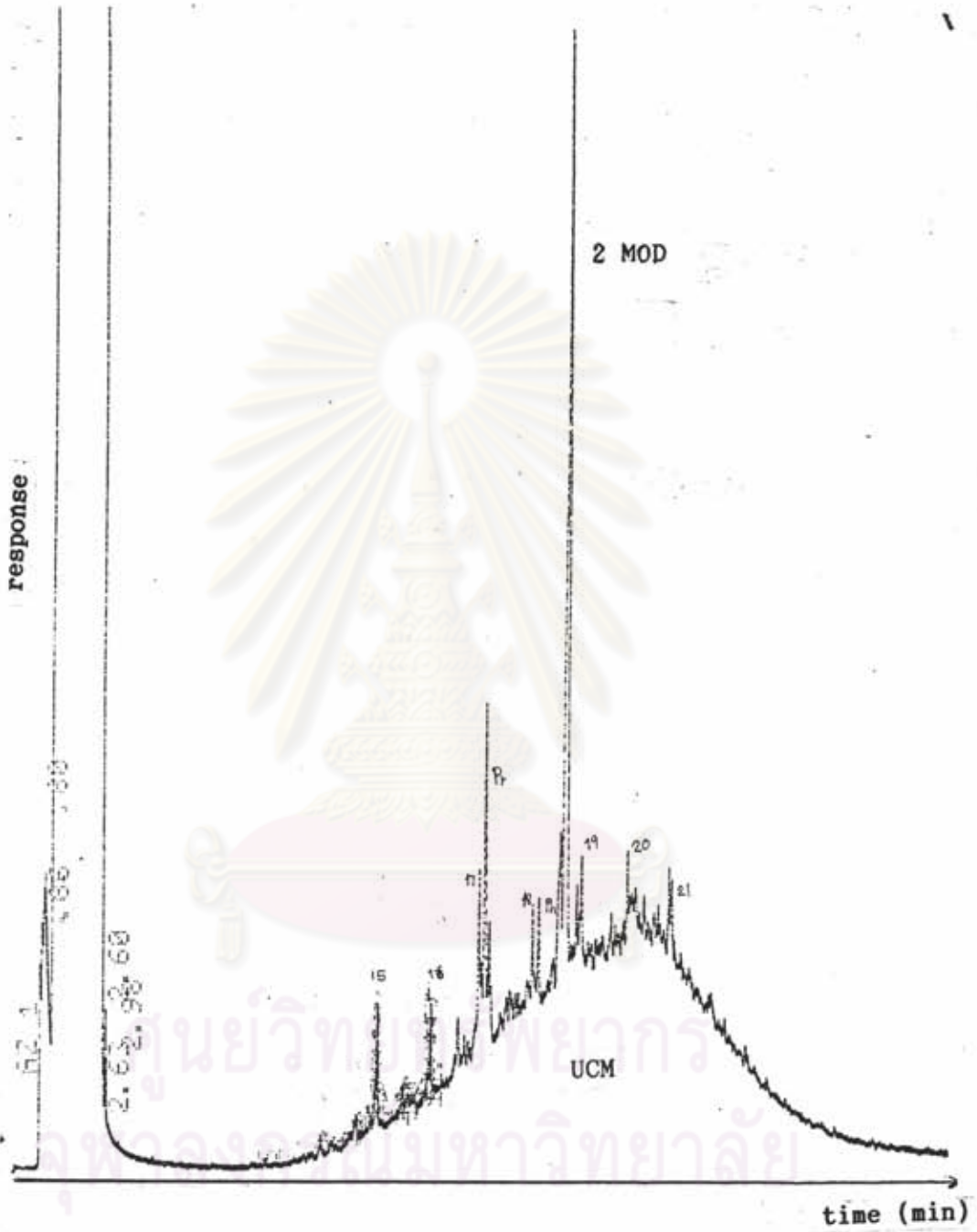


Table 4-8 Aliphatic Hydrocarbons in the Map Ta Phut sediments collected in October, 1988.

St.	Total ali.	Total n-alkane	UCM	CPI total	c17/ pris	c18/ phy	pris/ phy
n	10.0	0.4	9.6	1.9	1.8	1.0	1.4
n1	4.0	0.2	3.8	1.4	1.0	1.2	2.4
n2	3.4	0.3	3.1	3.9	2.5	3.8	8.1
n3	2.2	0.3	1.9	2.2	3.1	2.9	5.5
n4	3.2	0.3	2.9	2.1	2.3	4.6	7.4
n5	4.1	0.3	3.8	2.7	4.0	3.1	3.8
n6	2.2	0.1	2.1	3.4	0.5	0.5	2.9
n7	1.3	0.2	1.1	1.8	28.1	2.3	0.5
n8	0.9	0.5	0.4	1.7	5.1	2.3	0.7
n9	1.1	0.3	0.8	1.8	1.9	3.2	7.8
Nearshore n10	1.6	0.3	1.3	1.8	1.2	1.8	6.4
n11	2.0	0.2	1.8	3.2	3.1	2.1	6.5
n12	4.8	0.2	4.6	2.2	3.1	6.8	8.6
n13	2.3	0.2	2.1	1.4	0.9	1.2	2.8
n14	2.3	0.4	1.9	3.0	1.5	2.8	7.0
n15	0.6	0.2	0.4	1.9	0.9	3.1	7.7
n16	0.7	0.2	0.5	1.2	1.1	3.6	5.2
n17	2.0	0.2	1.8	1.2	1.9	1.5	2.6
n18	3.0	0.1	2.9	9.6	2.5	2.4	9.8
n19	1.9	0.2	1.7	1.9	0.7	1.6	8.4
n20	2.9	0.2	2.7	1.7	1.3	1.1	16.1
o1	16.0	0.8	15.3	1.6	1.6	1.1	2.4
o2	10.0	1.8	8.2	1.1	2.2	3.9	1.5
Offshore o3	11.7	0.5	11.2	1.4	1.3	1.1	1.7
o4	10.2	0.5	9.7	1.7	1.5	1.2	1.2
o5	13.7	0.5	13.2	1.3	1.3	1.0	0.9
o6	8.9	0.5	8.4	2.0	1.2	1.2	1.1
Klong c	8.8	0.2	8.6	1.4	1.4	1.4	1.2
Min	0.6	0.1	0.4	1.1	0.5	0.5	0.5
Max	16.0	1.8	15.3	9.6	28.1	6.8	16.1
Avg	4.8	0.4	4.5	2.4	2.8	2.3	4.7

Table 4-9 Aliphatic Hydrocarbons in the Map Ta Phut sediments collected in June, 1989. (ug/g dry sediment).

St.	Total ali.	Total n-alkane	UCM	CPI total	c17/ pris	c18/ phy	pris/ phy
n	12.8	1.4	11.4	1.0	1.0	1.8	1.1
n1	3.9	0.3	3.6	1.7	1.2	1.8	5.2
n2	4.3	0.5	3.8	1.8	1.3	1.6	5.8
n3	4.0	0.2	3.8	4.0	1.4	1.5	4.5
n4	4.5	0.1	4.4	2.4	2.0	3.8	4.0
n5	3.8	0.2	3.6	2.4	1.2	1.4	7.6
n6	3.4	0.3	3.1	2.3	2.0	4.3	8.9
n7	2.3	0.2	2.1	1.6	2.0	2.6	15.9
n8	9.5	0.1	9.4	2.0	1.1	1.5	8.5
n9	2.5	0.6	1.9	1.0	1.5	1.0	4.2
Nearshore n10	2.1	0.5	1.6	1.4	1.7	1.2	3.9
n11	4.0	0.2	3.8	2.3	1.4	1.7	4.5
n12	2.7	0.1	2.6	1.4	1.7	1.8	4.3
n13	3.5	0.3	3.2	1.8	3.1	2.9	5.5
n14	2.2	0.3	1.9	2.2	1.5	0.9	1.4
n15	1.8	0.3	1.5	1.2	0.4	2.4	3.4
n16	1.5	0.2	1.3	1.0	0.6	7.0	4.9
n17	3.3	0.2	3.1	1.6	1.5	1.2	3.5
n18	3.3	0.2	3.1	1.6	1.1	2.8	23.8
n19	2.7	0.3	2.4	1.0	0.8	1.2	4.3
n20	3.5	0.4	3.1	1.7	1.2	0.9	4.5
o1	12.2	0.8	11.4	1.4	1.6	1.3	2.2
o2	14.5	0.7	13.8	1.4	0.9	1.1	1.2
Offshore o3	15.2	0.5	14.7	1.4	0.8	1.0	1.3
o4	10.3	0.7	9.6	1.4	2.0	1.0	1.0
o5	9.2	0.9	8.3	2.2	1.3	2.5	4.0
o6	11.7	0.6	11.1	1.5	1.4	1.2	0.9
Klong c	12.4	0.5	11.9	1.3	11.9	1.3	0.2
Min	1.5	0.1	1.3	1.0	0.4	0.9	0.2
Max	15.2	1.4	14.7	4.0	11.9	7.0	23.8
Avg	6.0	0.4	5.6	1.8	1.8	1.9	5.0

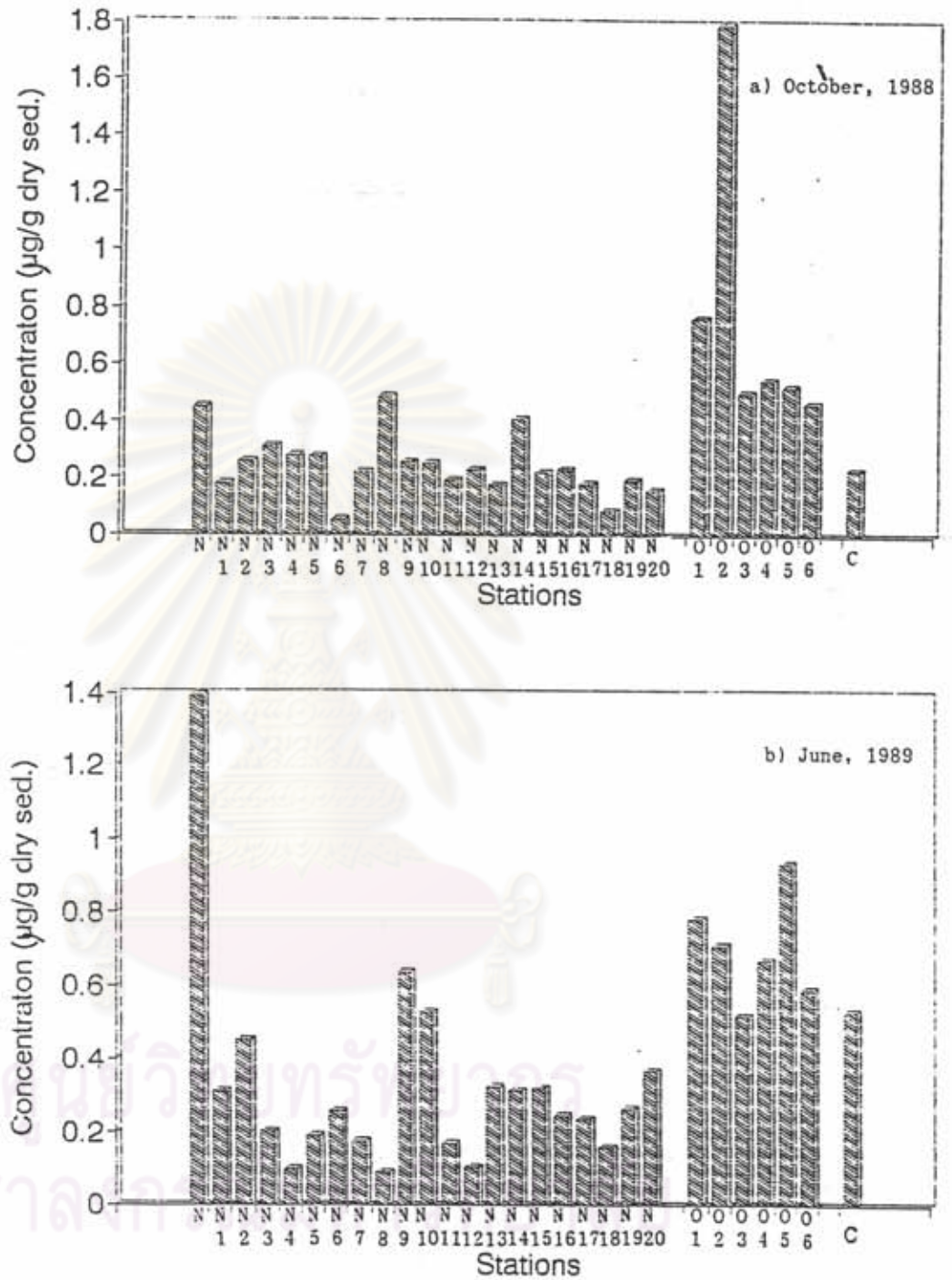


Figure 4-13 Distribution of total n-alkane in the Map Ta Phut sediments.
 (a) October, 1988
 (b) June, 1989

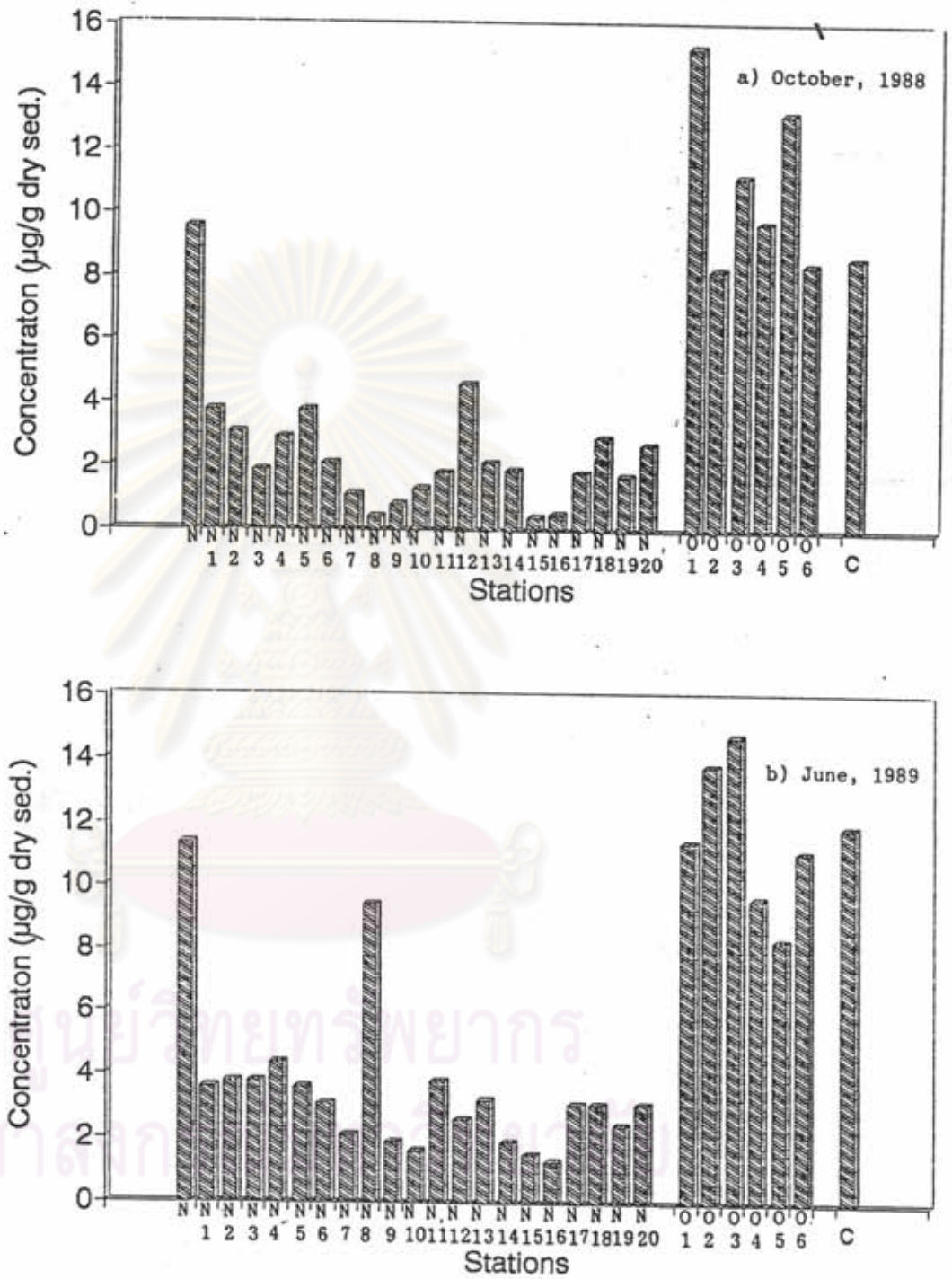


Figure 4-14 Distribution of aliphatic UCM in the Map Ta Phut sediments.
 (a) October, 1988
 (b) June, 1989

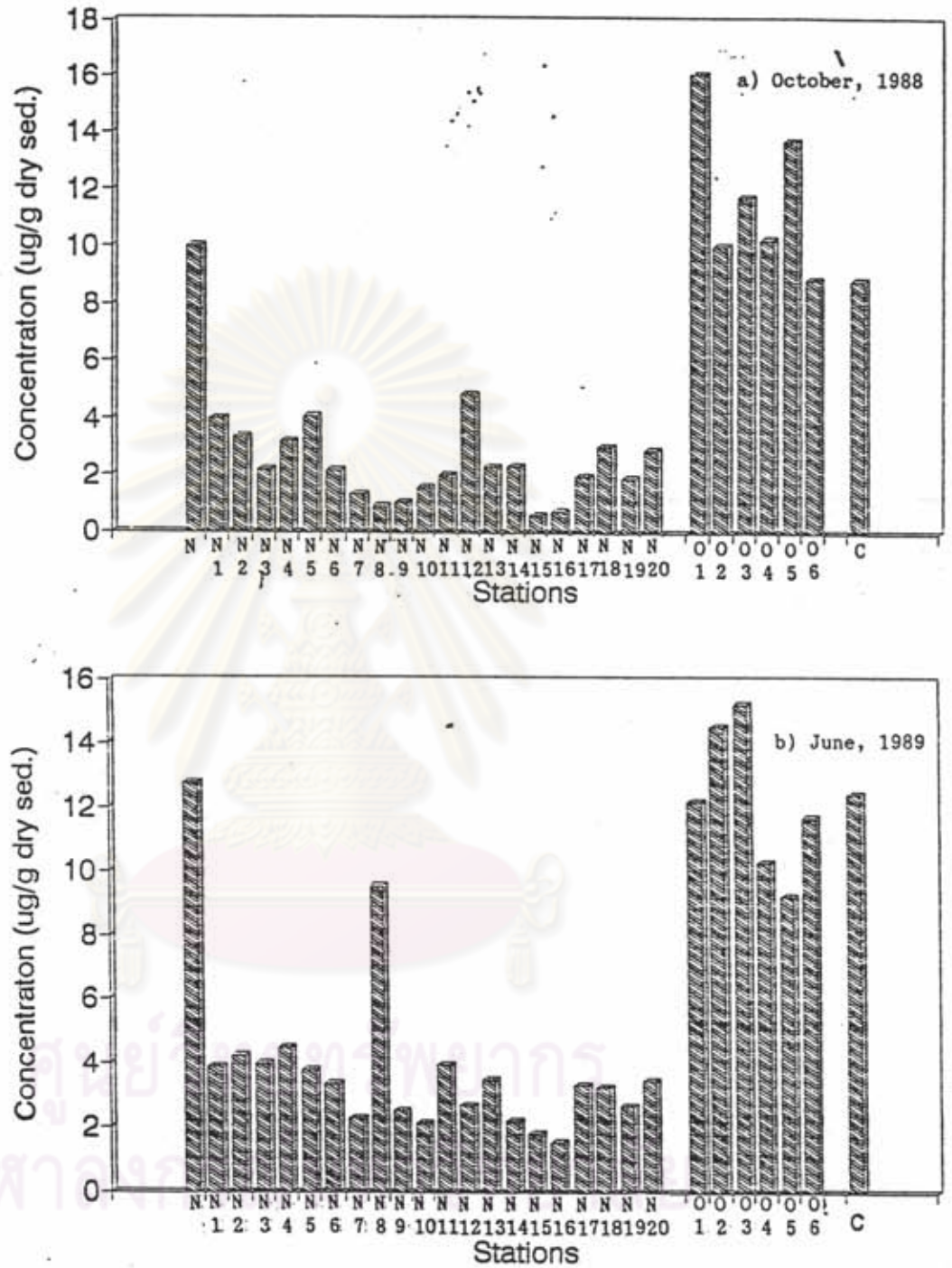


Figure 4-15 Distribution of total aliphatic hydrocarbons in the Map Ta Phut sediments
 (a) October, 1988
 (b) June, 1989

4.4.3 Distributions of Aromatic Hydrocarbons (Fraction 2) in Sediments

Aromatic hydrocarbons in the sediment samples were studied both by UVF and GC techniques. The results are as follows:

4.4.3.1 Aromatic Hydrocarbons by UVF Technique

Total aromatic hydrocarbons extracted from the Map Ta Phut sediments as quantified by UVF technique range from 0.06-0.87 ug/g dry weight in October and 0.27-1.86 ug/g dry weight in June. The detailed concentrations presented in Table 4-10.

The distribution of petroleum hydrocarbons in the two study periods are shown in Figure 4-16.

The synchronous spectra of sediment samples can be divided into 2 types according to the maximum emission peaks as follows:-

Type 1: Maximum emission peak occurred at 310-320 nm. The samples from nearshore stations exhibited this type.

Type 2. Broad peak at 310-400 nm. were observed which indicated that higher condensed aromatics from 2 to 5+ rings are presented in the samples. Samples from offshore area, stations N, C and some nearshore sediments(N1 and N3 (in October,1988) N1, N9, N20 (in June,1989)).

Synchronous spectral depicted from stations N8 (June) and N (October) were representative for type 1 and 2 spectra, respectively (Figure 4-17).

Table 4-10 Concentrations of aromatic hydrocarbons from the Map Ta Phut sediments around the ship-breaking area before and during operations in October 1988 and June 1989, respectively, determined by UVF method ($\mu\text{g/g}$ dry wt).

Site of collection	October 1988	June 1989
N	1.04	1.86
N1	0.39	1.43
N2	0.26	0.86
N3	0.35	0.65
N4	0.13	0.51
N5	0.09	0.44
N6	0.09	0.58
N7	0.08	0.27
N8	0.06	0.34
N9	0.06	0.77
N10	0.18	0.43
N11	0.1	0.48
N12	0.25	0.64
N13	0.18	0.38
N14	0.24	0.53
N15	0.11	0.49
N16	0.08	0.48
N17	0.27	0.86
N18	0.11	0.31
N19	0.22	0.73
N20	0.2	0.9
O1	0.64	0.64
O2	0.71	0.72
O3	0.87	0.87
O4	0.62	0.76
O5	0.69	0.77
O6	0.56	0.69
C	0.77	0.95
Min	0.06	0.27
Max	0.87	1.86
Mean	0.33	0.69

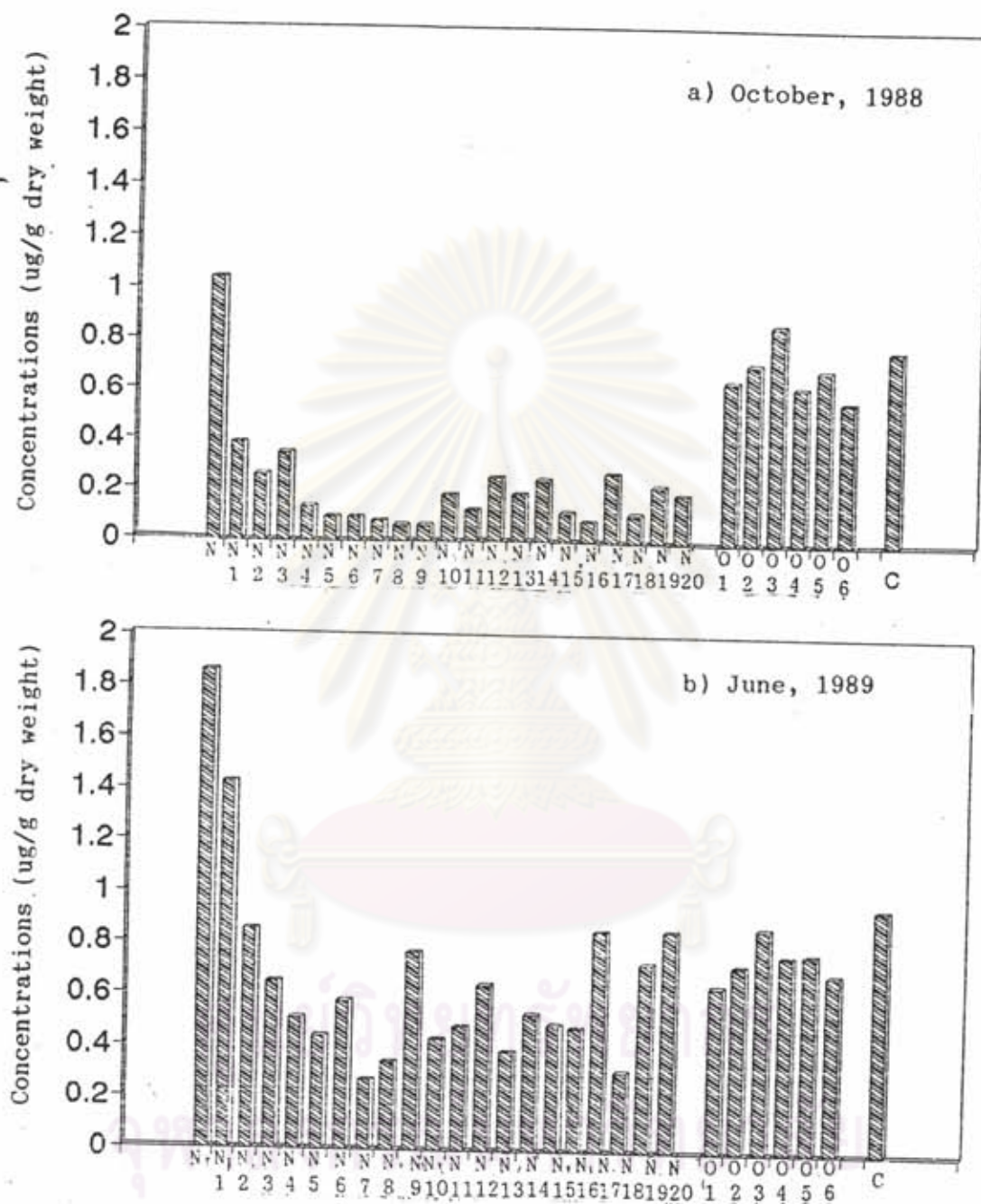


Figure 4-16 Distribution of total aromatic hydrocarbons in the Map Ta Phut sediments (UVF technique).
 (a) October, 1988
 (b) June, 1989

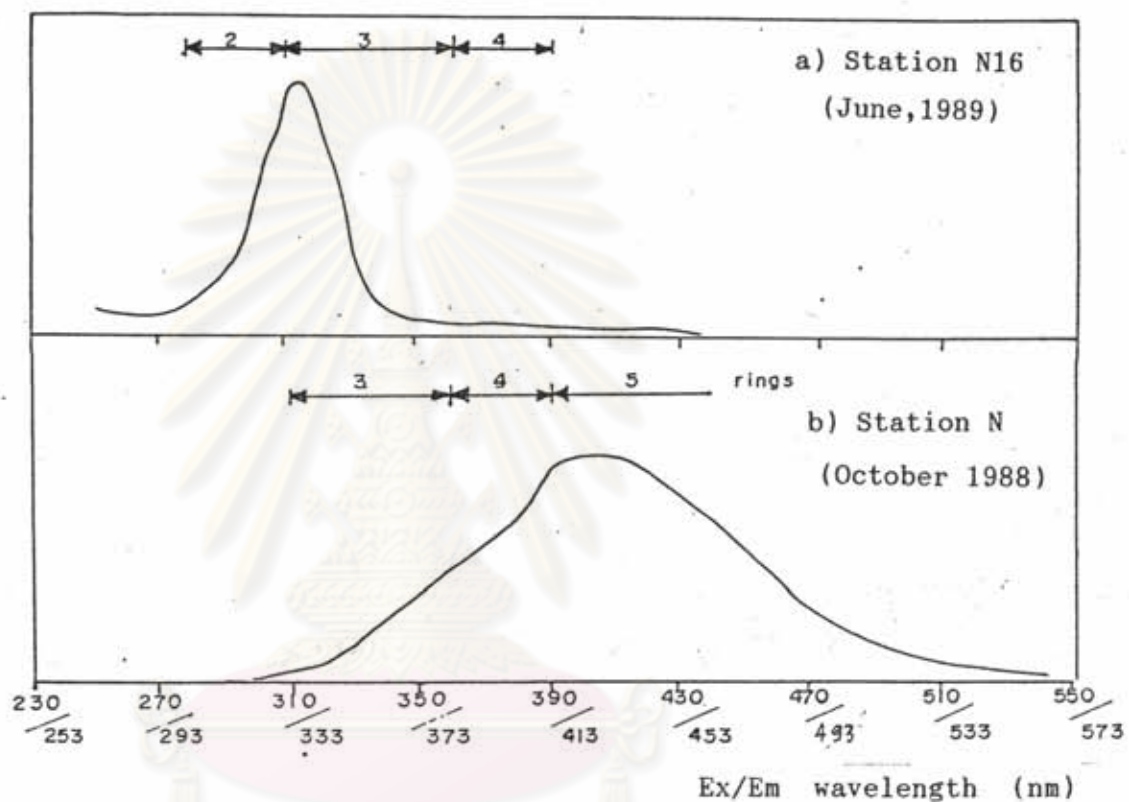


Figure 4-17 Synchronous fluorescence spectra from the Map Ta Phut sediment. iments.

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4.4.3.2 Aromatic Hydrocarbons by GC Technique

Retention times and Aromatic Retention Indices of standard aromatic mixture are presented in Table B-4 in Appendix B. Concentrations of identified aromatic hydrocarbons in each compounds were shown in Table 4-11 and 4-12. Concentrations range from 0.6 ng/g to 40.0 ng/g dry weight in October sediments and from 3.6 to 112.3 ng/g dry weight in June. The identified aromatic hydrocarbons found in sediments collected in October, 1988 were Binaphthyl, 2,6-Dimethylnaphthalene, Acenaphthylene, Acenaphthene, 9-Fluorenone, Dibenzothiophene, Phenanthrene, Anthracene, 1-Methylphenanthrene, Fluoranthene, Pyrene, 11H-benzo(b)fluorene, 1,1-Binaphthyl(spike), Benzo(a)anthracene, Chrysene, Benzo(e)pyrene and Perylene. The identified aromatic hydrocarbons found in sediments collected in June, 1989 were Naphthalene, 1-Methylnaphthalene, 2,6-Dimethylnaphthalene, Acenaphthylene, Acenaphthene, Dibenzofluran, Fluorene, 1-Methylfluorene, 9-Fluorenone, Dibenzothiophene, Phenanthrene, Anthracene, 1-Methylphenanthrene, Fluoranthene, Pyrene, 11H-benzo(b)fluorene, Benzo(a)anthracene and Chrysene. The recoveries for aromatic hydrocarbon analysis are found to be 61.1-88.5%. Concentrations of each individual compound are shown in Table 4-11 and 4-12. Total aromatic hydrocarbons range from 5.7 - 2486.5 ng/g and 13.7-3777.1 ng/g in October and June, respectively. Offshore sediments seems to contain higher aromatic hydrocarbon concentrations than nearshore sediments. The total aromatic hydrocarbon concentrations found by GC method are lower than those examined by the UVF procedure.

Gas chromatogram of standard aromatic hydrocarbon mixture used in this study is presented in Figure 4-18. The representative gas chromatograms depicted from station N6 and O6 (June) are shown in Figure 4-19.



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Table 4-11 Identified aromatic hydrocarbons from the Map Ta Phut sediments in October, 1989 (ng/g dry sediment).

Compounds	Nearshore																	Offshore						Klongs					
	ln	ln1	ln2	ln3	ln4	ln5	ln6	ln7	ln8	ln9	ln10	ln11	ln12	ln13	ln14	ln15	ln16	ln17	ln18	ln19	ln20	101	102	103	104	105	106	lc	
3 Binaphthyl	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4 2,6-Dimethylnaphthalene	-	-	-	-	-	-	-	-	-	-	0.6	-	-	1.2	-	-	-	-	-	3.4	7.1	-	6.3	5.3	-	-	-	-	-
5 Acenaphthylene	-	-	-	-	-	-	-	-	-	-	3.2	-	2.7	4.3	2.8	-	3.1	-	-	2.8	-	-	2.0	-	-	-	6.7	-	-
6 Acenaphthene	4.4	-	-	-	7.9	25.3	-	-	-	-	-	-	-	-	-	-	-	6.7	-	-	-	-	-	-	4.8	-	-	-	-
10 9-Fluorenone	-	-	-	-	6.1	-	-	-	-	-	-	11.3	-	-	-	-	-	-	-	-	-	12.3	-	-	-	-	-	5.9	-
11 Dibenzothiophene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.9	-	-	-	13.3	-	20.7
12 Phenanthrene	-	5.8	-	4.3	-	40.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5	-	-	6.2	-	9.8	-	-
13 Anthracene	-	4.2	-	-	-	-	-	5.6	6.0	9.2	-	8.5	-	21.2	-	8.1	-	7.2	16.4	-	2.9	-	-	-	-	-	-	-	-
14 1-Methylphenanthrene	-	-	-	-	7.8	-	-	-	-	-	1.9	-	-	-	1.3	-	2.5	-	-	-	-	3.9	-	2.2	5.8	-	-	-	21.3
15 Fluoranthene	19.5	-	3.2	3.1	8.6	37.2	3.6	-	-	-	-	1.2	-	-	-	-	-	-	-	-	-	18.6	-	-	-	-	-	-	26.2
16 Pyrene	-	-	-	2.6	-	-	-	-	-	-	-	-	-	3.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17 1H-benzo(b)fluorene	-	-	-	-	-	-	-	-	-	-	-	-	-	8.8	-	-	-	-	7.6	-	-	-	-	-	-	-	-	-	-
18 1,1-Binaphthyl(spike)	12.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19 Benzo(a)anthracene	-	-	-	4.2	-	-	-	-	-	-	-	10.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.5
20 Chrysene	-	6.1	-	4.0	-	-	-	-	-	-	-	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	24.6	-	-	-
22 Benzo(e)pyrene	-	-	-	-	-	-	-	2.4	2.9	-	-	-	-	-	-	2.2	-	-	-	-	-	-	-	-	-	-	-	-	-
24 Perylene	-	-	-	-	-	-	2.1	-	-	2.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Iden. Aro. (ng/g)	36.3	16.1	3.2	18.3	30.4	102.5	5.7	8.0	8.9	11.4	5.7	33.1	2.7	40.6	4.1	10.3	5.6	13.9	24.0	6.2	13.9	37.4	15.4	11.1	35.6	20.0	15.7	84.6	
UCN (ng/g)	2450.2	324.0	104.1	813.9	342.1	216.9	tr	tr	tr	tr	186.5	tr	tr	150.0	327.6	tr	tr	156.2	tr	262.9	102.4	1431.0	1265.3	1761.7	1861.0	1468.2	1302.6	760.0	
Total Aro (ug/g)	2486.5	340.1	107.3	832.2	372.5	319.4	5.7	8.0	8.9	11.4	192.2	33.1	2.7	190.6	331.7	10.3	5.6	170.1	24.0	269.1	116.3	1468.4	1280.7	1772.8	1896.6	1488.2	1318.3	844.6	

Table 4-12 Identified aromatic hydrocarbons from the Map Ta Phut sediments in June, 1989 (ng/g dry sediment).

Compounds	Nearshore														Offshore						Klongs								
	2n	2n1	2n2	2n3	2n4	2n5	2n6	2n7	2n8	2n9	2n10	2n11	2n12	2n13	2n14	2n15	2n16	2n17	2n18	2n19	2n20	201	202	203	204	205	206	2c	
1 Naphthalene	26.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 1-Methylnaphthalene	-	-	-	3.7	8.8	-	-	-	-	-	5.6	-	13.6	-	3.8	-	-	11.2	-	-	-	3.8	-	-	-	-	-	-	-
3 2,6-Dimethylnaphthalene	22.5	-	-	-	-	-	-	-	11.6	-	-	4.9	-	21.2	-	9.2	-	-	-	-	12.7	-	-	-	-	12.1	-	-	
4 Acenaphthylene	19.6	28.9	-	16.7	17.6	-	-	-	-	21.1	27.2	-	19.5	-	4.5	-	6.6	21.4	-	-	24.1	-	1.4	-	-	4.2	-	-	
6 Acenaphthene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.6	-	-	4.9	-	-	5.2	-	-	7.9	27.5	-	-	
7 Dibenzofluran	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.30	-	-	-	6.8	4.8	-	-	-	-	
8 Fluorene	68.1	13.7	-	-	-	17.6	36.7	-	-	-	-	-	-	-	-	-	-	14.6	-	21.0	-	6.7	16.3	9.1	-	-	58.7	-	
9 1-Methylfluorene	-	-	-	-	-	-	-	-	-	-	-	14.7	-	3.6	11.6	-	-	-	-	4.8	-	-	14.5	-	26.9	6.1	86.6	-	
10 9-Fluorenone	-	-	-	-	-	-	21.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	59.7	-	-	-	-	-	
11 Dibenzothiophene	-	-	-	-	-	17.4	-	-	-	-	-	-	-	-	-	-	-	3.6	14.70	-	23.4	-	-	-	-	3.8	-	-	
12 Phenanthrene	-	-	5.6	-	-	-	-	4.3	-	-	-	12.8	24.1	-	16.6	32.4	8.4	15.2	-	-	2.5	-	-	-	-	9.2	-	21.4	
13 Anthracene	11.6	16.1	8.1	-	-	-	-	6.5	-	-	-	-	-	-	98.6	-	-	-	-	-	-	-	26.7	-	-	-	112.3	-	
14 1-Methylphenanthrene	4.4	-	-	-	22.8	-	-	-	35.6	-	4.5	-	45.6	-	-	-	-	-	-	-	-	-	7.4	48.1	18.1	-	38.6	25.6	
15 Fluoranthene	45.9	-	-	5.6	27.9	-	-	-	-	17.2	6.1	-	78.6	-	-	-	-	-	-	-	-	-	-	37.5	-	-	-	-	
16 Pyrene	57.7	-	-	-	-	16.2	-	-	-	8.4	-	7.6	3.4	-	-	-	-	-	-	12.1	14.3	-	6.9	-	58.8	8.4	-	-	
17 1H-benzo(b)fluorene	-	-	-	-	-	-	-	-	-	8.7	-	-	15.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
19 Benzo(a)anthracene	-	-	-	-	-	-	-	-	6.7	34.6	-	-	5.9	-	-	-	-	-	-	21.1	-	-	-	38.4	-	-	-	12.6	
20 Chrysene	-	-	-	-	21.6	-	-	-	6.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total Iden. Aro. (ng/g)	256.5	58.7	13.7	26.0	98.7	51.2	57.9	10.8	60.1	90.0	43.4	20.4	101.3	124.2	49.7	142.6	28.8	66.0	39.1	66.1	25.9	54.2	70.1	259.8	58.2	43.3	323.7	59.6	
UCM (ng/g)	3520.6	2796.5	tr	1863.7	1378.1	573.2	1506.8	210.3	127.8	2178.6	tr	1325.1	168.5	375.6	216.4	788.5	165.3	121.8	tr	121.1	1965.2	1324.1	1879.2	2592.3	2149.5	tr	1917.3	2579.3	
Total Aro (ng/g)	3777.1	2855.2	13.7	1889.7	1476.8	624.4	1564.7	221.1	187.9	2268.6	43.4	1345.5	269.8	499.8	266.1	931.1	194.1	187.8	39.1	187.2	1991.1	1378.3	1949.3	2852.1	2207.7	43.3	2241.0	2638.9	

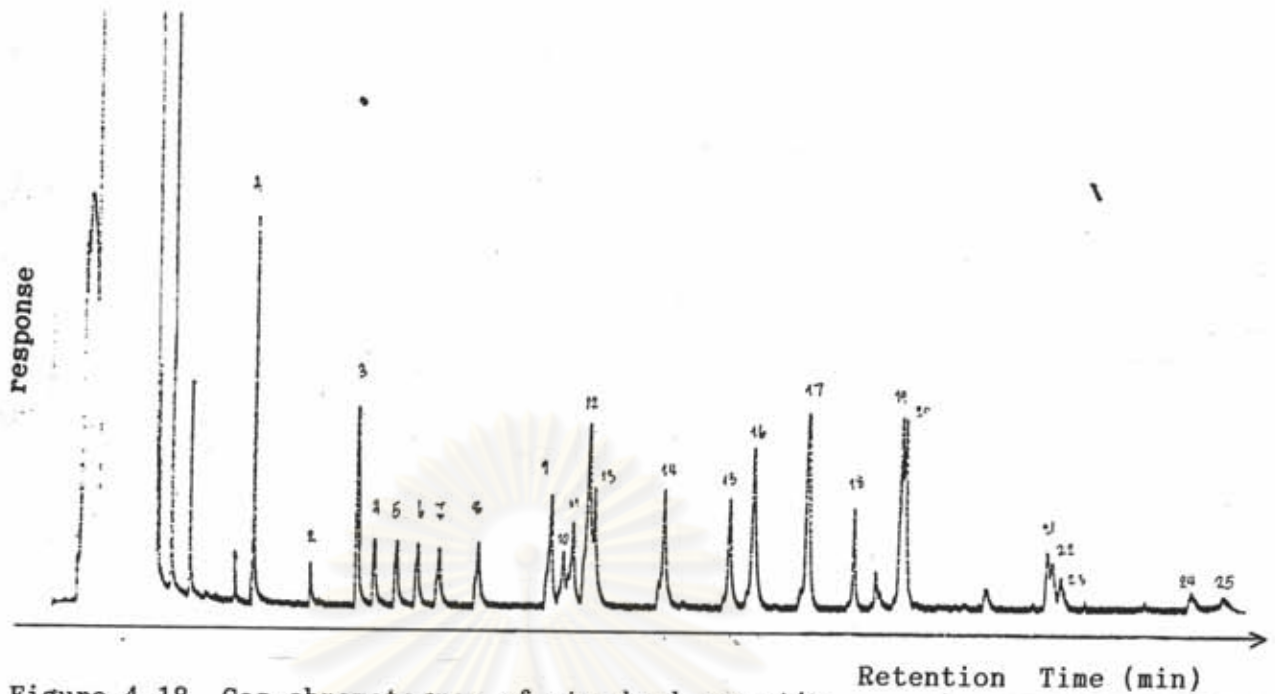


Figure 4-18 Gas chromatogram of standard aromatic hydrocarbon mixture :

- 1=Naphthalene
- 2=1-Methylnaphthalene
- 3=Binaphthyl
- 4=2,6-Dimethylnaphthalene
- 5=Acenaphthylene
- 6=Acenaphthene
- 7=Dibenzofluran
- 8=Fluorene
- 9=1-Methylfluorene
- 10=9-Fluorenone
- 11=Dibenzothiophene
- 12=Phenanthrene
- 13=Anthracene
- 14=1-Methylphenanthrene
- 15=Fluoranthene
- 16=Pyrene
- 17=11H-benzo(b)fluorene
- 18=1,1-Binaphthyl(spike)
- 19=Benzo(a)anthracene
- 20=Chrysene
- 21=Benzo(e)pyrene
- 22=Benzo(a)pyrene
- 23=Perylene
- 24=Dibenz(a,h)anthracene
- 25=benzo(ghi)perylene

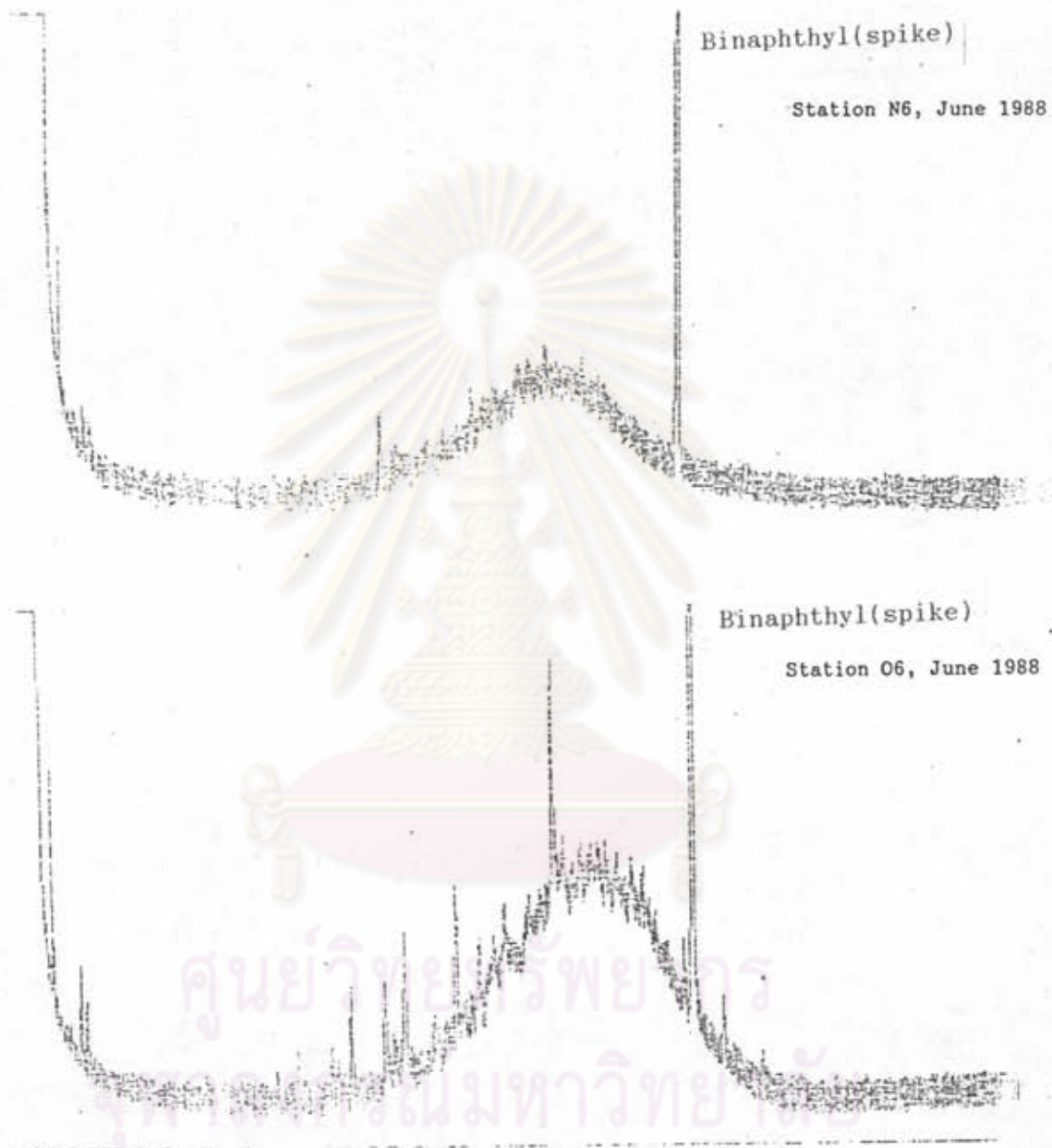


Figure 4-19 Representative gas chromatograms depicted from stations N6 and O6 in June, 1989.

4.4.4 Gas Chromatography/Mass Spectrometry (GC/MS) Analysis

The results of GC/MS analysis of selected sediment samples are shown in Appendix C. Mass spectra of some representative n-alkanes are shown in Figure C-1 and those of the PHA are shown in Figure C-2. Compound identification was based on a comparison of mass spectrometric fragmentation patterns and their retention times.



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4.4.5 Distribution of Petroleum Hydrocarbons in Sediment Core Samples

Forty centimeter long sediment core sample was taken at station C. The core sample was cut to 10 centimeter interval and each subsample was analyzed for petroleum hydrocarbons.

The results from ultraviolet fluorescence spectroscopy analysis of petroleum hydrocarbon in sediment cores are given in Table 4-13. The accumulation shows higher petroleum hydrocarbon concentrations at higher depth. The synchronous spectra depicted from each core subsamples is shown in Figure 4-20.

The distribution of n-alkane and aromatic hydrocarbons in sediment core sample show higher concentrations at higher depth. Most samples contain Unresolved Complex Mixture (UCM) and homologous series of n-alkane. Uniform distributions of odd and even n-alkane were shown. Gas chromatograms of n-alkane in sediment core samples are presented in Figure 4-21 and details stated in Table 4-14 and summarized in Table 4-15. Gas chromatograms of aromatic hydrocarbons in sediment core samples are presented in Figure 4-22 and Table 4-16.

Table 4-13 Petroleum hydrocarbons concentrations in sediment core.

Core no.	Depth (cm)	Sediment type	% OM	Petroleum concentration ($\mu\text{g/g}$ dry wt, chrysene eq.)
1	0-10	sand	0.22	0.89
2	10-20	sand	0.22	0.97
3	20-30	sand	0.25	1.64
4	30-40	sand	0.27	2.29

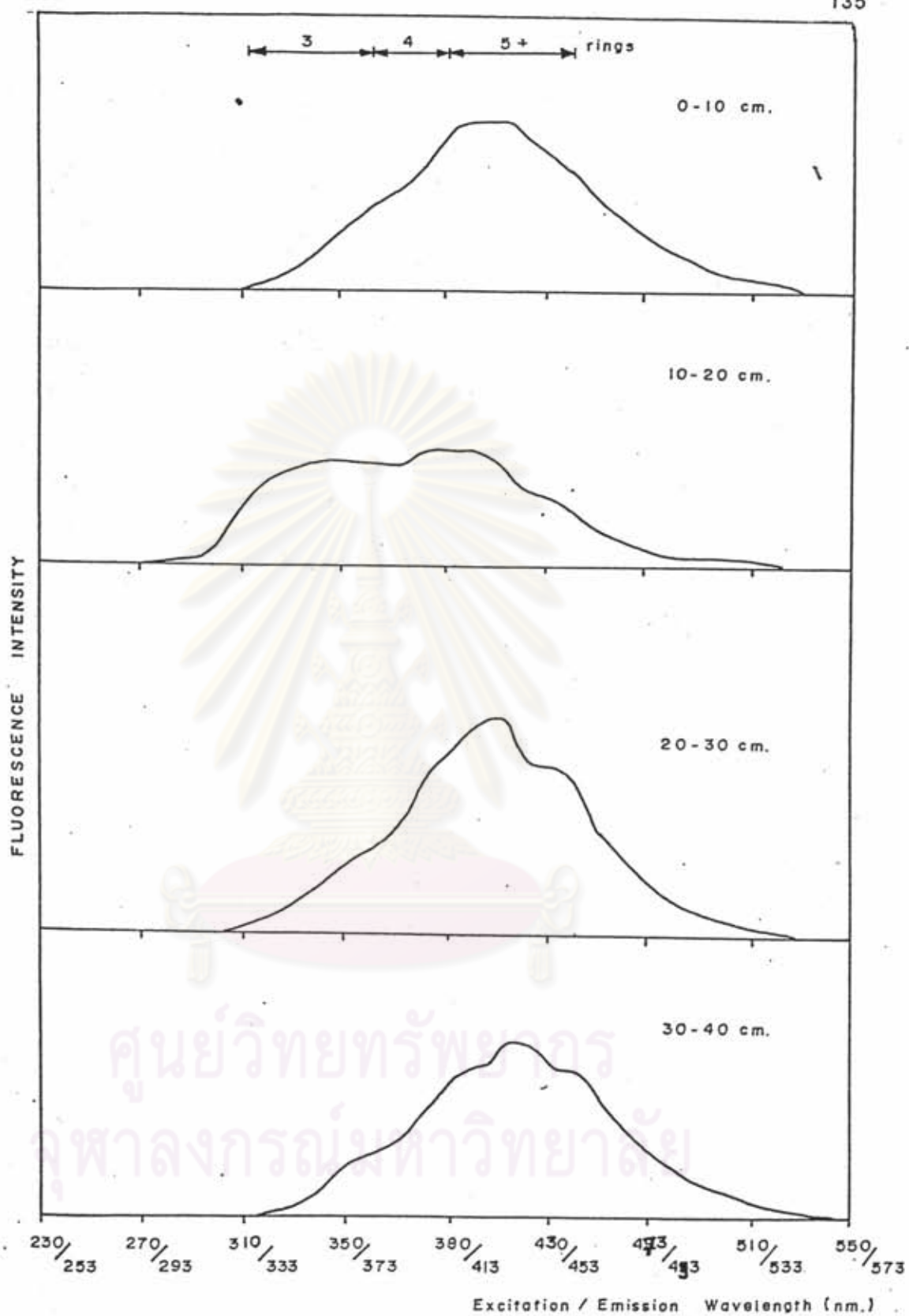


Figure 4-20 Fluorescence Spectrum of Sediment core sample collected at various depth at station C.

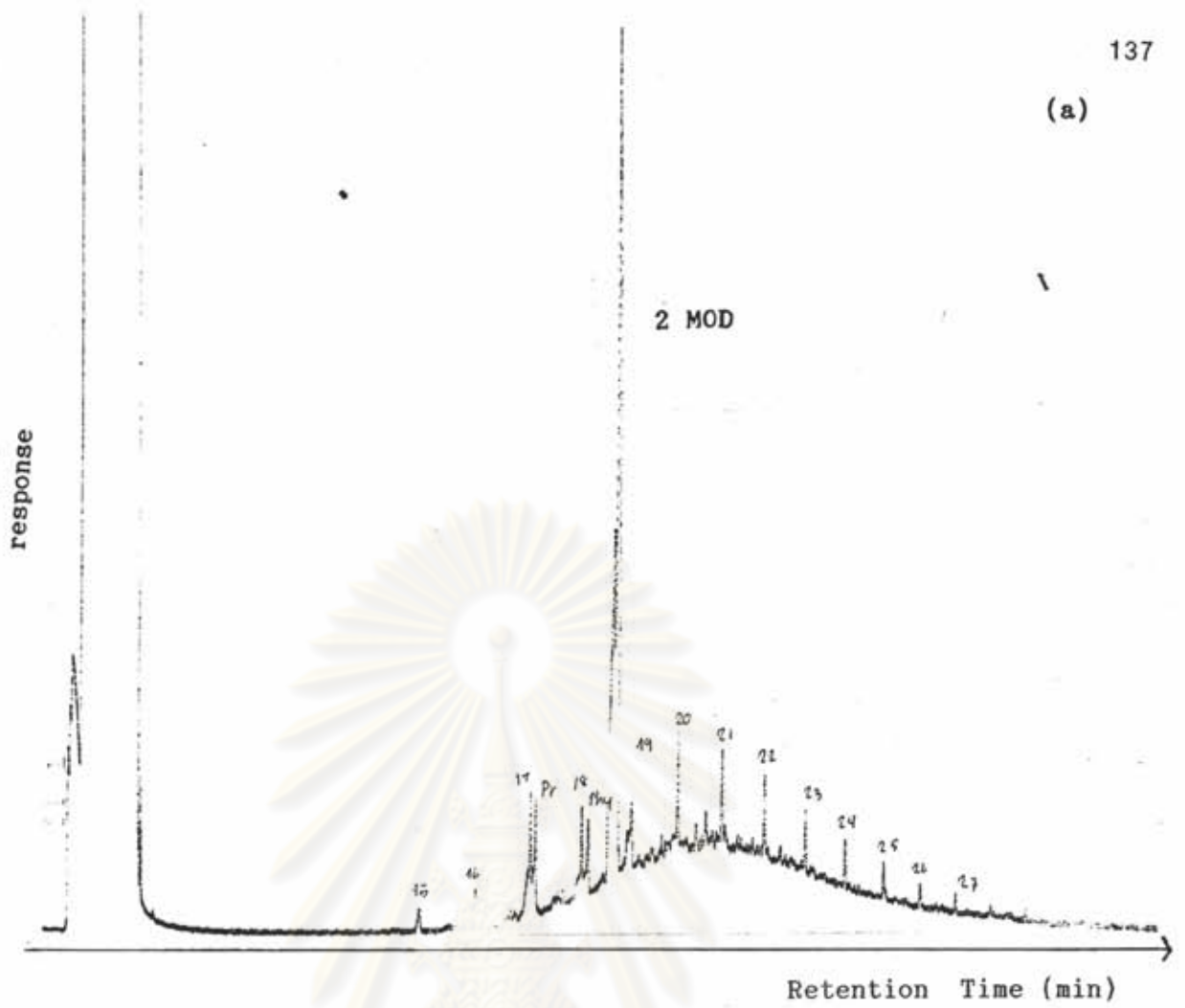
Figure 4-21 Distribution of n-alkane in various depths of sediment core sample.

- a) 0-10 cm
- b) 10-20 cm
- c) 20-30 cm and
- d) 30-40 cm

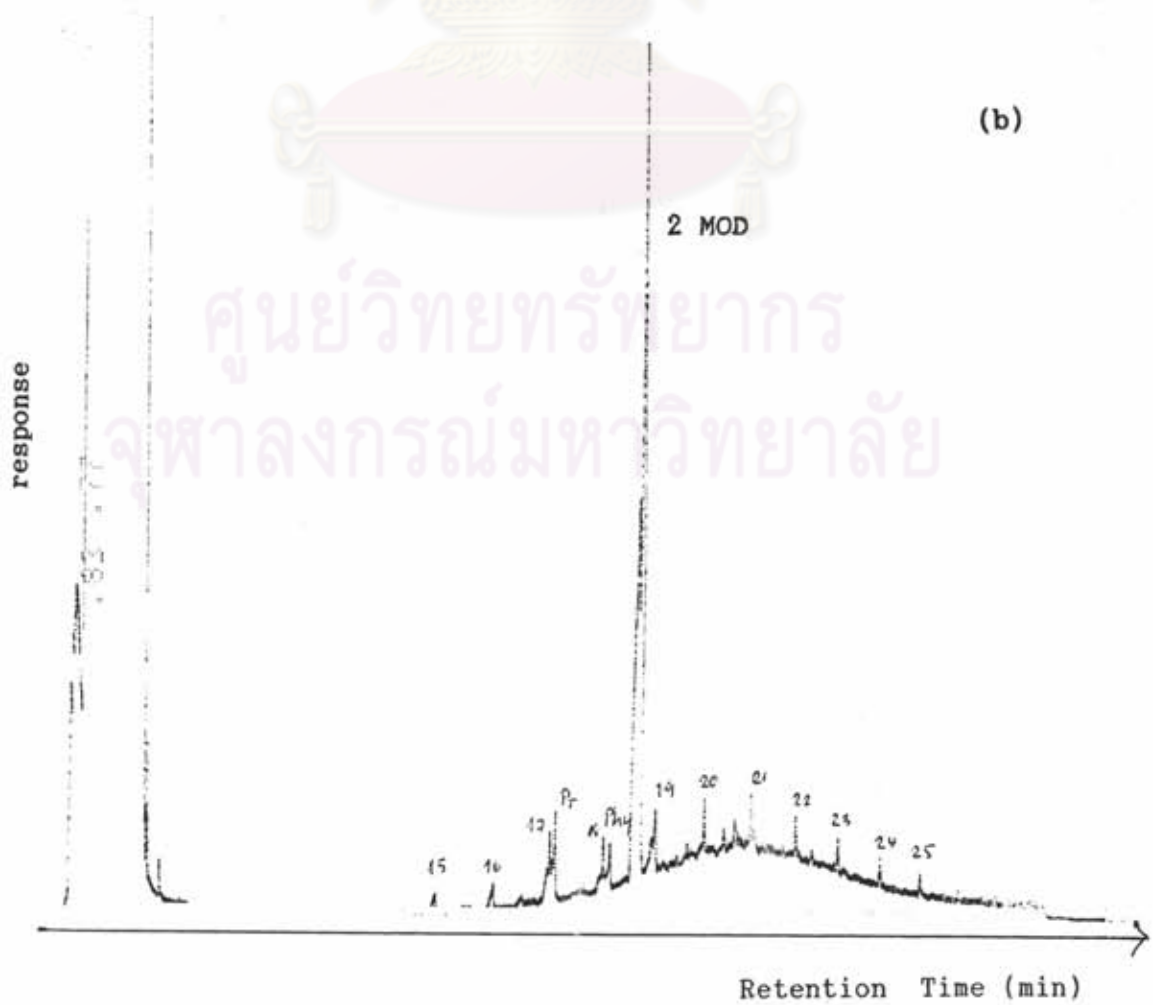


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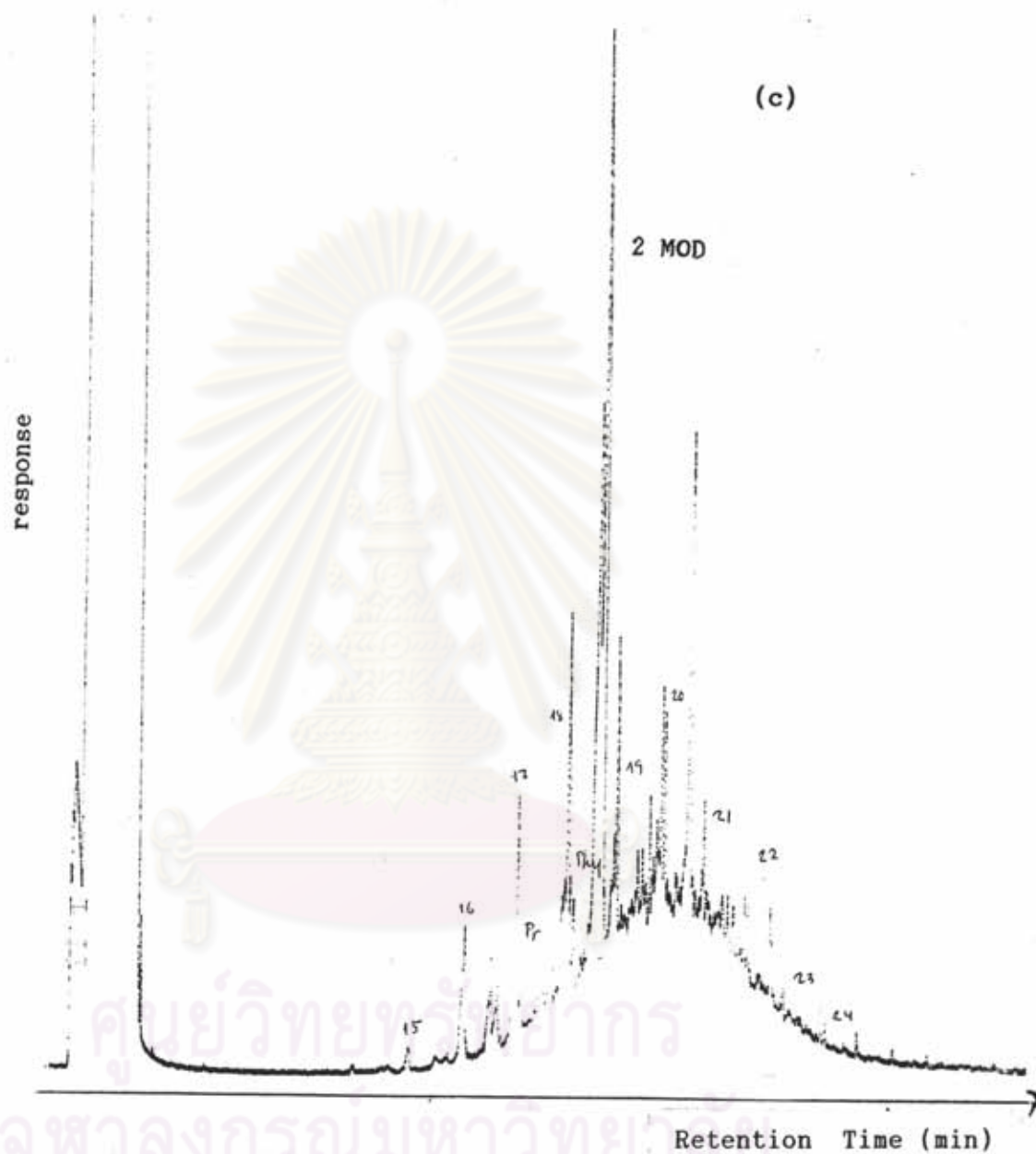
(a)



(b)



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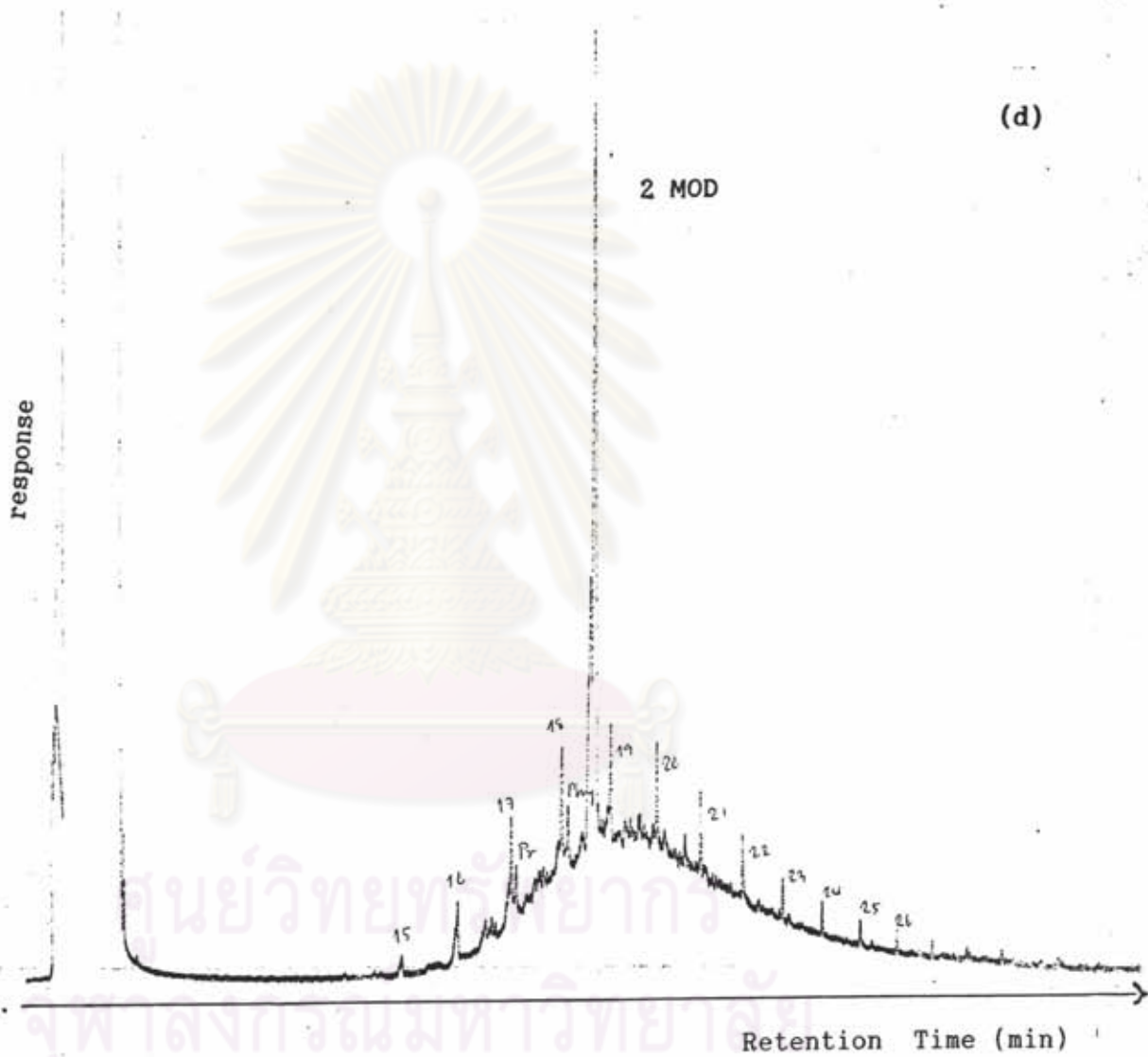


Table 4-14 Distribution of n-alkane in sediment core from Station C. (ng/g dry sediment weight).

Compounds	Depth (cm)			
	0-10	10-20	20-30	30-40
C15	30.2	24.8	52.2	39.4
C16	51.1	49.3	420.5	130.8
C17	116.7	92.6	386.0	366.0
C18	64.8	37.1	424.0	430.4
C19	49.0	25.2	346.0	197.8
C20	67.1	35.1	228.0	241.3
C21	30.0	22.3	74.0	143.4
C22	18.8	14.0	51.0	218.7
C23	12.0	2.2	66.2	57.4
C24	6.9	1.1	21.0	58.7
C25	4.0	2.0	10.0	21.3
C26	2.8	3.6	3.9	32.9
C27	4.0	1.4	-	13.0
C28	2.4	-	-	10.1
C29	1.7	-	-	-
TOTAL	461.5	310.7	2082.8	1961.2

Table 4-15 Aliphatic hydrocarbon concentrations from sediment core sample (ug/g dry sediment weight).

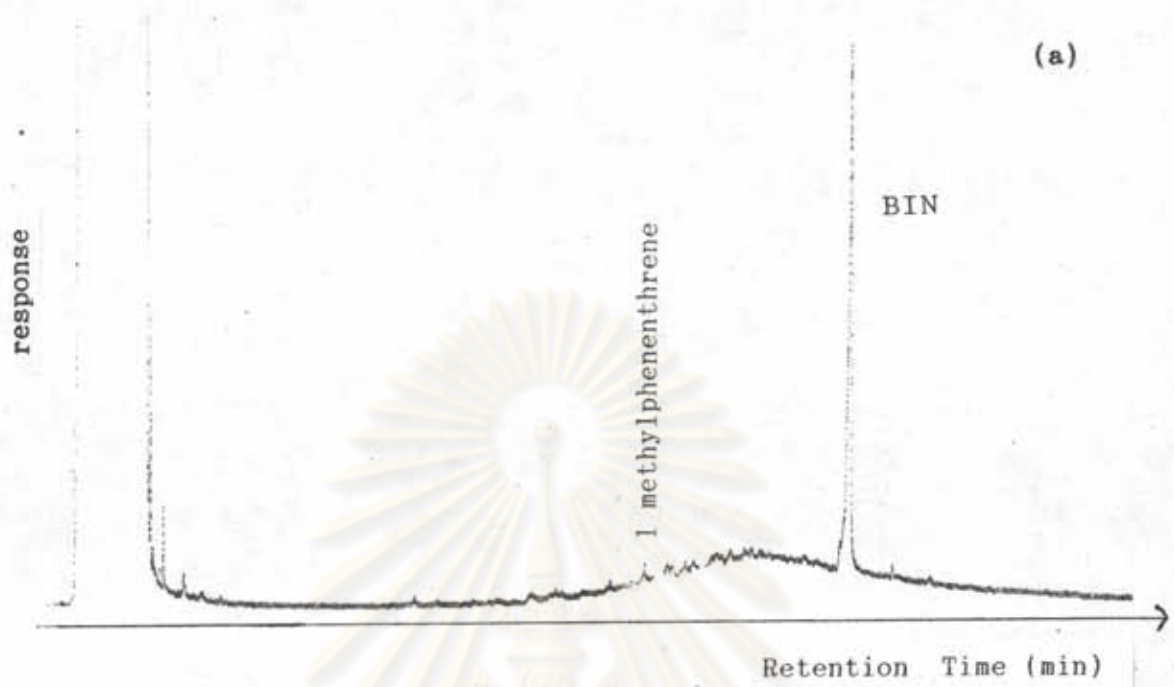
Compounds	Depth (cm)			
	0-10	10-20	20-30	30-40
Total ali	2.37	1.62	4.37	5.22
Total alkane	0.46	0.31	2.08	1.96
UCM	1.91	1.31	2.29	3.26

Figure 4-22 Distribution of aromatic hydrocarbons
in various depths of sediment core sample.

- a) 0-10 cm
- b) 10-20 cm
- c) 20-30 cm and
- d) 30-40 cm



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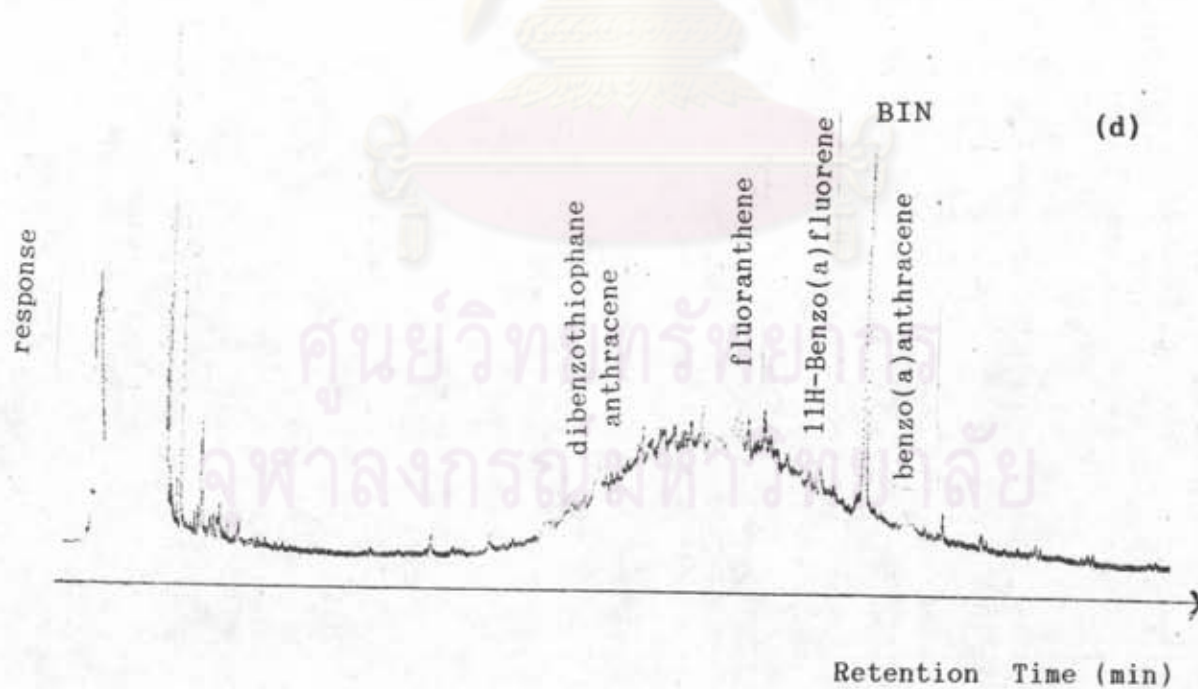
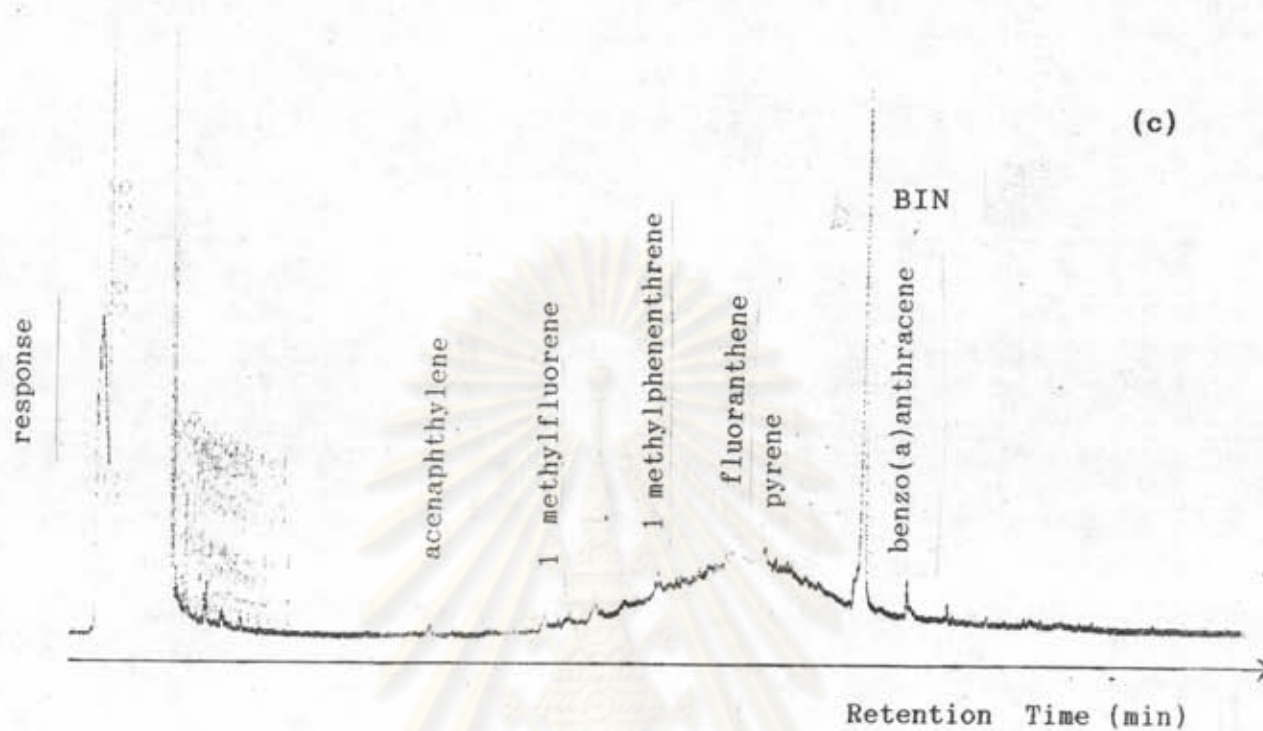


Table 4-16 Aromatic hydrocarbon concentrations from sediment core samples (ng/g dry sediment weight).

Compounds	Depth (cm)			
	0-10	10-20	20-30	30-40
Acenaphthylene	trace	-	10.64	trace
Dibenzofuran	trace	-	-	-
Fluorene	-	-	-	trace
1-Methylfluorene	trace	-	26.53	-
9-Fluorenone	-	-	-	trace
Dibenzothiophene	-	-	-	31.28
Anthracene	-	-	-	255.17
1-Methylphenanthrene	4.58	-	40.45	-
Fluoranthrene	-	9.75	111.06	183.46
Pyrene	-	10.39	121.13	-
11 H-Benzo(a)fluorene	-	-	-	435.95
Benzo(a)anthracene	-	15.38	38.3	115.82
Benzo(b)anthracene	trace	6.83	trace	trace
Total	4.58	42.35	386.08	1021.68

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4.5 Petroleum Hydrocarbons in Bivalve Tissue

Hydrocarbons in bivalve tissue of composite Donax sp. were analyzed. Samples were collected from 6 stations namely Ban Phala (N1), Ban Nam Tok(N2), Ban Payoon (N3), Ban Kong Pet (N6) and Ban Takuan (N8) before and during operations in October 1988 and June 1989, respectively. As a result of an UVF analysis, the concentration of petroleum hydrocarbons in bivalve Donax sp. tissue are presented in Table 4-17.

Table 4-17 Concentration of petroleum hydrocarbons in bivalve Donax sp. collected at ship-breaking industry area before and during operations in October 1988 and June 1989, respectively, analyzed by UVF method (ug/g dry weight).

Site of collection	October 1988	June 1989
N1	3.38	3.14
N2	1.46	1.96
N3	2.01	3.84
N6	2.31	4.17
N7	1.98	3.26
N8	2.15	2.98

Hydrocarbons were also quantified and identified by GC technique. Concentrations of total n-alkanes ranged from 9.57 to 43.23 ug/g dry weight. Dominant peaks at retention times of C₁₇, C₁₉ and C₁₇ were found. Identified aromatic hydrocarbons found in bivalve Donax sp. were acenaphthene, acenaphthylene, dibenzothiophene, phenanthrene, anthracene, 1-methylphenanthrene, fluoranthene, pyrene and benzo(a)pyrene. Concentrations of total identified aromatic

hydrocarbons range from 32.5-312.5 ng/g and 82.4-486.6 ng/g in October and June, respectively. The details concentrations in each samples are presented in table 4-18 and 4-19. Concentrations of identified aromatic in bivalve are shown in tables 4-20 and 4-21.



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Table 4-18 n-Alkane distribution in bivalve Donax sp. in October, 1988 ($\mu\text{g/g}$ dry weight).

Compounds	1	2	3	6	7	8
C15	0.43	-	-	-	-	0.35
C16	0.38	0.25	1.33	-	0.21	0.89
C17	2.67	1.13	1.93	0.44	0.32	3.57
C18	1.85	0.88	1.66	0.36	2.72	2.25
C19	2.02	0.97	1.01	0.98	1.26	3.61
C20	1.14	1.04	1.11	0.34	1.59	1.04
C21	0.64	1.32	0.89	11.65	1.48	1.85
C22	0.32	0.34	0.46	0.48	1.75	0.97
C23	0.21	0.25	0.49	0.26	0.82	0.38
C24	0.1	-	0.69	-	0.42	-
Total	9.76	6.18	9.57	14.51	10.57	14.91
UCM	115.32	67.15	80.37	76.41	42.26	84.6
Total	125.08	73.33	89.94	90.92	52.83	99.51

Table 4-19 n-Alkane distribution in bivalve Donax sp. in June, 1989 ($\mu\text{g/g}$ dry weight).

Compounds	1	2	3	6	7	8
C15	0.15	0.08	1.34	1.67	1.71	1.38
C16	0.08	0.18	1.67	1.88	2.91	2.65
C17	0.96	1.23	3.34	3.96	4.94	3.44
C18	0.7	1.56	3.86	4.65	5.1	4.79
C19	1.17	1.99	5.18	5.71	5.7	5.58
C20	0.51	2.04	6.69	6.64	6.21	5.68
C21	3.22	2.67	5.47	5.65	5.15	4.98
C22	0.47	0.44	4.66	4.38	3.99	3.87
C23	0.89	0.38	4.02	3.32	2.91	3.02
C24	1.39	0.17	3.38	2.14	1.94	1.95
C25	2.01	0.1	1.99	1.87	0.97	1.06
C26	1.22	-	1.46	1.04	0.67	0.54
C27	0.46	-	-	0.32	-	-
Total	13.23	10.84	43.06	43.23	42.2	38.94
UCM	114.23	73.82	120.62	147.62	112.5	125.43
Total	127.46	84.66	163.68	190.85	154.7	164.37

Table 4-20 Polycyclic aromatic hydrocarbons(PAHs)found in Donax sp. (October,1988)(ng/g dry weight).

Compounds	N1	N2	N3	N6	N7	N8
Acenaphthylene	46.5	-	38.8	76.5	-	25.2
Acenaphthene	23.9	-	29.6	71.7	11.1	-
Dibenzothiophene	-	6.9	-	38.6	12.9	21.1
Phenanthrene	85.2	16.7	29.9	54.4	33.8	18.6
1-Methylphenanthrene	46.7	8.9	36.5	58.7	27.1	-
Fluoranthene	12.6	-	11.1	18.6	-	-
Pyrene	6.8	-	-	-	-	-
Total	221.7	32.5	145.9	318.5	84.9	64.9

Table 4-21 Polycyclic aromatic hydrocarbons(PAHs) found in Donax sp. (June,1989)(ng/g dry weight).

Compounds	N1	N2	N3	N6	N7	N8
Acenaphthylene	41.6	-	76.4	89.9	91.6	25.2
Acenaphthene	29.4	-	14.6	95.2	38.7	41.4
Dibenzothiophene	-	17.7	25.9	38.6	-	18.5
Phenanthrene	132.1	26.1	132.1	198.2	123.4	132.6
1-Methylphenanthrene	43.2	38.6	197.3	58.7	13.7	39.8
Anthracene	12.8	-	38.7	76.3	9.7	-
Fluoranthene	-	-	-	-	-	-
Pyrene	-	-	-	15.7	-	0.2
Benzo(a)pyrene	0.3	-	1.6	1.2	-	-
Total	259.4	82.4	486.6	573.8	277.1	257.7

CHAPTER V

DISCUSSIONS

5.1 Distribution of Petroleum Hydrocarbons in Waters

The study indicates that the distribution patterns of petroleum concentrations in seawater for June and November are rather similar. Higher concentrations were found in June and November, during the operation period, as compared to the first and the last periods. As for data collected in May 1990, the contamination level is the same as that found in the first period but in the lower magnitude than that reported by Petpiroon et al., 1988 for the nearshore seawater at Pattaya to Trad Province (range from 0.02-5.29 with a mean of 0.65 μg chrysene equivalent per liter).

Hydrocarbons present in the marine environment are actually originated from various sources. The types of polycyclic aromatic hydrocarbons present in the samples can be determined by both emission and synchronous spectra. The latter is particularly sensitive to changes of composition of the petroleum hydrocarbons (Law, 1981).

Figure 4-4 shows for most samples, the majority of the emission fluorescence spectra occurred at higher wavelengths. This suggests that most samples contained higher molecular weight aromatics hydrocarbons (Law, 1981).

In synchronous spectra, compounds with different numbers of fused aromatic rings exhibit their maximum emission spectra at

certain wavelengths. Benzenes containing 1 aromatic ring emits the maximum emission spectra most strongly in the 280 - 290 nm region, naphthalenes containing 2 aromatic rings(around 310-320 nm) 3 and 4 aromatic rings between 340 and 380 nm, and compounds with 5 or more rings at above 400 nm (Hamilton, 1989).

It is found that most seawater samples exhibit their maximum emission fluorescence at 310-320 nm, which indicates that they contained mostly 2 aromatic rings. This peak is believed to derive primarily from diesel oil which is used in small and big fishing boats. Investigation of petroleum hydrocarbons in seawater from North Sea, Baltic Sea and North Atlantic Ocean showed that diesel oil exhibits a maximum emission synchronous spectra around 320 nm. (Theobald, 1989). There are approximately 58 diesel engine fishing boats in Ban Phala, Tambon Map Ta Phut (Fisheries Statistic Section, 1986) and approximately 103 diesel engine boats in 1989 (unpublished data from EMFDEC). Therefore, it can be concluded that a contamination of diesel oil in seawater comes from these diesel fishing boats.

Most seawater samples collected in June and November 1989, when the ship-breaking process was under way, contained peaks 310-320, 340 - 380 and higher than 400 nm which indicates the presence of more highly condensed aromatics. Other expected point sources of petroleum hydrocarbons in the area, however, do not exist. Therefore, it can be concluded that the ship-breaking plants were responsible for this type of oil. The oil contamination in seawater caused by escaped oils from machine, spaces, ballast tanks and fuel tank during scrapping. The marine bunker C oil, which is the kind of oil used in

cargo vessel, tanker, ocean transportation vessel, and Ekofish crude oil exhibit emission wavelengths of 320 nm. with distinct maxima at 360 and 410 nm. These spectra are caused by higher boiling aromatics which process more than three rings (Theobald, 1989).

The average concentration of hydrocarbons from creek water along the coastline in various sampling periods appear to be similar. High concentrations were observed at klong C, C1 and C5. This is due to an effluent discharged from ship-breaking plants. Klong C5 also received effluents from treatment plants of various factories located in the Map Ta Phut Industrial Estate, that contain petroleum hydrocarbons.

The surface microlayer of coastal area serves as an important habitat for organisms such as bacteria, microalgae, protozoa, crustaceans and invertebrate larva and eggs and larvae of many commercially important fish and shellfish. In addition the hydrophobic nature of organic carbon such as petroleum hydrocarbons associated with floatable particles at the surface microlayer. Therefore, many pollutants including organic carbon are found to concentrate in this aquatic surface microlayer (Hardy et al., 1990).

Recent studies have linked an aquatic surface contamination with negative biological impacts. Some reported that fish eggs exposed to contaminated surface microlayer showed reduce viability. Hardy et al, (1990) suggested that the surface contamination in the Chesapeake Bay potentially toxic to floating fish eggs and other surface organisms. In this study the effects of petroleum hydrocarbons

in surface microlayer on organisms are not observed. The enrichment factors of concentrations between surface to bulk water can determine the degree of aquatic surface microlayer pollution at selected sites (Hardy, et al, 1990). In this study it was found that petroleum hydrocarbons in the surface microlayer are higher in scraping periods of June and November, 1989 than in October 1987 and May 1990.

An attempt were made to investigate the effects of current and wind on the distribution of petroleum hydrocarbon.

Both hourly current and net tidal drifted observed in this study clearly demonstrated the effect of wind. The SSW wind recorded in 21-22 June should, according to Ekman Theory, induce flow toward the east and this is clearly noticed in Figure 4-9(a). Consequently, the net tidal drift is found to be in the SE direction. On the other hand, the NE prevailing wind in November explains the SSW direction of net tidal drift, Figure 4-9(d), indicates that majority of hourly recorded current is in the third quadrant as shown in Figure 4-9(c).

It was found that during the first scraping period in June, the concentrations of petroleum hydrocarbon were remarkably higher in those nearshore stations to the east of the cutting site than those on the west. The similarity is also true for those offshore stations. Very good agreement between the direction of net tidal drift and concentration of petroleum hydrocarbons observed leads to the conclusion that both wind and tidal current will transport oil contamination toward the SE direction in June. Results from November

observation reveal different picture but the same conclusion. Concentrations of petroleum hydrocarbon were found to be higher in those stations, both nearshore and offshore, in front of the ship-breaking site in relation to those on the east and west. With the net tidal drift in the SSW direction, toward offshore, the effect of wind and current in transporting contaminated oil is confirmed.

According to the physical characteristics of current in June and November, it is suggested that the oil tends to concentrate near the shoreline or in shallow water, especially the east side of the scraping factories in June but diluted to offshore area in November. This phenomena would be very important if the Map Ta Phut deep sea port is in operation in the next years. Treated and untreated effluents from the Map Ta Phut Industrial Estate, including petroleum hydrocarbons, will disperse in shallow water nearshore for sometime before they will be carried out offshore.

The progressive vector diagram and the direction and speed of current measured in 1 tidal cycle at surface level are similar to those from mid-depth and bottom waters as shown in Figure B-1 in Appendix B. The prevailing wind data obtained from the meteorological station of the Meteorological Department are shown in Table B-3 in Appendix B.

Effects of winds and tides on spilled oil at continental shelves and coastal waters was studied (Mimicos, 1980). It has shown that the dominant role of winds and weather systems are on forcing the motion on these waters. In the Torrey Canyon spill off the west coast of England large scale winds were the controlling factor. The Argo

Merchant spill was largely controlled by oceanic processes and strong tidal currents were important only in the immediate vicinity of the wreck (Murray, 1982). A year ago, the Exxon Valdez supertanker ran aground on Bligh Reef in Alaska's Prince William Sound and 11 million gallons of crude oil pushed by tides and wind slapped against the base of the Alaska Peninsula, 650 km away (Hodgson, 1990).

5.2 Distribution of Beach Tar

Most tar balls are originally derived from oily wastes discharged and the remainder turns into tar ball and deposited on the sea bottom or are acted with wind, waves and currents to carry tar balls to wash ashore. However, in this study area, other sources of oil pollution such as tankers, oil vessels, refineries, offshore oil drilling are not present, except wastes from the breaking activities. Hence, fresh tar deposits must come from this source. The findings also support this postulation.

The amount of beach tar observed seems to vary with the period of breaking activity. Heavy deposition was found during the ship-breaking operation periods in June and November 1989. At the first period in August 1988 which is the period before the operation, most of aged tar was washed ashore, while in the second and the third periods, which were during operation times, fresh tar predominated. Quantities of fresh tar collected at station N, after the activity had already been operated for 5 months were still predominant much more than those at the other stations but was lower when compared to those during the past operating periods.

However, during the preliminary survey in September 1988, 1

month before the first period of the water sampling, heavy fresh and sand coated tar was also found to wash ashore. The concentrations found in gram/metre were 41.99 (ST.N1), 19.64 (ST.N2), 16.99 (ST.N3), 165.78 (ST.N), 56.19 (ST.N6) and 6.51 (ST.N7). Again, the heaviest deposition was found at the scraping site when compared to other stations in the same period. Since the tar was fresh it seems to point out to breaking activities to be the responsible source for this heavy tar deposition. It could have been that the activities were carried out secretly without notifying the Authorities involved, as evidence by fresh tar deposition in the area.

Another reason to conclude that ship-breaking activities is the source of pollution for tar balls in this area, is that, if the tar came from offshore, tar balls distribution at stations located at a 1 km. interval should have been in the same levels as found by Petpiroon et al., (1986). However, this was not found during our surveys of tar balls in this area.

Wave action and current are found to have some effects on the distribution patterns of beach tar around the ship-breaking factories. In June during the scraping time, heavy deposition of tar ball was found in eastward area of the scraping site. This finding matched rather well with the direction of the net tidal drift found in June.

The beach tar contamination found around ship-breaking area in this study is probably minimal when compared with tar levels at other polluted areas of the world such as the Middle East region. However, the extent of contamination is about the same level as found during

north-east monsoon in the Andaman Sea coast of Thailand, as reported by Limpasaichol (1984). Heavy deposition was recorded during the South-West monsoon period between June and July, 1979. Whilst during April 1980 in the north-east monsoon period, a very small amount of tar was recorded to be less than 5 g/m maximum of which sand coated and aged tar predominated along the coast. Coles and Gunay (1989) studied the abundance of beach tar on Saudi Arabian Gulf beaches. and found that the highest deposition was 2.32 kg/m on Kuwait beach, while Bahrain, Bermuda and Oman were the only other areas to have tar balls exceeded 0.5 kg/m. Burns et. al.(1982) reported the amount of tar ball at Omani coastal waters, which is the world oil transportation route, ranged from 5 to 2325 g/m with an overall average of 224 g/m.

5.3 Distribution of Petroleum Hydrocarbons in Sediments

The difference of size composition between nearshore and offshore sediments was observed. Grain size of nearshore sediments are courser than those of the offshore sediments. Ocean Affairs board, (1975) reported that courser sediment such as sand and gravel allows greater penetration of oil derived hydrocarbons than finer sediments. The highest concentration of oil can generally associated with silt sediment possibly because sediments have a greater area for adsorption of oil. Courser sediments although allowing greater oil penetration also have high biodegradation rates relative to fine sediments, possibly because of greater aeration and nutrient flow to subsurface. Therefore, in this study the higher percentage of organic contents as well as hydrocarbon content, in offshore finer sediment were found.

For the analysis of aliphatic hydrocarbons from the sediments collected in this area the normal alkanes from C₁₅ to C₃₁ were found.

The chromatograms of those aliphatic hydrocarbons showed clear peaks dominant at retention times of C₁₇, C₁₉, C₂₁. These indicated the

class of biogenic hydrocarbons typically found in the marine phytoplankton (Anderson et al., 1981; Risebrough et al., 1983; Readman et al., 1986; Siron et al., 1987). Therefore, carbons numbered C₁₇, C₁₉ and C₂₁ are usually found in the marine environment.

In this study, normal alkanes with 17, 19 and 21 carbon atoms are dominant in all stations. Some stations where C₂₃ was found in addition to C₁₇, C₁₉, C₂₁ indicated the additional source from bacteria (Figures 4-12 d,e,f,g,h and i).

Besides biosynthesis hydrocarbons, an input of petroleum from anthropogenic (petroleum contamination) was found in this area. Chromatograms of hydrocarbons from petroleum contamination were found to be different from that of biosynthesis hydrocarbons. The homologous series of n-alkanes superimposed on Unresolved Complex Mixtures (UCM) were observed and the ratios between the total weight of odd-carbon homologous and weight of even-carbon homologous (refer to Carbon Preference Index (CPI)) were nearly one. Those features indicate large numbers of components, typically of petroleum (Johnes et al., 1983; Risebrough et al., 1983; Readman et al., 1986; Voundrias et al., 1986)

which were obviously stated in samples collected at the station nearest to ship-breaking plants and at the nearest along to the factories. This means that this area was clearly contaminated by n-alkane derived from petroleum (Figures 4-12 b and c).

The nearshore areas were contaminated by both petroleum and biosynthesis hydrocarbons. Therefore, their predominance of both sources were reflected in the chromatograms.

The features of the offshore chromatograms showed the predominance of C₁₇, C₁₉, C₂₁ and the absence of normal alkane eluting after C₂₁ as well as the presence of a large UCM. It appears to be a partially degraded petroleum residue possibly have been removed by microorganisms (Petrakis et al., 1980). However, this area was also found to contain biosynthesis hydrocarbons as indicated in the chromatograms in Figures 4-12(d,e,f,g,h,i,j,and k).

Sources of hydrocarbons in this study area were shown to be derived from oil from ship-breaking industry and the natural source. Sediments deposited nearest to the scraping area are able to expose to leaked oil from the breaking process. Therefore, its anthropogenic characteristic were found to be much more dominate than biogenic characteristic. Sediment collected from farther areas to the ship-breaking plants were found to be less contaminated with oil from anthropogenic source. This indicates that this over all area also encounter the problem of oil contamination.

For offshore area; where oil accumulated over a long period of time, some normal alkane are found to be degraded. The input of oil to an offshore area is from the transportation process of oil adsorbed

on fine particles from nearshore to offshore. Fine sediment adsorbed by petroleum were carried to offshore while sand or coarser sediment deposited nearshore. This is corresponding with the results discussed earlier that sand and silt sediments were found in offshore and sand sediment in the inner and outer areas. The higher concentrations of oil for offshore sediments than nearshore are caused by the type of sediments. The highest concentrations of oil can generally associated with silt and clay sediments possibly because these sediments have a greater adsorption area of oil. This is reasonably consistent with those reported elsewhere. Law (1981) reported the higher hydrocarbon concentrations from sediment from the UK marine waters, containing finer particles, which presumably had a higher adsorptive capacity owing to their greater effective surface area. The lower concentrations were also found in coarser sediments.

Pristane has been identified in sediments, it was most likely a degradation product of phytol (mentioned in chapter 2). A predominance of pristane signals a biogenic input (IOC/UNESCO, 1989). Phytane has been found in petroleum. Presence of pristane and phytane in sediments suggesting a biochemical origin for pristane and contamination of petroleum hydrocarbons. Both isoprenoid pristane and phytane are marker compounds for environmental monitoring. In this study, the sediments samples contained pristane associated with phytane could be considered as both of biological production and fossil fuel contamination. Isoprenoid pristane concentrations extracted from many nearshore and some offshore sediments were higher than those of phytane indicated the predominant signals of biogenic input. However ratio of isoprenoid pristane to phytane are useful

indicator of biodegradation in moderately weathered oil (Siron.al.,1987). Pristane can easily degraded than phytane, the ratio of pristane to phytane is lower than one determined biodegradation which is corresponding to the ratios from sediment collected from stations N7, N8 O5 (October) and O6 (June).

The existence and sources of polycyclic aromatic hydrocarbons (PAHs) in the environment is of great interest for several reasons. One of the most important reasons is that several PAHs such as benzo(a)anthracene, benzo(e)pyrene, chrysene, dibenz(a,h)anthracene and benzo(ghi)perylene are known carcinogens to human being and may be accumulating in the environment. Furthermore, many PAHs are not thought to be produced biogenitically or diagenitically, so their presence in environment indicates contamination from natural events, such as forest fires (high-temperature combustion sources) and oil seeps, and variety of anthropogenic input, such as motor oils from automobile exhaust, industrial pollution, and oil spills. Petroleum and low-temperature combustion process yield primarily highly PAHs (Phillips, et al.,1987) while high-temperature combustion sources results in many nonalkyl PAHs (Overton and Laseter, 1980). Biosynthesis is an unlikely origin for aromatic hydrocarbons. With the possible exception of certain bacteria, there are no marine organism known to have the ability to synthesize aromatic hydrocarbons. Therefore, most the aromatic hydrocarbons in the Map Ta Phut sediments around ship-breaking industry area are anthropogenic input. However, in this study area around ship-breaking factories, other sources of oil pollution such as tankers, oil vessels, refineries, offshore oil drilling are not present. The PAHs found in

this area was likely to come from the leaked oil from scraping process and high-temperature combustion, such as motor oils from fisherman boats. The fisherman villages were located at Ban Phala, 7 kms westwards of the scraping site.

The statistic calculations revealed that aliphatic hydrocarbon concentrations in sediments collected in two periods tended to increase but not significantly different. For aromatic hydrocarbon concentrations analyzed by UVF and GC technique, the significantly increase was found. It can be postulated that increasing of both aliphatic and aromatic hydrocarbon in sediments may come from contamination of leaked oil from ship-breaking processes. However, aliphatic hydrocarbons in sediment can be rapidly degraded by hydrocarbon-degrading microbes with slower attack on branched-chain alkane, cycloalkanes and aromatic hydrocarbon (Pelezar and Reid, 1965 cited by Lee,1980). Degradation also happens in nature. Studies on growth of petroleum-degrading bacteria isolated from sediments or water (Jobson,et al.,1972 cited by Lee, 1980) showed typical log growth curves. Crude oil degradation rates is reported in Irish Sea water to be 82 ug/l/day (30 mg/l/y) (Gibbs,et al., 1975 cited by Lee,1980)

Comparison of aromatic hydrocarbons analyzed by UVF and GC techniques reveal the significantly different in mean concentrations. Oil and oil products contain polycyclic aromatic hydrocarbons which, if excited with UV light and emit fluorescence light with a characteristic spectral energy distribution. In addition sediment may contain substances with fluorescence characteristics

similar to or identical with those of oil residues. Therefore, the results may represent both of oil and those compounds. Farrington et al.,(1986) found the fluorescence of what appeared to be an oil residue attributed by metabolic product of a marine polychaete. Comparison to GC, the analysis of extracted sediment for single compound identifications seems to be different.

Comparison of individual aromatic hydrocarbon concentrations from sediments collected in the global regions (Table 5-1), it can be concluded that the concentrations were the same level to similar area such as Baltic. Meanwhile, PAHs found to be lower concentration when compared to high industrial area in USK River in England and higher than that of remote area in Amazon River.



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Table 5-1 Concentrations of PAH in sediments and soils from around the world.

Area	Phen.	Fluor.	Pry.	(a)	(b)
1 Charles River	5000	15000	13000	21000	33000
2 Maine Soil	70	120	100	140	250
3 Gulf of Maine	43	120	100	80	200
4 Buzzards Bay 1	53	130	120	160	240
5 Buzzards Bay 2	42	130	120	200	380
6 Buzzards Bay 3	8	11	7	12	25
7 New York Bright	740	1200	1300	890	1700
8 Abyssal Plain	N.D.	4	4	13	34
9 South Carolina Soil	78	26	14	22	13
10 Nebraska 1	4	5	5	31	N.A.
11 Nebraska 2	8	8	8	17	37
12 Mono Lake 1	91	13	24	29	N.A.
13 Mono Lake 2	110	74	65	93	57
14 Mono Soil	10	9	9	26	10
15 Yosemite Soil	7	1	1	2	1
16 Nevada Soil	N.D.	N.D.	N.D.	N.D.	N.D.
17 Alaska K-30	67	4	8	23	11
18 Alaska H-24	2	0.6	0.6	1	0.6
19 Walvis Bay	8	10	15	10	25
20 Cariaco Trench	18	9	16	13	1700
21 Flood plain Amazon River	2	1	2	6	6
22 Station 7 Amazon River	N.D.	N.D.	N.D.	N.D.	N.D.
23 Coari River Amazon River	9	3	4	4	520
24 Rio Ica Amazon River	6	3	3	13	500
25 Obidos 16 Amazon River	6	6	6	16	510
26 South Baltic Sea	120	110	50	-	-
				*1	*2
27 Usk River, U.K.	9000	3000	500	2500	11000
				3*	*4
In this study (max.)	40.0	78.6	58.8	24.6	21.6

NA. = not analyzed.

ND. = not detected

All concentrations are in ng/g (part per billion), dry weight basis.

(a) = components includes chrysene, triphenylene and C₁₈H₁₂ isomer.

(b) = components includes benzofluorenes, benzo(a)pyrene and perylene

*1

= Chrysene only

*2

= Benzo(a)pyrene only

*3

= Chrysene only

*4

= Perylene only

Source : Laflamme and Hites (1978), Law and Andruliewicz (1983), Kayal (1989).

Distribution of Petroleum Hydrocarbons in Sediment Core Sample

Study of the accumulation of petroleum hydrocarbons in the sediment core sample indicates higher petroleum concentration at higher depth. Since no dredging activity has been observed to disturb the accumulation and deposition of sediment in this area, it can be concluded that the deeper sediment has existed at a longer period of time, hence older, than sediment at the top of the core. Therefore, the data suggest that sediments in this study area have been contaminated by oil for quite some time. The evidence of less contaminated oil found in younger sediments could be explained to occur as results of better mitigation measure implemented by the ship-breaking plant owners in recent years as compared to the past. In addition, strict enforcements of concerned government authorities such as the Harbor Department, the Office of the National Environment Board and the Fishery Department in recent years seem to effectively reduce the extent of oil leaked into the environment. However, to be able to clearly explain previous activities related to the contamination of petroleum in the area the deposition rate and the age of sediments at various depth should further be studied.

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5.4 Petroleum hydrocarbons in bivalve Donax sp. tissue.

The wide geographical distribution of bivalve in addition to its ability to accumulate hydrocarbons in the gut and hepatopancreas from suspended particles and those dissolved in sea water. Therefore, bivalve can be an indicator of pollution from petroleum hydrocarbons. Results in this study showed the presence of hydrocarbons in beach calms Donax sp. from both study periods. This study is considered to be the first of the observation of petroleum hydrocarbons in Donax sp. The fishermen who settle in this area reported their experience on the oily smell from these beach calms some times after oil spilled from the ship-breaking factories. This was not observed, however, during our study. Polycyclic aromatic hydrocarbons (PAHs) found in the Donax sp. were acenaphthene, acenaphthylene, dibenzothiophene, phenanthrene, anthracene, 1-methylphenanthrene, fluoranthene, pyrene and benzo(a)pyrene. PAHs found probably have a number of sources. Alkyl PAHs, eg. 1-methylphenanthrene is usually abundant in petroleum, whereas unsubstituted PAHs are produced by combustion and pyrolysis processes.

Ehrhardt and Heinemann (1975) showed that bivalve collected from the vicinity of known fossil fuel discharges, spillage background pollution contain significantly higher concentration of hydrocarbon than those from clean area. Hydrocarbon, however, may be accumulated rapidly. Lee et al.(1972) observed that 10-15 mg of mineral oil was taken up by mussel in two days. However, when transferred to clean water, bivalve depurate hydrocarbons and maintained at concentrations higher than background (Clark and Finly,

1975). The levels of petroleum hydrocarbons in the bivalve tissue can be considered as the baseline data for the area.



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CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. The trends of petroleum contamination in water samples collected in scraping periods in June and November, 1989 are similar, that is, the concentrations observed are higher than those in the first and the last periods of non-scraping activity in October 1988 and May 1990.

2. High concentrations of petroleum hydrocarbon were found at Klong C which is running across the two ship-breaking industries. Klong C5, an artificial outlet of the treated and/or untreated effluent from various factories located in the Map Ta Phut industrial estate, also contains high concentrations of petroleum hydrocarbon.

3. Petroleum hydrocarbons concentrations found are higher in the surface microlayer than in the bulk water and are much higher in scraping periods of June and November, 1989 than in October 1987 and May 1990.

4. Currents and wind have significant influence on the movement of petroleum hydrocarbons from ship-breaking factories.

5. Heavy deposition of beach tar appeared during the ship-breaking operation periods in June and November 1989.

6. Wind and current affect the distribution patterns of escaping oil and floating tars from ship-breaking factories.

7. Lower amount of beach tar was found compared to those reported for polluted areas of the world.

8. Concentration of aromatic hydrocarbons in sediments analyze by UVF method ranged from 0.06-0.87 $\mu\text{g/g}$ dry weight with the average of 0.33 $\mu\text{g/g}$ in October and 0.27-1.86 $\mu\text{g/g}$ dry weight with the average of 0.69 $\mu\text{g/g}$ in June, 1989.

9. N-alkane found in this study area dominant at C₁₇, C₁₉ and C₂₁ including presence of homologous series of odd and even numbered alkanes superimposed on UCM indicate biogenic hydrocarbons and petroleum contamination in this area.

10. Total aromatic hydrocarbons in sediment samples ranged from 0.06-0.87 $\mu\text{g/g}$ dry weight with an average of 0.33 $\mu\text{g/g}$ in October and ranged from 0.27-1.87 $\mu\text{g/g}$ dry weight with the average of 0.69 $\mu\text{g/g}$ dry weight in June. The identified aromatic hydrocarbons found in sediments were Naphthalene, 1-Methylnaphthalene, Binaphthyl, 2,6-Dimethylnaphthalene, Acenaphthylene, Acenaphthene, 1-Methylfluorene, 9-Fluorenone, Dibenzothiophene, Phenanthrene, Anthracene, 1-Methylphenanthrene, Fluoranthene, Pyrene, 11H-benzo(b)fluorene, 1,1-Binaphthyl(spike), Benzo(a)anthracene, Chrysene, Benzo(e)pyrene and Perylene.

11. PAHs found in bivalve Donax sp. were acenaphthene, acenaphthylene, dibenzothiophene, phenanthrene, anthracene, 1-methyl phenanthrene, fluoranthene, pyrene and benzo(a)pyrene.

6.2 Recommendations

1. Bioassay on negative biological impacts of petroleum hydrocarbons on aquatic organisms should be studied.
2. Water quality monitoring program and mitigation plan to control pollution from effluent through Klong C and C5 should also be carried out.
3. Sedimentation rate and age of sediment core sample should be carried out to accurately predicate of petroleum hydrocarbon contamination in the past.
4. Monthly observation of beach tars should be carried out to accurately describe the distribution of beach tars in this area.
5. Oil contaminations and beach tar depositions should be monitored by the government officers in order to force the operators to follow the conditions of ship-breaking activities as mentioned in Appendix D.
6. Integrated effect of wind and current on dispersion pattern of pollutants, as shown in this study, should also be carried out for other kinds of pollutant discharging into the coastal areas.