



### CHAPTER III

#### RESULTS

##### Distribution of Lead, Copper, Zinc and Iron in Seawater.

The concentrations of four metals namely lead, copper, zinc and iron in seawater at different sampling stations were determined both in dissolved and particulate forms.

##### 1. Particulate Form.

The concentrations of particulate lead, copper, zinc and iron in seawater samples during the four periods are shown in Tables 3-1, 3-2, 3-3 and 3-4. The ranges of concentration were: lower than 0.01  $\mu\text{g/l}$  or not detected (ND) to 15.77  $\mu\text{g/l}$  for lead, ND to 12.11  $\mu\text{g/l}$  for copper, ND to 100.08  $\mu\text{g/l}$  for zinc, and 5.54  $\mu\text{g/l}$  to 1053.91  $\mu\text{g/l}$  for iron. The variations of concentration can be summarized as the following.

##### 1.1 Lead.

The average concentrations were 0.11, 0.17, 0.21 and 1.00  $\mu\text{g/l}$ , and ranges were 0.02 - 0.30, ND - 0.96, ND - 1.61 and 0.05 - 15.77  $\mu\text{g/l}$  for samples collected in October 1988, June-July 1989, November 1989 and May 1990, respectively. On the average, the concentration observed in May 1990 was the highest and in October 1988 was the lowest.

Table 3-1 Concentrations of particulate lead in seawater off  
Ban Nong Faeb, Mab Ta Phud, Rayong Province. (in  $\mu\text{g/l}$ )

Station	Sampling Period			
	Oct,88	Jun & Jul,89	Nov,89	May,90
C-1	-	0.16	0.08	0.60
C-2	-	0.96	0.35	0.27
C-3	-	0.38	0.74	-
C-4	-	0.00	0.88	-
C-5	-	-	-	-
C-6	-	-	0.34	15.77
C-7	-	0.06	0.07	0.17
SB-01	0.04	ND	0.15	0.42
SB-02	0.05	0.70	0.02	0.08
SB-03	0.11	0.04	0.03	0.07
SB-04	0.07	0.13	0.19	0.08
SB-05	0.04	0.10	0.02	0.07
SB-06	0.09	0.07	1.61	0.10
SB-07	0.12	0.02	0.15	0.22
SB-08	0.11	0.00	0.03	0.94
SB-09	0.18	0.05	0.02	0.13
SB-10	0.02	0.01	0.01	0.09
SB-11	0.03	0.18	0.00	0.07
SB-12	0.08	0.01	0.05	0.18
SB-13	0.02	0.06	0.01	0.10
SB-14	-	0.07	0.02	0.09
SB-15	0.28	0.04	0.03	0.80
SB-16	0.24	0.27	0.03	0.75
SB-17	0.30	0.28	0.04	0.05
Average	0.11	0.17	0.21	1.00
Range	0.02-0.30	ND -0.96	0.00-1.61	0.05-15.77

Remark - : No sample  
 ND : Not detected  
 Oct, 1988 : before ship-breaking activities started  
 Jun & Jul, 1989 : during ship-breaking activities  
 Nov, 1989 : during ship-breaking activities  
 May, 1990 : after ship-breaking activities finished

Table 3-2 Concentrations of particulate copper in seawater off  
Ban Nong Faeb, Mab Ta Phud, Rayong Province. (in  $\mu\text{g/l}$ )

Station	Sampling Period			
	Oct,88	Jun & Jul,89	Nov,89	May,90
C-1	-	0.06	ND	ND
C-2	-	0.08	0.35	ND
C-3	-	0.59	0.52	-
C-4	-	0.00	0.46	-
C-5	-	-	-	-
C-6	-	-	2.00	12.11
C-7	-	0.05	0.16	0.14
SB-01	ND	0.03	ND	0.29
SB-02	ND	0.00	0.04	ND
SB-03	ND	0.00	0.01	ND
SB-04	ND	0.02	0.17	ND
SB-05	ND	0.13	0.00	ND
SB-06	ND	0.01	0.01	ND
SB-07	0.05	ND	ND	0.00
SB-08	0.05	0.13	ND	ND
SB-09	0.00	ND	0.03	0.02
SB-10	0.00	0.00	0.09	ND
SB-11	0.00	0.00	ND	0.00
SB-12	ND	0.16	ND	0.18
SB-13	0.01	0.03	0.02	0.03
SB-14	-	ND	0.14	0.11
SB-15	ND	ND	0.03	0.30
SB-16	0.16	ND	0.00	0.12
SB-17	0.08	ND	0.01	1.05
Average	0.02	0.06	0.17	0.68
Range	ND -0.16	ND -0.59	ND -2.00	ND -12.11

Remark - : No sample  
 ND : Not detected  
 Oct, 1988 : before ship-breaking activities started  
 Jun & Jul, 1989 : during ship-breaking activities  
 Nov, 1989 : during ship-breaking activities  
 May, 1990 : after ship-breaking activities finished

Table 3-3 Concentrations of particulate zinc in seawater off  
Ban Nong Faeb, Mab Ta Phud, Rayong Province. (in  $\mu\text{g/l}$ )

Station	Sampling Period			
	Oct,88	Jun & Jul,89	Nov,89	May,90
C-1	-	2.21	0.28	2.49
C-2	-	2.63	0.99	ND
C-3	-	3.55	1.84	-
C-4	-	0.00	7.36	-
C-5	-	-	-	-
C-6	-	-	3.87	100.08
C-7	-	3.34	5.62	8.72
SB-01	0.73	0.65	0.47	1.07
SB-02	1.00	7.25	0.45	0.08
SB-03	2.39	0.75	0.45	0.06
SB-04	0.77	0.57	2.40	0.02
SB-05	0.55	0.64	0.57	0.05
SB-06	1.05	1.06	0.87	0.69
SB-07	1.79	0.52	1.14	0.35
SB-08	2.70	0.11	ND	0.15
SB-09	0.79	0.31	0.33	0.19
SB-10	0.65	0.20	0.00	ND
SB-11	0.26	0.38	0.24	0.05
SB-12	0.85	0.20	0.31	0.49
SB-13	0.46	0.18	0.49	1.65
SB-14	-	0.61	0.17	1.06
SB-15	0.86	0.28	0.87	0.09
SB-16	1.90	1.68	0.34	0.39
SB-17	1.92	1.22	0.64	0.17
Average	1.17	1.35	1.29	5.61
Range	0.26-2.70	0.11-7.25	ND -7.36	ND -100.08

Remark - : No sample  
 ND : Not detected  
 Oct, 1988 : before ship-breaking activities started  
 Jun & Jul, 1989 : during ship-breaking activities  
 Nov, 1989 : during ship-breaking activities  
 May, 1990 : after ship-breaking activities finished

Table 3-4 Concentrations of particulate iron in seawater off  
Ban Nong Faeb, Mab Ta Phud, Rayong Province.(in  $\mu\text{g/l}$ )

Station	Sampling Period			
	Oct,88	Jun & Jul,89	Nov,89	May,90
C-1	-	318.07	114.79	239.92
C-2	-	609.79	156.67	206.15
C-3	-	695.82	108.84	-
C-4	-	0.00	59.55	-
C-5	-	-	-	-
C-6	-	-	57.09	1053.91
C-7	-	96.17	27.00	370.11
SB-01	31.00	50.76	28.47	91.14
SB-02	21.23	81.97	27.72	13.90
SB-03	19.87	15.87	19.06	13.90
SB-04	28.79	35.38	47.16	27.95
SB-05	20.41	13.93	18.15	12.73
SB-06	18.19	41.03	27.94	30.61
SB-07	42.50	21.11	39.10	32.24
SB-08	22.21	7.22	19.66	11.75
SB-09	6.63	11.88	30.62	13.36
SB-10	16.48	11.50	25.49	9.58
SB-11	10.49	18.94	11.21	25.71
SB-12	23.03	12.57	13.66	19.39
SB-13	9.93	8.13	16.43	23.60
SB-14	-	46.90	11.96	24.45
SB-15	52.61	5.54	14.06	11.52
SB-16	324.71	86.78	21.84	18.22
SB-17	277.68	37.63	22.32	34.93
Average	57.86	106.05	39.95	108.81
Range	6.63-324.71	5.54-695-82	11.21-156.67	9.58-1053.91

Remark - : No sample  
 ND : Not detected  
 Oct, 1988 : before ship-breaking activities started  
 Jun & Jul, 1989 : during ship-breaking activities  
 Nov, 1989 : during ship-breaking activities  
 May, 1990 : after ship-breaking activities finished

### 1.2 Copper.

The average concentrations were 0.02, 0.06, 0.17 and 0.68  $\mu\text{g/l}$ , and ranges were ND - 0.16, ND - 0.59, ND - 2.00 and ND - 12.11  $\mu\text{g/l}$  for samples collected in October 1988, June-July 1989, November 1989 and May 1990, respectively. On the average, the concentration observed in May 1990 was the highest and in October 1988 was the lowest.

### 1.3 Zinc.

The average concentrations were 1.17, 1.35, 1.29 and 5.61  $\mu\text{g/l}$ , and ranges were 0.26 - 2.70, 0.11 - 7.25, ND - 7.36 and ND - 100  $\mu\text{g/l}$  for samples collected in October 1988, June-July 1989, November 1989 and May 1990, respectively. On the average, the concentration observed in May 1990 was the highest and in October 1988 was the lowest.

### 1.4 Iron.

The average concentrations were 57.86, 106.05, 39.95 and 108.81  $\mu\text{g/l}$ , and ranges were 6.63 - 324.71, 5.54 - 695.82, 11.21 - 156.67 and 9.58 - 1053.91  $\mu\text{g/l}$  for samples collected in October 1988, June-July 1989, November 1989 and May 1990, respectively. On the average, the concentration observed in May 1990 was the highest and in November 1989 was the lowest.

## 2. Dissolved Form.

The results of dissolved lead, copper, zinc and iron concentration in seawater samples are shown in Tables 3-5, 3-6, 3-7, and 3-8. The ranges of concentration were : lower than

Table 3-5 Concentrations of dissolved lead in seawater off  
Ban Nong Faeb, Mab Ta Phud, Rayong Province. (in  $\mu\text{g/l}$ )

Station	Sampling Period			
	Oct,88	Jun & Jul,89	Nov,89	May,90
C-1	-	0.52	0.06	7.76
C-2	-	0.49	0.63	0.28
C-3	-	1.10	0.74	-
C-4	-	-	0.40	-
C-5	-	-	-	-
C-6	-	-	0.79	3.53
C-7	-	0.02	0.06	11.36
SB-01	0.11	1.43	0.12	0.44
SB-02	0.12	0.63	0.12	0.34
SB-03	0.12	22.41	0.15	0.08
SB-04	0.24	0.56	0.15	0.15
SB-05	0.16	1.20	0.13	0.28
SB-06	0.08	0.96	0.40	0.31
SB-07	0.18	1.35	0.13	0.48
SB-08	0.34	0.82	ND	0.12
SB-09	0.16	0.07	0.07	0.23
SB-10	0.10	0.09	0.04	0.11
SB-11	0.02	0.26	0.03	0.25
SB-12	0.10	0.07	0.11	1.47
SB-13	0.13	0.14	0.04	0.24
SB-14	-	0.11	0.03	1.78
SB-15	0.30	0.10	0.08	0.75
SB-16	0.34	0.12	0.12	0.50
SB-17	0.12	7.61	0.06	0.17
Average	0.16	1.91	0.19	1.46
Range	0.02-0.34	0.02-22.41	0.03-0.79	0.08-11.36

Remark - : No sample  
 ND : Not detected  
 Oct, 1988 : before ship-breaking activities started  
 Jun & Jul, 1989 : during ship-breaking activities  
 Nov, 1989 : during ship-breaking activities  
 May, 1990 : after ship-breaking activities finished

Table 3-6 Concentrations of dissolved copper in seawater off  
Ban Nong Faeb, Mab Ta Phud, Rayong Province. (in  $\mu\text{g/l}$ )

Station	Sampling Period			
	Oct, 88	Jun & Jul, 89	Nov, 89	May, 90
C-1	-	0.48	1.67	0.59
C-2	-	0.44	0.29	0.42
C-3	-	0.67	0.29	-
C-4	-	-	0.21	-
C-5	-	-	-	-
C-6	-	-	23.56	5.76
C-7	-	0.53	0.18	0.89
SB-01	0.15	0.27	0.18	0.85
SB-02	0.21	0.23	0.20	0.34
SB-03	0.11	2.55	0.21	0.33
SB-04	0.20	0.20	0.39	0.36
SB-05	0.26	0.36	0.19	0.31
SB-06	0.25	0.50	23.85	0.56
SB-07	0.34	0.16	0.46	0.42
SB-08	0.15	0.41	0.22	0.41
SB-09	0.22	0.33	0.19	0.56
SB-10	0.22	0.31	0.30	0.36
SB-11	0.35	0.22	0.23	0.48
SB-12	0.27	0.27	0.15	1.20
SB-13	0.14	0.19	0.26	0.52
SB-14	-	0.30	0.44	0.64
SB-15	0.15	0.30	0.26	1.05
SB-16	0.23	0.65	0.20	1.16
SB-17	0.26	1.65	0.18	0.87
Average	0.22	0.52	2.35	0.86
Range	0.11-0.35	0.16-2.55	0.15-23.85	0.31-5.76

Remark - : No sample  
 ND : Not detected  
 Oct, 1988 : before ship-breaking activities started  
 Jun & Jul, 1989 : during ship-breaking activities  
 Nov, 1989 : during ship-breaking activities  
 May, 1990 : after ship-breaking activities finished



Table 3-7 Concentrations of dissolved zinc in seawater off  
Ban Nong Faeb, Mab Ta Phud, Rayong Province. (in µg/l)

Station	Sampling Period			
	Oct,88	Jun & Jul,89	Nov,89	May,90
C-1	-	ND	3.64	1.98
C-2	-	ND	3.42	0.06
C-3	-	0.66	2.70	-
C-4	-	-	3.03	-
C-5	-	-	-	-
C-6	-	-	4.93	34.22
C-7	-	0.07	10.51	0.58
SB-01	1.25	1.42	2.28	0.55
SB-02	1.55	0.80	0.30	0.21
SB-03	1.26	4.72	2.87	0.27
SB-04	1.64	1.42	7.07	0.21
SB-05	2.61	1.95	2.52	0.33
SB-06	2.59	4.18	25.76	5.44
SB-07	4.77	2.72	6.69	0.45
SB-08	ND	2.17	0.56	0.47
SB-09	1.50	3.39	0.49	1.35
SB-10	0.97	2.35	2.74	0.21
SB-11	2.18	3.24	0.63	0.42
SB-12	2.61	2.50	1.00	1.14
SB-13	1.38	4.61	1.47	1.80
SB-14	-	3.44	1.65	3.73
SB-15	0.77	3.76	1.83	3.35
SB-16	1.01	9.81	0.58	2.85
SB-17	3.07	11.16	0.92	0.49
Average	1.82	3.07	3.81	2.86
Range	ND -4.77	ND -11.16	0.30-25.76	0.06-34.22

Remark - : No sample  
 ND : Not detected  
 Oct, 1988 : before ship-breaking activities started  
 Jun & Jul, 1989 : during ship-breaking activities  
 Nov, 1989 : during ship-breaking activities  
 May, 1990 : after ship-breaking activities finished

Table 3-8 Concentrations of dissolved iron in seawater off  
Ban Nong Faeb, Mab Ta Phud, Rayong Province. (in µg/l)

Station	Sampling Period			
	Oct,88	Jun & Jul,89	Nov,89	May,90
C-1	-	1.40	45.68	21.79
C-2	-	5.61	32.74	17.40
C-3	-	1.10	45.58	-
C-4	-	-	44.55	-
C-5	-	-	-	-
C-6	-	-	38.72	21.69
C-7	-	4.14	2.12	0.14
SB-01	0.01	ND	1.61	5.34
SB-02	ND	ND	0.20	3.97
SB-03	ND	12.53	0.25	4.02
SB-04	ND	0.15	1.61	7.58
SB-05	13.37	0.25	0.30	3.20
SB-06	ND	1.76	10.15	4.82
SB-07	6.19	0.56	4.89	6.48
SB-08	2.72	0.62	1.69	13.04
SB-09	ND	0.56	.00	12.44
SB-10	ND	2.37	1.66	12.87
SB-11	0.43	0.25	ND	10.13
SB-12	3.14	1.08	0.00	8.47
SB-13	ND	0.86	ND	7.97
SB-14	-	1.23	ND	7.33
SB-15	0.02	2.64	1.30	15.77
SB-16	ND	0.80	0.90	13.60
SB-17	1.24	3.99	ND	11.12
Average	1.69	1.99	10.17	9.96
Range	ND -13.37	ND -12.53	ND -45.68	0.14-21.79

Remark - : No sample  
 ND : Not detected  
 Oct, 1988 : before ship-breaking activities started  
 Jun & Jul, 1989 : during ship-breaking activities  
 Nov, 1989 : during ship-breaking activities  
 May, 1990 : after ship-breaking activities finished

0.01 µg/l or not detected (ND) to 22.41 µg/l for lead, 0.11 µg/l to 23.85 µg/l for copper, ND to 34.22 µg/l for zinc, and ND to 45.68 µg/l for iron. The variations of concentration at each sampling times are as follow :

### 2.1 Lead.

The average concentrations were 0.16, 1.91, 0.19 and 1.46 µg/l, and ranges were 0.02 - 0.34 , 0.02 - 22.41, ND - 0.79 and 0.08 - 11.36 µg/l for samples collected in October 1988, June-July 1989, November 1989 and May 1990, respectively. On the average, the concentration observed in June-July 1989 was the highest and in October 1988 was the lowest.

### 2.2 Copper.

The average concentrations were 0.22, 0.52, 2.35 and 0.86 µg/l, and ranges were 0.11 - 0.35 , 0.16 - 2.55, 0.15 - 23.85 and 0.31 - 5.76 µg/l for samples collected in October 1988, June-July 1989, November 1989 and May 1990, respectively. On the average, the concentration observed in November 1989 was the highest and in October 1988 was the lowest.

### 2.3 Zinc.

The average concentrations were 1.82, 3.07, 3.81 and 2.86 µg/l, and ranges were ND - 4.77 , ND - 11.16 , 0.30 - 25.76 and 0.06 - 34.22 µg/l for samples collected in October 1988, June-July 1989, November 1989 and May 1990, respectively. On the average, the concentration observed in November 1989 was the highest and in October 1988 was the lowest.

#### 2.4 Iron.

The average concentrations were 1.69, 1.99, 10.17 and 9.96  $\mu\text{g}/\text{l}$ , and ranges were ND - 13.37, ND - 12.53, ND - 45.68 and 0.14 - 21.79  $\mu\text{g}/\text{l}$  for samples collected in October 1988, June-July 1989, November 1989 and May 1990, respectively. On the average, the concentrations observed in November 1989 was the highest and in October 1988 was the lowest.

#### Distribution of Dissolved Organic Carbon in Seawater.

The dissolved organic carbon content in the same seawater samples were also determined and the results are shown in Table 3-9. The average concentrations at each sampling period were 6.90, 5.10, 4.68 and 12.12  $\text{mgC}/\text{l}$ , and ranges were 1.97 - 11.94 , 1.91 - 8.65 , 2.17 - 27.37 and 7.05 - 32.16  $\text{mgC}/\text{l}$  .

#### Variation of Lead, Copper, Zinc and Iron Concentrations in 24 Hour.

Two sets of seawater sample were collected at station SB-10 (Figure 1-1) on June 21-22, 1989 and November 23-24, 1989. The samples were collected at every 4 hours within 24 hour period at 1 meter depth. The concentrations of lead, copper, zinc and iron were determined both in dissolved and particulate forms. The results are shown in Tables 3-10, 3-11, 3-12 and 3-13.

The average lead, copper, zinc and iron concentrations both in dissolved and particulate forms and their standard deviations are as follow :

Table 3-9 Concentrations of dissolved organic carbon in Seawater off Ban Nong Faeb, Mab Ta Phud. (mgC/l)

Station	Sampling Period			
	Oct,88	Jun & Jul,89	Nov,89	May,90
C-1	-	4.56	3.87	17.47
C-2	-	5.33	4.70	25.67
C-3	-	6.05	4.72	-
C-4	-	-	3.93	-
C-5	-	-	-	-
C-6	-	-	27.37	32.16
C-7	-	5.78	4.66	22.80
SB-01	8.51	5.50	3.98	10.85
SB-02	8.18	7.00	2.39	8.60
SB-03	7.53	3.00	3.89	10.40
SB-04	8.07	2.98	5.56	9.89
SB-05	6.52	5.87	2.30	7.05
SB-06	8.45	3.72	4.76	11.50
SB-07	5.93	3.63	4.07	8.94
SB-08	8.65	5.83	3.68	8.46
SB-09	11.95	4.62	3.22	7.93
SB-10	1.97	6.65	2.58	8.63
SB-11	7.53	8.65	3.53	9.48
SB-12	6.89	6.06	2.31	8.09
SB-13	6.71	4.70	2.91	8.39
SB-14	-	5.05	3.68	7.74
SB-15	3.95	3.73	2.17	11.56
SB-16	2.26	1.91	4.46	10.95
SB-17	7.33	6.58	2.98	8.02
Average	6.90	5.10	4.68	12.12
Range	1.97-11.95	1.91-8.65	2.17-27.37	7.05-32.16

Remark - : No sample  
 ND : Not detected  
 Oct, 1988 : before ship-breaking activities started  
 Jun & Jul, 1989 : during ship-breaking activities  
 Nov, 1989 : during ship-breaking activities  
 May, 1990 : after ship-breaking activities finished

Table 3-10 Variation of particulate lead, copper, zinc and iron concentrations in seawater in 24 hours at station SB-10 on June 21-22, 1989. (in  $\mu\text{g/l}$ )

Time	Metal			
	Pb	Cu	Zn	Fe
15:00	0.05	0.02	0.72	32.60
19:00	0.07	0.03	0.65	32.64
23:00	0.01	0.01	0.71	37.09
03:00	0.01	0.00	0.38	26.76
07:00	0.01	0.00	0.37	28.48
11:00	0.00	0.00	0.02	22.35
15:00	0.03	0.00	0.14	32.39
Average	0.03	0.01	0.43	30.33
SD ( $\pm$ )	0.02	0.01	0.26	4.48

Remark SD ( $\pm$ ) : Standard deviation

Table 3-11 Variation of particulate lead, copper, zinc and iron concentrations in seawater in 24 hours at station SB-10 on November 23-24, 1989. (in  $\mu\text{g/l}$ )

Time	Metal			
	Pb	Cu	Zn	Fe
13:00	0.01	0.00	0.00	18.24
17:00	0.19	0.02	0.93	32.12
21:00	0.16	0.12	0.72	41.69
01:00	0.07	0.12	0.57	38.58
05:00	0.13	0.25	0.54	26.50
09:00	0.14	0.00	0.35	30.57
13:00	0.04	0.03	0.39	31.41
Average	0.11	0.07	0.50	31.30
SD ( $\pm$ )	0.06	0.08	0.27	7.13

Remark SD ( $\pm$ ) : Standard deviation

Table 3-12 Variation of dissolved lead, copper, zinc and iron concentrations in seawater in 24 hours at station SB-10 on June 21-22, 1989. (in  $\mu\text{g/l}$ )

Time	Metal			
	Pb	Cu	Zn	Fe
15:00	2.11	10.10	2.11	0.00
19:00	3.59	0.29	6.43	0.26
23:00	4.08	0.23	1.54	0.00
03:00	12.10	0.28	1.72	0.42
07:00	0.93	0.00	2.86	0.00
11:00	0.98	0.21	1.99	1.23
15:00	18.96	1.07	16.97	0.11
Average	6.11	1.74	4.80	0.29
SD ( $\pm$ )	6.33	3.43	5.21	0.41

Remark SD ( $\pm$ ) : Standard deviation

Table 3-13 Variation of dissolved lead, copper, zinc and iron concentrations in seawater in 24 hours at station SB-10 on November 23-24, 1989. (in  $\mu\text{g/l}$ )

Time	Metal			
	Pb	Cu	Zn	Fe
13:00	0.12	0.23	0.62	0.09
17:00	0.13	0.38	0.86	0.93
21:00	0.24	0.36	3.41	35.69
01:00	0.49	0.26	1.43	43.27
05:00	0.24	0.64	5.07	5.77
09:00	0.13	0.23	2.95	7.24
13:00	0.04	0.30	2.74	1.66
Average	0.20	0.34	2.44	13.52
SD ( $\pm$ )	0.13	0.13	1.46	16.72

Remark SD ( $\pm$ ) : Standard deviation

## 1. Particulate Form.

Ranges of particulate metal concentration were : ND to 0.19  $\mu\text{g/l}$  for lead, ND to 0.25  $\mu\text{g/l}$  for copper, ND to 0.93  $\mu\text{g/l}$  for zinc, and 18.24 to 41.69  $\mu\text{g/l}$  for iron. The variations of concentration at each sampling period are as follow :

### 1.1 June 1989.

The averages and ranges were :  $0.03 \pm 0.02$  and ND - 0.07  $\mu\text{g/l}$  for lead,  $0.01 \pm 0.01$  and ND - 0.03  $\mu\text{g/l}$  for copper,  $0.43 \pm 0.26$  and  $0.02 - 0.72$   $\mu\text{g/l}$  for zinc, and  $30.33 \pm 4.48$  and  $22.35 - 37.09$   $\mu\text{g/l}$  for iron.

The maximum concentration of lead at 0.07  $\mu\text{g/l}$  was found at 19:00 hr. At 11:00 hr, the minimum concentration was found. The maximum concentration of copper at 0.03  $\mu\text{g/l}$  was found at 19:00 hr. At 03:00, 07:00, 11:00 and 15:00 hr, the minimum concentrations were found. The maximum concentration of zinc at 0.72  $\mu\text{g/l}$  was found at 15:00 hr. At 11:00 hr, the minimum concentration was found. The maximum concentration of iron at 37.09  $\mu\text{g/l}$  was found at 23:00 hr. At 11:00 hr, the minimum concentration was found.

### 1.2 November 1989.

The averages and ranges were :  $0.11 \pm 0.06$  and  $0.01 - 0.19$   $\mu\text{g/l}$  for lead,  $0.07 \pm 0.08$  and ND - 0.25  $\mu\text{g/l}$  for copper,  $0.50 \pm 0.27$  and ND - 0.93  $\mu\text{g/l}$  for zinc, and  $31.30 \pm 7.13$  and  $18.24 - 41.69$   $\mu\text{g/l}$  for iron.

The maximum concentration of lead at 0.19  $\mu\text{g/l}$  was



found at 17:00 hr. At 13:00 hr, the minimum concentration was found. The maximum concentration of copper at 0.25 µg/l was found at 05:00 hr. At 13:00 and 19:00 hr, minimum concentrations were found. The maximum concentration of zinc at 0.93 µg/l was found at 17:00 hr. At 13:00 hr, the minimum concentration was found. The maximum concentration of iron at 41.69 µg/l was found at 21:00 hr. At 13:00 hr, the minimum concentration was found.

## 2. Dissolved Form.

Ranges of dissolved metal concentration were : 0.04 µg/l to 18.96 µg/l for lead, ND to 10.10 µg/l for copper, 0.62 µg/l to 16.97 µg/l for zinc, and ND to 43.27 µg/l for iron. The variations of concentration at each sampling period are as follow :

### 2.1 June 1989.

The averages and ranges were :  $6.11 \pm 6.33$  and 0.93 - 18.96 µg/l for lead,  $1.74 \pm 3.43$  and ND - 10.10 µg/l for copper,  $4.80 \pm 5.21$  and 1.54 - 16.97 µg/l for zinc, and  $0.29 \pm 0.41$  and ND - 1.23 µg/l for iron.

The maximum concentration of lead at 18.96 µg/l was found at 15:00 hr. At 07:00 hr, the minimum concentration was found. The maximum concentration of copper at 10.10 µg/l was found at 15:00 hr. At 07:00 hr, the minimum concentration was found. The maximum concentration of zinc at 16.97 µg/l was found at 15:00 hr. At 23:00 hr, the minimum concentration was found. The maximum concentration of iron at 1.23 µg/l was found at 11:00 hr. At 23:00 and 07:00 hr, minimum concentrations were found.

## 2.2 November 1989.

The averages and ranges were :  $0.20 \pm 0.13$  and  $0.04 - 0.49$   $\mu\text{g/l}$  for lead,  $0.34 \pm 0.13$  and  $0.23 - 0.64$   $\mu\text{g/l}$  for copper,  $2.44 \pm 1.46$  and  $0.62 - 5.07$   $\mu\text{g/l}$  for zinc, and  $13.52 \pm 16.72$  and  $0.09 - 43.27$   $\mu\text{g/l}$  for iron.

The maximum concentration of lead at  $0.49$   $\mu\text{g/l}$  was found at 01:00 hr. At 13:00 hr, the minimum concentration was found. The maximum concentration of copper at  $0.64$   $\mu\text{g/l}$  was found at 05:00 hr. At 13:00 and 09:00 hr, the minimum concentrations were found. The maximum concentration of zinc at  $5.07$   $\mu\text{g/l}$  was found at 05:00 hr. At 13:00 hr, the minimum concentration was found. The maximum concentration of iron at  $43.27$   $\mu\text{g/l}$  was found at 01:00 hr. At 13:00 hr, the minimum concentration was found.

### Concentrations of Lead, Copper, Zinc and Iron in Bivalves.

Pen shells, Atrina vexillum, were sampled in June 1989 and November 1989. The pen shells samples were bought from a local fisherman who collected them from the coastal area nearly Ban Pla, Mab Ta Phud, Rayong Province. The concentrations observed and the average concentrations are shown in Table 3-14.

The average concentrations of lead, copper, zinc and iron in pen shell (Atrina vexillum) of two samples in June 1989 were  $13.86 \pm 5.93$   $\mu\text{g/l}$  for lead,  $95.92 \pm 6.71$   $\mu\text{g/l}$  for copper,  $306.82 \pm 43.65$   $\mu\text{g/l}$  for zinc and  $184.85 \pm 301.10$   $\mu\text{g/l}$  for iron. The ranges were  $9.56$  to  $24.08$   $\mu\text{g/l}$  for lead,  $86.66$  to  $105.55$   $\mu\text{g/l}$  for copper,  $242.33$  to  $348.39$   $\mu\text{g/l}$  for zinc and  $0.78$  to  $705.97$

Table 3-14 Concentrations of lead, copper, zinc and iron in pen shells, Atrina vexillum. ( $\mu\text{g/g}$  dry wt.)

Sample No.	Date	Metal ( $\mu\text{g/g}$ )			
		Pb	Cu	Zn	Fe
1	Jun, 1989	11.00	96.49	242.33	705.97
2	Jun, 1989	9.56	105.55	348.39	30.26
3	Jun, 1989	10.79	95.00	345.40	2.37
4	Jun, 1989	24.08	86.66	291.16	0.78
Average	Jun, 1989	13.86	95.92	306.82	184.85
SD ( $\pm$ )		5.93	6.71	43.65	301.10
5	Nov, 1989	ND	33.22	263.31	987.00
6	Nov, 1989	ND	36.25	269.02	477.54
Average	Nov, 1989	ND	34.74	266.17	732.27
SD ( $\pm$ )		ND	1.51	2.86	254.73

Remark SD ( $\pm$ ) : Standard deviation

Table 3-15 Average concentrations and concentration factors (C.F.) of lead, copper, zinc and iron in seawater and pen shells, Atrina vexillum.

Metal	June 1989			November 1989		
	Seawater ( $\mu\text{g/l}$ )	Pen shell ( $\mu\text{g/g}$ )	C.F.*	Seawater ( $\mu\text{g/l}$ )	Pen shell ( $\mu\text{g/g}$ )	C.F.*
Pb	2.23	13.86	6,220	0.09	ND	ND
Cu	0.52	95.92	184,000	5.55	34.74	6,260
Zn	3.74	306.82	82,000	5.89	266.17	45,200
Fe	1.74	184.85	106,000	2.48	732.27	295,000

Concentration of metal in pen shell  
( $\mu\text{g/g}$ )

C.F.\* (Concentration Factor) =  $\frac{\text{Concentration of metal in pen shell (}\mu\text{g/g)}}{\text{Concentration of metal in seawater (}\mu\text{g/g)}}$

µg/l for iron. In November 1989, the average concentrations were ND for lead,  $34.74 \pm 1.51$  µg/l for copper,  $266.17 \pm 2.86$  µg/l for zinc and  $732.27 \pm 254.73$  µg/l for iron, and the ranges were ND for lead, 33.22 to 36.25 µg/l for copper, 263.31 to 269.02 µg/l for zinc and 477.54 to 987.00 µg/l for iron respectively. The concentration factors of lead, copper, zinc and iron in Atrina vexillum are shown in Table 3-15.

It can be seen that both zinc and iron were highly accumulated in the pen shells. Highest zinc concentrations detected were 248.39 and 269.02 µg/g dry wt. for sampling periods June 1989 and November 1989 respectively. For iron concentrations, the maximum observed in the pen shells were 705.07 and 987.00 µg/g dry wt. for sampling periods June 1989 and November 1989 respectively.

The maximum concentration factors of zinc and iron were observed in pen shells. High concentration factors of zinc were  $8.20 \times 10^4$  and  $4.52 \times 10^4$  for sampling periods June 1989 and November 1989 respectively. For concentration factors of iron, the maximum values were  $1.06 \times 10^5$  and  $2.95 \times 10^5$  for sampling periods June 1989 and November 1989. Concentration factors of lead and copper were also observed. The concentration factors of lead were  $6.22 \times 10^3$  and not detected for sampling period June 1989 and November 1989. The concentration factors of copper were  $1.84 \times 10^5$  and  $6.26 \times 10^3$  for sampling period June 1989 and November 1989 respectively.

### Survey of Current Characteristics

The current velocity observed on June 21-22, 1989 and November 23-24, 1989 are shown in Tables 3-16 and 3-17. The directions and speeds of current in June 1989 show less variations than in November 1989.

### Result of Leaching Experiments.

Concentrations of four heavy metal in seawater, both before and after experiments, are shown in Table 3-18. After the experiments, both the particulate and dissolved forms of metals were analyzed.

The results shown the high leaching rates of scrap-iron. The amounts leached were 1.69, 0.52, 203.35 and 18.19  $\mu\text{g/l}$  for dissolved lead, copper, zinc and iron respectively. For particulate forms, the broken down amounts were 349.47, 15.01, 193.08 and 152,496.50  $\mu\text{g/l}$  for lead, copper, zinc and iron respectively.

### Recovery Yield of the Solvent Extraction Method.

The limitation of the solvent extraction method which was used for the determination of lead, copper, zinc and iron concentrations in dissolved form were determined. Triplicate experiments were carried out and the results are shown in Tables 3-19, 3-20, 3-21 and 3-22. The average percentage recoveries of the method for lead, copper, zinc and iron were 91.57, 94.19, 94.04 and 98.05, respectively.

Table 3-16 Current velocity observed at station SB-10  
on June 21-22, 1989.

Date	Time	Depth					
		Surface (2 m)		Mid-depth (8 m)		Bottom (18 m)	
		Speed (m/s)	Direction (degree)	Speed (m/s)	Direction (degree)	Speed (m/s)	Direction (degree)
21/06/89	15:00	0.201	270	-	-	-	-
21/06/89	16:00	0.243	270	-	-	-	-
21/06/89	17:00	0.276	270	-	-	-	-
21/06/89	18:00	0.241	270	0.215	280	0.158	270
21/06/89	19:00	0.149	290	0.156	270	0.146	280
21/06/89	20:00	0.083	110	0.080	50	0.095	310
21/06/89	21:00	0.094	300	0.082	310	0.047	120
21/06/89	22:00	0.104	100	0.095	50	0.080	60
21/06/89	23:00	0.138	110	0.149	85	0.173	90
21/06/89	24:00	0.098	140	0.122	60	0.128	70
22/06/89	01:00	0.116	130	0.138	90	0.112	60
22/06/89	02:00	0.088	80	0.113	30	0.110	130
22/06/89	03:00	0.088	150	0.092	20	0.180	160
22/06/89	04:00	0.088	50	0.082	80	0.136	150
22/06/89	05:00	0.161	150	0.106	150	0.106	110
22/06/89	06:00	0.156	95	0.173	93	0.112	91
22/06/89	07:00	0.219	120	0.164	100	0.156	90
22/06/89	08:00	0.255	100	0.259	100	0.222	90
22/06/89	09:00	0.319	90	0.300	90	0.179	91
22/06/89	10:00	0.312	91	0.300	91	0.143	91
22/06/89	11:00	0.234	90	0.215	90	0.098	91
22/06/89	12:00	0.186	90	0.138	92	0.113	120
22/06/89	13:00	0.156	90	0.136	110	0.118	180
22/06/89	14:00	0.083	80	0.162	290	0.094	272
22/06/89	15:00	0.113	271	0.247	271	0.201	270

Table 3-17 Current velocity observed at station SB-10  
on November 23-24, 1989.

Date	Time	Depth					
		Surface (2 m)		Mid-depth (8 m)		Bottom (18 m)	
		Speed (m/s)	Direction (degree)	Speed (m/s)	Direction (degree)	Speed (m/s)	Direction (degree)
23/10/89	13:00	0.069	310	0.095	170	0.132	140
23/10/89	14:00	0.112	240	0.041	280	0.058	110
23/10/89	15:00	0.155	260	0.149	45	0.241	270
23/10/89	16:00	0.061	90	0.179	100	0.227	120
23/10/89	17:00	0.279	80	0.104	200	0.106	300
23/10/89	18:00	0.055	250	0.059	90	0.122	100
23/10/89	19:00	0.095	100	0.179	100	0.094	210
23/10/89	20:00	0.155	130	0.173	90	0.146	300
23/10/89	21:00	0.059	170	0.098	240	0.128	300
23/10/89	22:00	0.058	120	0.092	290	0.174	290
23/10/89	23:00	0.074	260	0.071	270	0.116	285
23/10/89	24:00	0.063	250	0.132	270	0.126	300
24/10/89	01:00	0.068	120	0.087	300	0.129	270
24/10/89	02:00	0.068	270	0.198	280	0.082	280
24/10/89	03:00	0.059	290	0.106	270	0.210	280
24/10/89	04:00	0.201	105	0.257	180	0.572	160
24/10/89	05:00	0.249	185	0.990	55	0.403	280
24/10/89	06:00	0.149	290	0.180	220	0.158	130
24/10/89	07:00	0.201	200	0.210	120	0.088	290
24/10/89	08:00	0.152	200	0.101	300	0.107	290
24/10/89	09:00	0.144	290	0.144	295	0.068	150
24/10/89	10:00	0.186	180	0.106	300	0.156	270
24/10/89	11:00	0.106	280	0.122	280	0.077	280
24/10/89	12:00	0.094	270	0.092	300	0.083	210
24/10/89	13:00	0.064	260	0.070	230	0.029	280

Table 3-18 Concentrations of lead, copper, zinc and iron leached from scrap-paint, iron oxide, scrap-iron, scrap-iron left lying on the beach.

* Type	Metal (µg/l)							
	Pb		Cu		Zn		Fe	
	Diss.	Part.	Diss.	Part.	Diss.	Part.	Diss.	Part.
I	0.11	1.38	5.78	0.55	1078.63	1.68	0.00	15.15
II	0.03	16.31	0.64	8.15	11.67	59.82	0.96	53003.44
III	1.69	349.47	0.52	15.01	203.35	193.08	18.19	152496.50
IV	3.60	57.58	3.78	1.77	73.89	6.22	24.75	617.75
Seawater	0.15		0.48		1.64		0.67	

\* : I = scrap-paint, II = iron oxide,  
 III = scrap-iron, IV = scrap-iron on the beach.

Remark Diss. = Dissolved form  
 Part. = Particulate form

ศูนย์วิทยทรัพยากร  
 จุฬาลงกรณ์มหาวิทยาลัย



Table 3-19 Recovery yield of the solvent back-extraction method for dissolved lead in seawater ( $\mu\text{g/l}$ ).

1			2			3		
Conc. of Standard	Conc. Observed	Percent Recovery	Conc. of Standard	Conc. Observed	Percent Recovery	Conc. of Standard	Conc. Observed	Percent Recovery
0.25	0.2495	100.05	0.24	0.2410	98.46	0.24	0.2411	98.86
0.51	0.4562	90.12	0.50	0.3988	80.23	0.49	0.3979	81.17
2.42	2.1137	87.18	2.49	2.0344	81.60	2.45	1.9960	81.44
4.89	4.7487	97.11	4.98	4.6917	94.19	4.87	4.8123	98.78
9.79	9.1713	93.65	9.88	9.4779	95.91	9.81	9.3070	94.86
Average		93.62			90.08			91.02
SD $\pm$		4.63			7.62			8.06
Average			91.57					

Remark SD ( $\pm$ ) : Standard deviation

Table 3-20 Recovery yield of the solvent back-extraction method for dissolved copper in seawater ( $\mu\text{g/l}$ ).

1			2			3		
Conc. of Standard	Conc. Observed	Percent Recovery	Conc. of Standard	Conc. Observed	Percent Recovery	Conc. of Standard	Conc. Observed	Percent Recovery
0.25	0.2515	100.83	0.24	0.2447	99.94	0.24	0.2342	96.05
0.51	0.4849	95.79	0.50	0.4469	89.91	0.49	0.4412	90.00
2.42	2.3059	95.11	2.49	2.2501	90.25	2.45	2.2215	90.64
4.89	4.6264	94.61	4.98	4.8483	97.33	4.87	4.7121	96.72
9.79	8.3626	85.39	9.88	8.9104	90.16	9.81	9.8189	100.07
Average		94.35			93.52			94.70
SD $\pm$		5.00			4.26			3.83
Average			94.19					

Remark SD ( $\pm$ ) : Standard deviation

Table 3-21 Recovery yield of the solvent back-extraction method for dissolved zinc in seawater ( $\mu\text{g/l}$ ).

1			2			3		
Conc. of Standard	Conc. Observed	Percent Recovery	Conc. of Standard	Conc. Observed	Percent Recovery	Conc. of Standard	Conc. Observed	Percent Recovery
0.25	0.2226	89.24	0.24	0.2434	99.44	0.24	0.2391	98.06
0.51	0.7979	157.61	0.50	0.4460	89.72	0.49	0.4518	92.18
2.42	3.0120	124.24	2.49	2.4811	99.51	2.45	2.2172	90.46
4.89	4.6956	96.03	4.98	4.7528	95.42	4.87	4.6378	95.20
9.79	8.8464	90.33	9.88	9.1481	92.57	9.81	8.6184	87.84
Average		111.49			95.33			92.75
SD $\pm$		26.35			3.83			3.57
Average			94.04					

Remark SD ( $\pm$ ) : Standard deviation

Table 3-22 Recovery yield of the solvent back-extraction method for dissolved iron in seawater ( $\mu\text{g/l}$ ).

1			2			3		
Conc. of Standard	Conc. Observed	Percent Recovery	Conc. of Standard	Conc. Observed	Percent Recovery	Conc. of Standard	Conc. Observed	Percent Recovery
0.25	0.5402	216.57	0.24	0.2449	100.03	0.24	0.2377	97.46
0.51	1.2371	244.38	0.50	0.4967	99.92	0.49	0.5045	102.92
2.42	4.0088	165.36	2.49	2.6285	105.42	2.45	2.0968	85.55
4.89	6.7907	138.87	4.98	4.8257	96.88	4.87	4.7703	97.92
9.79	13.1200	133.97	9.88	9.7372	98.53	9.81	9.4105	95.91
Average		179.83			100.16			95.95
SD $\pm$		43.60			2.87			5.71
Average			98.05					

Remark SD ( $\pm$ ) : Standard deviation