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APPENDIX A

Location of sampling stations in the Gulf of Thailand (March-April 1985)

Station	Lattitude (N)	Longitude (E)	D-M-Y	Bot-DP (m)	Bottom type	Bot-pH	Bot-Oxy	Bottom Salinity
5A	13:18	100:09	29 Apr 85	10	1	8.50	4.04	30.1400
6A	13:20	100:20	29 Apr 85	11	2	8.45	4.08	31.7200
7A	13:20	100:30	29 Apr 85	12	1	8.52	4.30	31.9100
8A	13:20	100:40	29 Apr 85	18	2	8.50	4.40	32.4600
9A	13:20	100:50	29 Apr 85	14	1	8.50	4.04	32.2700
10A	13:09	100:09	29 Apr 85	18	1	8.41	3.10	32.0700
12A	13:10	100:30	30 Apr 85	18	2	8.50	4.29	32.7600
13A	13:10	100:40	30 Apr 85	22	2	8.50	4.35	32.8200
14A	13:10	100:51	29 Apr 85	22	1	8.50	4.20	32.6200
15A	13:00	100:10	28 Apr 85	16	2	8.40	3.47	32.2800
17A	13:00	100:30	30 Apr 85	21	2	8.49	4.32	32.9100
19A	13:00	100:50	30 Apr 85	12	2	8.50	4.16	32.6400
21A	12:50	100:10	28 Apr 85	19	2	8.50	4.40	32.8100
23A	12:50	100:30	30 Apr 85	-	-	-	-	-
24A	12:50	100:40	30 Apr 85	30	3	8.50	4.27	32.8100
25A	12:50	100:50	30 Apr 85	17	2	8.49	4.00	32.7200
27A	12:40	100:10	28 Apr 85	20	2	8.50	4.38	32.9400
33A	12:30	100:10	28 Apr 85	23	2	8.49	4.31	33.0700
34A	12:30	100:20	28 Apr 85	25	2	8.50	4.51	32.8100
35A	12:30	100:30	28 Apr 85	27	2	8.49	4.40	32.7600
36A	12:30	100:40	28 Apr 85	33	2	8.46	4.43	32.8500
1	11:45	99:55	02 Apr 85	24	1,5	8.40	3.82	32.7000
2	12:01	100:25	02 Apr 85	32	2	8.50	4.38	32.7400
3	12:15	100:45	02 Apr 85	29	2	8.50	4.56	32.7500
4	12:30	101:10	29 Mar 85	23	2	8.30	4.28	32.8500
5	11:00	99:40	02 Apr 85	41	1	8.50	1.56	32.5900
6	11:15	100:05	02 Apr 85	45	2	8.50	4.01	32.3500
7	11:30	100:31	03 Apr 85	49	2	8.50	3.08	32.6300
8	11:47	100:53	03 Apr 85	48	1	8.50	4.24	32.5300
9	11:58	101:18	29 Mar 85	45	2	8.40	4.25	32.5400
10	12:15	101:45	29 Mar 85	26	2,5	8.40	4.30	32.4400
11	10:14	99:25	04 Apr 85	32	1	8.30	2.84	32.6200
12	10:30	99:50	04 Apr 85	51	1,2	8.38	3.66	-
13	10:45	100:15	03 Apr 85	57	1	8.40	4.19	32.3300
14	10:59	100:40	03 Apr 85	57	2	8.35	3.34	32.6600
15	11:15	101:05	03 Apr 85	57	1	8.34	3.23	32.7600
16	11:30	101:30	03 Apr 85	58	1	8.36	1.38	33.1800
17	11:48	101:55	28 Mar 85	53	2	8.45	4.12	-
18	11:50	102:15	29 Mar 85	31	1,2	8.42	4.42	32.3700
19	09:50	99:40	04 Apr 85	26	2	8.26	2.35	32.5500
20	10:05	100:05	04 Apr 85	46	1	8.38	3.74	32.3300
21	10:20	100:30	04 Apr 85	58	2,5	8.36	3.78	32.2900
22	10:35	100:55	04 Apr 85	60	1	8.38	3.50	32.3700
23	10:50	101:20	05 Apr 85	62	2	8.31	2.64	32.9400
24	11:05	101:45	05 Apr 85	63	2	8.25	2.07	33.2000
25	11:20	102:10	27 Mar 85	61	2	8.30	1.79	33.3700
26	11:35	102:30	27 Mar 85	29	2	8.50	4.42	32.3300
27	09:35	100:15	05 Apr 85	24	1	8.35	3.30	32.3300

Location of sampling stations in the Gulf of Thailand (March-April 1985) (cont.)

Station	Lattitude (N)	Longitude (E)	D-M-Y	Bot-DP (m)	Bottom type	Bot-pH	Bot-Oxy	Bottom Salinity
28	09:50	100:40	05 Apr 85	55	1	8.38	3.60	32.3700
29	10:05	101:05	05 Apr 85	63	2	8.50	4.04	32.3200
30	10:20	101:30	05 Apr 85	73	1	8.40	2.43	32.8900
31	08:55	100:10	07 Apr 85	23	1	8.43	4.18	32.1600
32	09:10	100:35	07 Apr 85	37	2	8.48	4.47	32.1600
33	09:25	101:00	07 Apr 85	57	2	8.42	4.10	32.2300
34	09:40	101:25	07 Apr 85	72	1	8.38	3.07	32.6600
35	08:30	100:30	08 Apr 85	25	2	8.51	4.35	32.1100
36	08:45	100:55	08 Apr 85	39	2	8.49	4.40	32.3700
37	09:00	101:20	08 Apr 85	63	1	8.42	3.84	32.6900
38	09:15	101:45	08 Apr 85	75	2	8.30	2.26	33.1800
39	08:00	100:40	08 Apr 85	25	2	8.52	4.50	32.1500
40	08:15	101:05	08 Apr 85	47	2	8.51	4.48	32.5000
41	08:30	101:30	08 Apr 85	53	2	8.48	3.43	32.7100
42	08:45	101:55	08 Apr 85	72	2	8.40	3.55	33.4500
43	07:30	100:50	09 Apr 85	21	3	8.50	4.45	32.2300
44	07:45	101:15	09 Apr 85	48	1	8.49	4.18	32.5400
45	08:00	101:40	09 Apr 85	56	2	8.35	2.46	33.1800
46	08:15	102:05	08 Apr 85	65	2	8.41	3.49	33.5900
47	07:15	101:25	12 Apr 85	43	2	8.41	4.03	32.7300
48	07:30	101:50	12 Apr 85	48	2	8.42	3.82	32.8000
49	07:45	102:15	12 Apr 85	72	2	8.38	3.32	
50	08:00	102:40	13 Apr 85	73	1	8.39	3.76	33.5900
51	06:50	101:45	14 Apr 85	33	2	8.45	4.17	32.0600
52	07:05	102:10	14 Apr 85	47	2	8.55	3.91	32.7900
53	07:20	102:34	14 Apr 85	55	2	8.52	4.07	33.2800
54	07:35	103:00	14 Apr 85	58	2	8.60	4.62	33.4500

Bottom type codes :CODE	DESCRIPTION
0	Not otherwise specfied
1	Mud or ooze
2	Sand and mud
3	Sand
4	Sand, with shell and/or gravel
5	Shells
6	Gravel
7	Rock
8	Coral
9	Stone

The Upper Gulf of Thailand's data (station XXA) is from field data on board of research vessel of Department of Fisheries.

The Lower Gulf of Thailand's data is from field data on board of R/V Suk of Royal Thai Navy.

APPENDIX B

Removal of Organic Matter from Sediment

1. Accurately weigh 20-30 g of dried homoginized sediment.

2. Treat the sediment with 10% (v/v) hydrogen peroxide (H_2O_2) solution in order to remove organic matter and help the sediment to disperse.

3. Allow the reaction to progress overnight.

4. Heat at about 60 °C for completing the reaction.

5. More amounts of H_2O_2 are required for some samples which are contained large amount of organic matter.

6. Remove the excess H_2O_2 by boiling off (Jackson et al., 1949).

APPENDIX C

Calculation of the Time Required in Pipette Method

Before analysis of fine-grained sediment by doing sedimentation technique one should calculate the time for pipette out the representative solution from the designed depth by using Strokes' Law as described below.

From Strokes' Law

$$k = 175 \left[\frac{\eta h}{t(\rho_k - \rho_f)}\right]^{1/2}$$

η = vicosity of the suspension in poises

ρ_k = specific gravity of substance

ρ_f = specific gravity of the liquid

t = time (minute)

h = cm from surface of the liquid

In this experiment the representative particle for calculate the time required was quartz. At 20 °C for quartz dispersed in water the value of $\rho_k = 2.65$, $\rho_f = 0.998$ and $\eta = 0.0100$

This formula is for calculate the time (t) that no particle sizes larger than k μm in the layer above the depth h.

when k <2μm; h = 5 cm

$$2 = 175 \left[\frac{(0.01)(5)}{t(2.65-0.998)}\right]^{1/2}$$

t = 231.726695 minute

= 3 hr. 52 min.

Sedimentation Technique Using Pipette Method

1. The suspension that left after removal organic matter is then wet-sieved through 63 μm sieve.

2. The >63 μm is dried and weighed (nearest 0.0001 g), result was sand size fraction.

3. The <63 μm fraction containing silt and clay fraction is analysed by pipette method by transfer to the sedimentation cylinder.

4. 10% (w/v) Sodium hexametaphosphate is used as helping to disperse the fine sediment (add about 8-10 ml of each sample).

5. Add distilled water giving a final volume to the top line of the cylinder, the exact total value should be made.

6. Shake the cylinder well and start counting the time immidiately after shaking (the analysis should be made at constant temperature of 20 °C, if the temperature is not 20 °C the time should be change by using the equation above).

7. After 3 hr. 52 min. (see above), the aliquot is taken off by pipette at depth 5 cm to the preweighed 50-ml beaker wash the pipette with distilled water into the same container to ensure that all the sediment is transferred from the pipette.

8. Dry at the temperature not highly than 100 °C (if the sample is allowed to boil, loss of sediment is likely to occur.

9. Transfer the beaker to a dessicator to cool and then weigh accurately nearest 0.0001 g

10. Calculation of clay size fraction weight should be substract with the weight of dispersing agent.

The percentage values were plotted in a triangular diagram which proposed by Gorsline (1960) for the purpose of showing relative amount of components by their sizes (Figure 29).

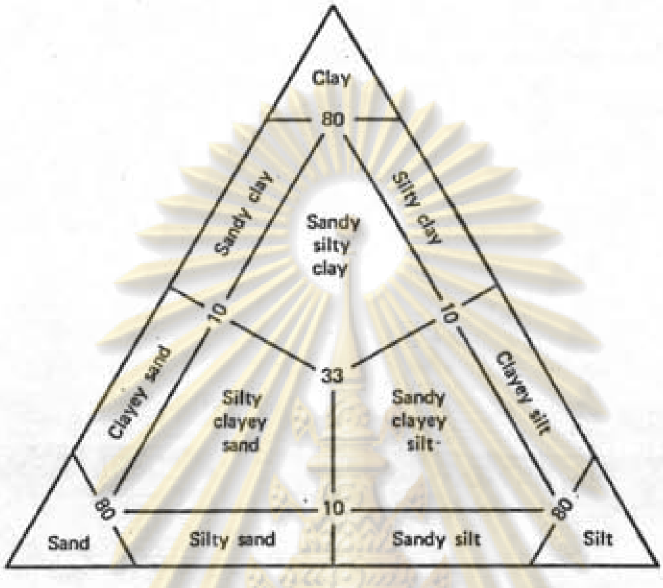


Figure 29 Category of sediments according to relative of sand, silt and clay (After Gorsline, 1960).

APPENDIX D

Clay Mineral Analysis

According to the sedimentation method from grain size analysis, the clay suspension is alliquoted and dried by evaporation. The dried clay is ground in a mortar and keeped in glass bottle until use.

To prepare slide for x-ray diffractometry, the dried sediment is dispersed in a small amount of distilled water making a thick slurry, then drop onto a clean glass slide. Allow to dry quickly at room temperature.

Four x-ray diffractogram traces are run of the oriented aggregate in the following order (Schultz, 1964; Carroll, 1974).

- untreated slide
- glycolated slide
- heat at 300 °C for half an hour
- heat at 550 °C for half an hour

The glycolated slides are prepared by place the untreat slides in the dessicator that contain ethylene glycol overnight. Leave the slide in the dessicator until require (Carroll, 1974). Avoiding that do not leave in the dessicator for too long because of the ethylene glycol that replace the H_2O molecule in the clay-layer will make the slide to be inflamed.

X-ray diffractometer to be used ia Ni-filter copper radiation generated at 40 KV and 20 mA, 1^{o} beam slit and 0.2 inch detector slit, and scanning at 1^{o} 2θ per minute over 2-37 $^{o}2\theta$ distance.

1. Indentification Technique

The °2θ that each peak occurred is converted to d spacing value by using Bragg's Law. The value in d(Å) of the characteristic reflection of kaolinite, chlorite, montmorillonite and illite before and after diagnostic treatment were shown in Table 14.

Table 14 X-ray identification of the clay minerals (<2 µm) in an oriented mount (after Carroll, 1974).

Mineral	Basal d spacing (001)	Glycolation effect; 1 hour, 60 °C	Heating effect; 1 hour
Kaolinite	7.15 Å (001); 3.75 Å (002)	No change	Becomes amorphous 550-600 °C
Kaolinite, disordered	7.15 Å (001) broad; 3.75 Å (002) broad	No change	Becomes amorphous at lower temperature than kaolinite
Illite	10 Å (002), broad, other basal spacing present but small e.g. 5 Å, 3.3 Å	No change	(001) noticeably more intense on heating as water layers are removed
Monmorillonite group	15 Å (001) and integral series of basal spacings	(001) expands to 17 Å with rational sequence of higher orders	At 300 °C (001) becomes 9 Å
Chlorite, Mg-form	14 Å (001) and integral series of basal spacing e.g. 7 Å, 4.8 Å, 3.5 Å	No change	Intensity; < 800 °C shows loss but no structural change
Chlorite, Fe-form	14 Å (001) less intense than in Mg-form; integral series of basal spacings	No change	(001) scarely increase; structure collapses below 800 °C

2. Quantitative Aspects of Clay Mineral Analysis

Truly quantitative evaluation are not yet possible in complex clay mineral assemblages, but by utilizing the intensities of characteristic x-ray peaks, approximations which may be called "semi-quantitative" can be found that useful.

The intensity of mineral's characteristic x-ray diffraction peaks can not be used directly as a measure of its abundance because of variation between diffractograms due to x-ray machine condition and to sample-mount conditions such as thickness and degree of preferred orientation. In addition, different minerals, different atomic planes within a mineral, and different samples of the same mineral generally do not have the same ability to different x-rays. Lately, variations in crystallinity and chemical composition of different samples of the same minerals detract strongly from the use of pure mineral standards for quantitative reference (Johns, Grims and Bradley, 1954; Brindley, 1961)

A peak area ratio express information about only two of the minerals in a sample and the observed ratio variations between samples may be caused by variation in one or both of the minerals. Thus, it is more practical to express the abundance of each mineral with respect to the mineral composition. The peak-area ratio can be converted into relative abundance or weight percentage by multiplying each part of the ratio by a reciporcal value of the "weighing factor" (John et al., 1954), thus, making direct comparison of their peak areas more reasonable. It involves the assumptions that the weighing factors for each mineral apply equally to all the particles of that mineral in the sample and to all the samples compared, and that the sum of the weighted peak areas accounted for 100% of the mineralogy of the sample. Therefore, weighted peak-area percentages are calculated for the <2 µm fraction because the assumption that montmorillonite, illite, kaolinite and chlorite constitute 100% of the mineralogy in that fraction is generally reasonable.

Chen (1978) argued that no single set of weighing factors can be applied to all types of clays because of the differences in ionic substitutions, degrees of in layer stacking, and particle sizes of different types of clays. However, it is beyond the scope of this work to investigate a suitable set of weighing factor for clay minerals in the Gulf. Therefore, the weighing factors proposed by Biscaye (1965) is employed for 17 Å and 10 Å glycolated peaks while the weighing factor for 7 Å glycolated peaks proposed by Chen (1978) is adopted. They are 2. 5 for 7 Å, 4 for 10 Å, and 1 for 17 Å reprsenting kaolinite and chlorite, illite, and montmorillonite respectively. The 7 Å peak area is arbitarily divided between kaolinite and chlorite. The value of 1 : 2.5 for kaolinite : chlorite is adopted. The four weighted peak areas are summed, and the weighted peak area of each mineral times 100 and divided by the sum of the areas giving the "percentage" of each mineral. The percentages calculated are, at best, untestable approximation of real percentages.

$$\text{Total } 100\% = 1(7\ \text{Å}) + 2.5(7\ \text{Å}) + 4(10\ \text{Å}) + 1(17\ \text{Å})$$

Kaolinite : chlorite in 7 Å peak = 1 : 2.5 (Fe-from chlorite).

The mentioned peak areas, which are represented by the measurement of multiple height (Schultz, 1964), is a summation of the component peak heights, including the maximal height and subordinate heights on both side of the maximam at intervals of every $0.5^{\circ}\ 2\theta$ within the peak area above the background.

APPENDIX E

Determination of Readily Oxidizable Organic Matter

The method for determine the readily oxidizable organic matter content in the sediments from the Gulf of Thailand was the Walkey-Black method (1947), which adopted by Loring and Rantala (1977). The readily oxidizable organic matter in sediment is allowed to oxidize by chromic acid and the excess chromic acid is reduced by using ferrous solution. This method will not interupt other non-sensitive organic carbon like charcoal, graphite, etc.. Proteins may also remain unoxidized. Since carbon only constitutes about 58% of the soft organic remains in sediments, the carbon content can be converted to the organic matter content by multiplying the formular.

The oxidation of carbon by chromic acid may be represented as follows :-

$$2Cr_2O_7^{2-} + 3C + 28H^+ \longrightarrow 4Cr^+ + 3C^{4+} + 14H_2O$$

and the reduction of $Cr_2O_7^{2-}$ by ferrous solution may be given as :-

$$Cr_2O_7^{2-} + 6Fe(NH_4)_2^{4+} + 14H^+ \longrightarrow 2Cr^+ + 6Fe(NH_4)^{4+} + 6NH_4^+ + 7H_2O$$

1. Materials
    - Erlenmeyer falsks, 500 ml capacity
    - Burette, 25 ml capacity, scale division 0.1 ml or more
    - Pipettes

2. Reagents
    1. 85% Orthophosphoric acid (H_3PO_4) (sp.gr. = 1.71)
    2. Concentrated sulfuric acid (H_2SO_4) with silver sulfate : dissolve 2.5 g of Ag_2SO_4 in 1 liter of conc.H_2SO_4

3. Sodium fluoride solid (NaF) (sp.gr. = 1.84)

4. Diphenylamine indicator : dissolve 0.5 g of diphenylamine in 20 ml of distilled water and 100 ml of conc.H_2SO_4

5. 0.1 N Potassium dichromate solution as primary standard : dissolve exactly 49.04 g of $K_2Cr_2O_7$ in 1 liter of distilled water.

6. 0.5 N Ferrous ammonium sulfate solution : dissolve 196.1 g of $Fe(NH_2)(SO_4)_2 \cdot 6H_2O$ in 800 ml of distilled water containing 20 ml conc. H_2SO_4 then dilute to 1 liter.

3. <u>Procedure</u>

1. Carefully weigh 0.5 g of freeze-dried sediment sample, ground in an agate mortar and passed through 70 μm nylon sieve (non-ferrous) placed in a 500 ml Erlenmeyer flask.

2. Add exactly 10 ml of 0.1 N Potassium dichromate solution by pipette and mixed carefully by gently swirling.

3. Add 20 ml of conc.H_2SO_4, mix by gently rotating the flask of the solution and sample for 1 minute, avoid spattering of the sediment onto the side of the flask.

4. After 30 minutes, let the chemical reaction complete, dilute the solution to about 200 ml by distilled water.

5. Add 10 ml of 85% orthrophosphoric acid, 0.2 g of sodium fluoride and 15 drops (or 1 ml of indicator), respectively.

6. The sample is then back titrate with 0.5 N ferrous ammonium sulfate solution until the colour of the solutions change from dull green to brillant green. Titration should be made with carefully because the colour changed is quite difficult to separate. In the beginning the colour of the sample is dull green because of the

chromous ions, and then become a turbid blue as the titration proceeds before change sharply to a brillant green at the end-point (but not every sample that can be seen the turbid blue colour).

7. If most of dichromate solution is consumed, the analysis should be repeated with smaller sediment sample.

8. Standardization of blank should be run with each new batch of samples (or every 3 hours).

4. Standardization

1. Standardization is run by using a clean 500 ml Erlenmeyer flask (without sediment).

2. Follow the above procedure.

3. Three replicate should be done.

5. Calculation of Results

The volume in ml of used ferrous ammonium salfate solution is calculated by the eqaution below. This equation is derived as shown at the end of this Appendix.

$$\%\ \text{organic carbon} = 10\left(1-\frac{T}{S}\right)(1.0)\left(\frac{12}{4000}\right)\left(\frac{100}{\text{sample weight}}\right)$$

or

$$\%\ \text{organic matter} = 10\left(1-\frac{T}{S}\right)(1.0)\left(\frac{12}{4000}\right)(1.72)\left(\frac{100}{\text{sample weight}}\right)$$

where

S = Standardization blank titration, ml of ferrous ammonium sulfate solution

T = Sample titration, ml of ferrous ammonium sulfate solution

1.72 = Conversion factor of carbon content of organic carbon

$\frac{12}{4000}$ = Milliequivalent weight carbon

Derived Equation for Calculated Readily Oxidizable OrganicMatter

1. Standardization of Ferrous Ammonium Sulfate Solution

used 1.0 N $K_2Cr_2O_7$ solution = 10 ml

used ferrous ammonium sulfate solution in titration = S ml

equivalent weight of $K_2Cr_2O_7$ in solution = $\frac{(1.0)(10)}{(1000)}$

at the equilibrium :

equi.wt. of $K_2Cr_2O_7$ = equi.wt. of Fe^{2+} solution

so Fe^{2+} concentration in solution = $\frac{(1.0)(10)}{(1000)} \frac{(1000)}{S}$ N

$$= \frac{(1.0)(10)}{S} \quad N$$

2. Titration of Sample

used ferrous ammonium sulfate solution in titration = T ml

equi. wt. of Fe^{2+} = equi.wt. of $Cr_2O_7^{2-}$ was not used

$$= \frac{(T)(1.0)(10)}{(1000)(S)}$$

At the beginning $K_2Cr_2O_7$ = $\frac{(1.0)(10)}{(1000)}$

so $K_2Cr_2O_7$ used in the reaction

$$= \frac{(1.0)(10)}{(1000)} - \frac{(T)(1.0)(10)}{(S)(1000)}$$

$$= (1.0)(10)(1-\frac{T}{S})(\frac{1}{1000})$$

= equivalent weight of carbon in organic matter

equivalent weight of C in organic matter = $(1.0)(10)(1-\frac{T}{S})(\frac{1}{1000})$

grams C in organic matter = $(1.0)(10)(1-\frac{T}{S})(\frac{1}{1000})(\frac{12}{4})$

Since carbon only constitudes about 58% of the soft organic remains in sediments, the carbon content can be converted to the organic matter content by multiplying the formular by 1.72 if want in % of organic carbon.

so $$\% \text{ organic matter} = (1.72)\left(\frac{1}{1000}\right)\left(\frac{12}{4}\right)(1.0)(10)\left(1-\frac{T}{S}\right)\left(\frac{100}{\text{sample weight}}\right)$$

APPENDIX F

Determination of Inorganic Carbon (Carbonate Content)

Several methods could be used to determine the contents of carbonate in sediment samples such as x-ray diffraction analysis, acid treatment to liberate carbondioxide (CO_2) and then detected the volume of gas or the acid-base titration technique.

In this experiment, the acid-base titration technique (Gross, 1971) is chosen because of its simplicity and suitability to clayey sediments. The sediment sample is treated with excess amount of standardized hydrochloric acid (checking by the of solution). Completing the reaction between acid and carbonate by heating, then back titrate the untreated acid with sodium hydroxide solution using phenolphthaline as an indicator.

1. Materials
   - Erlenmeyer falsks, 500 ml capacity
   - Burette, 25 ml capacity, scale division 0.1 ml or more
   - Pipettes
   - pH paper

2. Reagents
   1. 0.5 N Hydrochloric acid solution (HCl)
   2. 0.25 N Soudium hydroxide solution (NaOH)
   3. Phenolphthalien solution : dissolve 100 mg of solid indicator in 100 ml of 80% ethyl alcohol (0.1% in ethyl alcohol).
   4. Sodium carbonate (Na_2CO_3)
   5. Potassium hydrogen pthalate ($KHC_8H_4O_4$)

6. Bromocresal green solution : prepare by triturating 100 mg of solid indicator with 1.45 ml of 0.1 N NaOH, dilute to 100 ml with distilled water.

3. Procedure

1. Accurately weigh 1 g of freeze-dried sediment sample, ground in an agate mortar and pass through 70 µm nylon sieve, transfer to a 250 ml erlenmeyer flask.
2. Add 10 ml of hydrochloric acid solution
3. Heat at about 90 °C for 20 minute
4. Test pH with pH paper, if the pH was >2, add another 10 ml of hydrochloric acid solution and resume heating for 20 minute.
5. When pH is <2 after heat, dilute the solution by using distilled water to about half-full of the flask.
6. Back-titrate with sodium hydroxide solution using phenolphthalien as an indicator. The color of the solution will change sharply from colourless to purple at the end-point.
7. Standardization of acid and base solution is made dialy.

4. Standardization of Sodium Hydroxide Solution

1. Dry potassium hydrogen pthalate at 110 °C for 2 hr. and cool in a dessicator.
2. Weigh 0.9-1.0 g of potassium hydrogen pthalate (to the nearest 0.1 mg) into 250 ml Erlenmeyer flask.
3. Dissolve in 100 ml of distilled water.
4. Add 3-4 drops of phenophthalien.
5. Titrate with sodium hydroxide solution until the pink colour of the indicator persists for 30 seconds.

6. Three replicate should be done.

5. Standardization of Hydrochloric Acid Solution

1. Dry sodium carbonate at 110 °C for 2 hr. and cool in a dessicator.

2. Weigh 0.6-0.7 g portion of the sodium carbonate (to the nearest 0.1 mg) into 250 ml Erlenmeyer flask.

3. Dissolve the solid with about 25-50 ml distilled water.

4. Add 3-4 drops of bromocresal green.

5. Titrate with hydrochloric acid solution until the solution just begins to change from blue to green.

6. Boil the solution for 2-3 minutes, cool at room temperature, and complete the titration if the color is changed back from green to blue.

7. Three replicate should be done.

6. Calculation

The reactions during standardization are

Standardization of sodium hydroxide solution

$$KHC_8H_4O_4 + NaOH \longrightarrow NaK(C_8H_4O_4) + H_2O$$

Standardization of hydrochloric acid solution

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2CO_3$$

The results from the acid-base titration for carbonate contents are calculated as follows :-

a) percent CO_3-C = $[(100)(0.006)(ml_{HCl})(N_{HCl})] - [(ml_{NaOH})(N_{NaOH})]$

(This involves no assumptions about the forms of the carbonate phases)

b) percent $CaCO_3$ = $[(100)(0.05)(ml_{HCl})(N_{HCl})] - [(ml_{NaOH})(N_{NaOH})]$

(This assumes that all the carbonate occurs as $CaCO_3$)

APPENDIX G

Non-lattice Held Metals Analysis

The leachable Cd, Cr, Zn, Fe and Mn metals from non-lattice held fraction are extracted from 0.5 g of <70 μm sediment (passing through nylon seive) by 20 ml of 1 N distilled nitric acid at 100 °C for 15 minute in teflon vials. Allow the extract to cool to room temperature, then centifuge and decante the supernate into an acid-cleaned polyethylene vial. After weigh the supernate, substract with the weight of teflon vial and sediment down to at least the second decimal point. A reagent blank of samples prepare by using 1 N distilled nitric acid, and follow the same process as sediment analysis. Measurement of metal concentrations is done by using atomic adsorption spectrophotometer. Standards addition calibration curves are prepared from BDH spectrophotometric standard. Both calibration curve and blank are run with every batch of samples. This methods is found effective as the time-consuming method proposed by Chester and Voutinou (1981) (Surat, 1982).

APPENDIX H

Total Metals Analysis

The analytical technique for total Fe, Mn and Al metals in sediments is a non-destructive method by neutron ativation. The analyses were prefromed at Atomic Energy for Peace Agency by Mr. Wanchai Dharmvanij. The advantages of this method is its capability in multielement analysis without destroying the sample. The fine-grained sediments are encapsulated in acid-cleaned polyethylene vials, each containing accurately weigh 100 mg of sediment. Blank of sealed polyethylene vials are tested for contamination with every batch of samples. The standard materials employed are 5 mg of pure aluminium powder, 3 mg of high purity magnesium oxide powder, and 120 mg IAEA SD-N-1/2 standard sediments which are also encapsulated in polyethylene vials.

The samples and standard are irradiated under the same conditions in two successive steps. Short irridiations (1m-1h) are at a neutron flux of 10^{10} n/cm^2/s for 5 minutes. After leaving to decay for 9 minutes, measurements of radiation from the aluminium, and manganese isotopes are performed with Ge(Li) detector connecting to multichannel analyzer. Long irradiation are made later at neutron flux of 10^{11} n/cm^2/s for 40 hours (non-continuous irradiation) and leave to decay for 45 days before making measurement. Each sample has its flux monitor irradiate under the same conditions. Hyperpure Germanium and Ge(Li) detectors connected to multichannel analyzer are used in measuring radiation from the Fe isotope. The kind of isotopes produce under irradiation and their characteristics are listed in

Table 15.

Table 15 Nuclear properties of isotopes utilized in NAA (Habib and Minski, 1981).

Element	(n,r) product	Half-life	r-Ray energy (Kev)
<u>Short-irradiation</u>			
Al	^{28}Al	2.25 m	1179
Mn	^{56}Mn	2.6 h	847, 1811
Cr	^{51}Cr	27.8 d	320
<u>Long-irradiation</u>			
Fe	^{59}Fe	45.1 d	1099

Reference Standard SD-N-1/2

Sediment

Source : International Atomic Energy Agency
Analytical Quality Contrrol Service
Laboratory Seibersdorf
P.O. Box 100
A-1400 Vienna
Austria

Description :

This material is a natural fine-grained sediment collected from the top 0-30 cm layer of the North Sea floor in the coastal zone near the Scheldt Estuary. The sediment was growed sieved, homogenized, and stored in polyethylene bottles. A subsample of SD-N-1/1 was used for this material. A more complete description of this material can be found in the description sheet (IAEA, 1985).

Certified concentration (μg/g dry weight) :

Element	Concentration	Confidence interval
Cd	11.0	10.0-12.0
Cr	149	125-161
Zn	439	423-452

Reference :

International Atomic Energy Agency (1985) Certified reference material IAEA/Sediment SD-N-1/2, description sheet. International Atomic Energy Agency, Laboratory Seibersdorf, P.O. Box 100, A-1400 Vienna, Austria, June 1985.

International Atomic Energy Agency (1985) Intercomparison of natural radionuclide measurements in marine sediment sample SD-N-1/2. Report no. 25. International Atomic Energy Agency, Laboratory Seibersdorf, P.O. Box 100, A-1400 Vienna, Austria, June 1985.

APPENDIX I

Purification of used chemical reagent

Hydroxylamine hydrochloride ($NH_2OH \cdot HCl$)

Cryst. from aq. 75% ethanol and dried under vacumm over $CaSO_4$ or P_2O_5

Sodium acetate (NaOAc)

Cryst. from aq. ethanol as the trihydrate (if slowly heat until the dryness it will be anhydrous)

Sodium bicarbonate ($NaHCO_3$)

Cryst. from hot water (6 ml/g), the solid should not be heat above 40°C

SDS (sodium dodecyl sulfate or sodium lauryl sulfate; $CH_3(CH_2)_{11}OSO_3Na$; MW = 288.38)

(not done in this experiment because of the grade of reagent was good enough)

Purified by dissolving in hot 95% ethanol (14 ml/g) filtering and cooling, then drying in a vacuum dessicator

Trisodium citrate (solubility in hot water = 167 gm/100 ml)

Cryst. from warm water by cooling to 0°C

Na_2-EDTA (disodium dihydrogen ethylenediamine tetraacetate)

Cryst. from deionized double distilled water or prepared 10% of aq. solution at room temperature and then slowly add ethanol until precipitation, filtered with sintered-glass washed by acetone, ethyl ether and dried over night to dihydrate or at 80°C to anhydrous form.

FROM : Purification of Laboratory Chemicals, 2nd edition (D.D. Perrin, W.L. Armarego and D.R. Perrin, 1980)

APPENDIX J

Sodiumacetate-acetic acid buffer clean up

Sodium acetate-acetic acid buffer (NaOAc (1.0 M) + HOAc, pH 5) solution should be cleaned up by passing through chelex-100 resin column.

Preparation of chelex-100 column

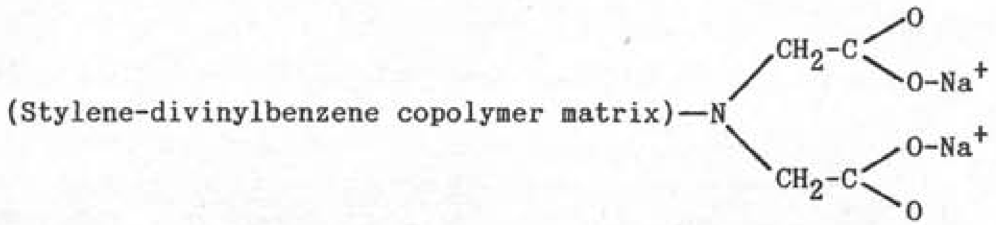
1. pack the chelex-100 resin into the column
2. rinse the resin column with methanol 4 times to wash out organic residue
3. rinse 3 times with deionized double distilled water
4. rinse 2 times with 1 N HCl
5. rinse 5 times with deionized double distilled water
6. rinse 2 times with 1 N NaOH
7. rinse 5 times with deionized double distilled water

Chelex-100

Chelex-100 is weakly acidic cation chelating resin.

Stability : breakdown in strong oxidizing agents.

Chelex-100 is a styrene divinylbenzene copolymer containing paired iminodiacetate ions which act as chelating groups in binding metal ions. Its selectivity for divalent over monovalent ions is about 5,000:1, and it has a very strong attraction for transition metals, even in highly concentrated salt solution. It's widely used for ultra purification of buffers and ionic reagents since it will scavenge metal contaminants to an extremely high degree of purity without altering the concentration of non-metallic ions.



The quantity of metals chelex-100 will absorb is a function of pH : absoption is very low below pH 2; it increases sharply from pH 2 to pH 4; and it reaches a maximum above pH 4. Any metal removed from solution is placed by an equivalent of the ions originally on the resin.

APPENDIX K

Table 16 Size composition of sand : silt : clay in the sediment samples (in percent).

Station	sand	silt	clay	sediment name
5A	8.48	80.58	10.94	silt
6A	23.95	59.17	16.88	sandy clayey silt
7A	-	-	-	-
8A	34.89	48.79	16.32	sandy clayey silt
9A	4.92	80.16	14.92	silt
10A	20.86	60.22	18.92	sandy clayey silt
12A	63.70	29.93	6.37	silty sand
13A	70.14	24.34	5.52	silty sand
14A	12.75	66.68	20.57	sandy clayey silt
15A	32.32	56.73	10.95	sandy clayey silt
17A	74.75	21.67	3.58	silty sand
19A	49.47	42.78	7.75	silty sand
21A	69.19	27.20	3.61	silty sand
23A	84.93	10.86	4.21	sand
24A	90.15	8.85	1.00	sand
25A	63.06	19.20	17.74	silty clayey sand
27A	71.00	21.10	7.90	silty sand
33A	86.82	6.11	7.07	sand
34A	-	-	-	-
35A	86.84	11.07	2.09	sand
36A	82.41	14.59	3.00	sand
1	30.07	61.96	7.97	sandy silt
2	71.06	22.25	6.69	silty sand
3	86.04	12.57	1.39	sand
4	81.66	17.89	0.45	sand
5	3.21	86.95	9.84	silt
6	63.59	32.73	3.68	silty sand
7	59.70	33.77	6.53	silty sand
8	41.50	42.45	16.05	sandy clayey silt
9	70.83	25.00	4.17	silty sand
10	85.85	13.80	0.35	sand
11	9.53	69.98	20.49	clayey silt
12	0.62	61.76	37.62	clayey silt
13	8.67	65.42	25.91	clayey silt
14	38.77	52.22	9.01	sandy silt
15	6.75	75.80	17.45	clayey silt
16	1.46	67.22	31.32	clayey silt
17	-	-	-	-
18	54.52	38.61	6.87	silty sand
19	66.03	25.81	8.16	silty sand
20	0.50	67.41	32.09	clayey silt
21	42.33	40.45	17.22	silty clayey sand
22	20.65	70.10	9.25	sandy silt
23	35.95	49.04	15.01	sandy clayey silt
24	48.25	44.41	7.34	silty sand
25	31.72	46.87	21.41	sandy clayey silt
26	46.25	46.92	6.83	sandy silt
27	0.61	64.09	35.30	clayey silt
28	3.43	65.12	31.45	clayey silt
29	28.83	58.44	12.73	sandy clayey silt
30	8.53	79.50	11.97	clayey silt
31	0.86	70.00	29.14	clayey silt
32	14.19	64.63	21.18	sandy clayey silt
33	38.50	45.88	15.62	sandy clayey silt
34	31.98	60.11	7.91	sandy silt
35	6.35	74.03	19.62	clayey silt
36	19.48	59.23	21.29	sany clayey silt
37	1.71	74.69	23.60	clayey silt
38	41.13	47.19	11.68	sany clayey silt
39	56.09	39.50	4.41	silty sand
40	4.57	74.39	21.04	clayey silt
41	33.67	53.91	12.42	sany clayey silt
42	41.26	42.84	15.90	sany clayey silt
43	100.00	0.00	0.00	sand
44	3.21	85.45	11.34	silt
45	46.68	40.56	12.76	silty clayey sand
46	36.31	49.96	13.73	sandy clayey silt
47	46.36	44.33	9.31	silty sand
48	11.36	79.44	9.20	sandy silt
49	32.37	50.68	16.95	sandy clayey silt
50	3.58	62.45	33.97	clayey silt
51	79.38	16.72	3.90	silty sand
52	-	-	-	-
53	26.47	65.57	7.96	sandy silt
54	35.80	48.26	15.94	sandy clayey silt

- data not available

sand : >63 µm

silt : 2-63 µm

clay : <2 µm

APPENDIX L

Table 17 The peak intensity of x-ray diffractograms of glycolated slides from <2 µm fraction represented by the sum of component peak heights.

Station	Peak area			Station	Peak area		
	7 Å	10 Å	17 Å		7 Å	10 Å	17 Å
5A	4.40	1.80	8.40	18	6.30	3.55	18.25
6A	9.60	8.20	21.55	19	8.40	4.05	15.30
7A	13.05	7.85	15.80	20	7.00	4.05	21.10
8A	4.45	3.00	9.00	21	18.40	12.55	25.30
9A	13.40	7.85	16.30	22	5.20	4.25	7.90
10A	6.35	4.95	12.85	23	9.00	5.35	14.70
12A	3.90	2.55	5.15	24	6.70	4.05	7.75
13A	4.70	4.15	7.40	25	12.05	7.30	27.60
14A	5.50	2.60	7.75	26	8.20	3.75	13.35
15A	5.95	5.25	9.05	27	11.80	6.70	26.10
17A	6.70	3.85	10.40	28	13.05	9.45	24.30
19A	4.70	2.45	9.00	29	9.40	5.60	23.90
21A	6.30	6.20	17.60	30	10.20	5.60	27.50
23A	4.10	2.95	2.00	31	8.50	4.20	16.55
24A	3.45	3.85	3.40	32	12.30	6.20	26.50
25A	7.70	5.35	12.20	33	11.40	8.60	23.20
27A	5.50	5.75	10.70	34	7.40	5.25	18.80
33A	4.70	3.70	8.50	35	14.00	4.80	21.70
34A	4.75	5.25	4.40	36	11.05	7.00	15.45
35A	4.00	2.95	4.50	37	7.35	3.75	21.20
36A	4.00	3.00	3.45	38	14.00	8.05	30.25
1	3.35	4.75	5.80	39	9.15	4.45	10.80
2	5.35	4.00	8.15	40	11.40	5.55	23.30
3	ND	ND	ND	41	9.60	7.10	32.95
4	ND	ND	ND	42	8.75	6.30	21.30
5	3.05	4.25	9.55	43	-	-	-
6	ND	ND	ND	44	11.25	10.95	18.95
7	4.90	4.10	5.00	45	5.50	4.45	11.10
8	8.85	4.35	12.70	46	9.25	5.45	22.80
9	ND	ND	ND	47	10.10	5.45	12.70
10	ND	ND	ND	48	13.50	9.35	27.45
11	7.25	3.25	12.15	49	10.30	7.65	34.30
12	7.60	3.65	21.85	50	8.90	4.90	16.85
13	14.75	6.95	40.55	51	7.60	4.65	13.60
14	10.45	4.85	19.30	52	8.05	7.30	13.70
15	11.80	6.80	18.00	53	4.85	5.55	19.85
16	6.00	2.85	19.95	54	15.35	13.90	22.05
17	4.25	3.95	8.40				

ND : no peak showed in the x-ray diffractrogram

* Station lacked of <63 µm fraction

Table 18 Clay composition in weight percent of the Gulf of Thailand sediments.

Station	Montmorillonite + Mixed layer	Illite	Chlorite	Kaolinite
5A	32	27	29	12
6A	27	42	22	9
7A	20	39	29	12
8A	28	37	25	10
9A	20	39	29	12
10A	27	41	23	9
12A	20	41	28	11
13A	21	46	24	9
14A	24	33	31	12
15A	20	47	24	9
17A	25	36	28	11
19A	29	32	28	11
21A	30	43	19	8
23A	8	49	31	12
24A	12	56	23	9
25A	23	41	26	10
27A	23	48	21	8
33A	24	42	24	10
34A	12	56	23	9
35A	17	45	27	11
36A	14	47	28	11
1	18	57	18	7
2	22	43	25	10
3	ND	ND	ND	ND
4	ND	ND	ND	ND
5	28	50	16	6
6	ND	ND	ND	ND
7	15	49	26	10
8	25	33	30	12
9	ND	ND	ND	ND
10	ND	ND	ND	ND
11	28	30	30	12
12	39	26	25	10
13	39	26	25	10
14	30	30	29	11
15	24	37	28	11
16	43	25	23	9
17	24	45	22	9
18	38	30	23	9
19	29	31	29	11
20	38	30	23	9
21	21	41	27	11
22	21	45	24	10
23	25	37	27	11
24	19	40	29	12
25	32	33	25	10
26	27	31	30	12
27	32	32	26	10
28	26	40	24	10
29	34	32	24	10
30	36	30	24	10
31	30	31	28	11
32	32	30	27	11
33	27	40	24	9
34	32	36	23	9
35	29	25	33	13
36	22	39	28	11
37	39	27	24	10
38	31	33	26	10
39	21	34	32	13
40	31	30	28	11
41	39	33	20	8
42	31	37	23	9
43	-	-	-	-
44	21	48	22	9
45	26	42	23	9
46	34	32	24	10
47	21	37	30	12
48	28	38	24	10
49	38	34	20	8
50	29	33	27	11
51	27	36	26	11
52	22	46	23	9
53	37	41	16	6
54	19	48	24	9

* Station 43 lacked of fine-grained fraction.

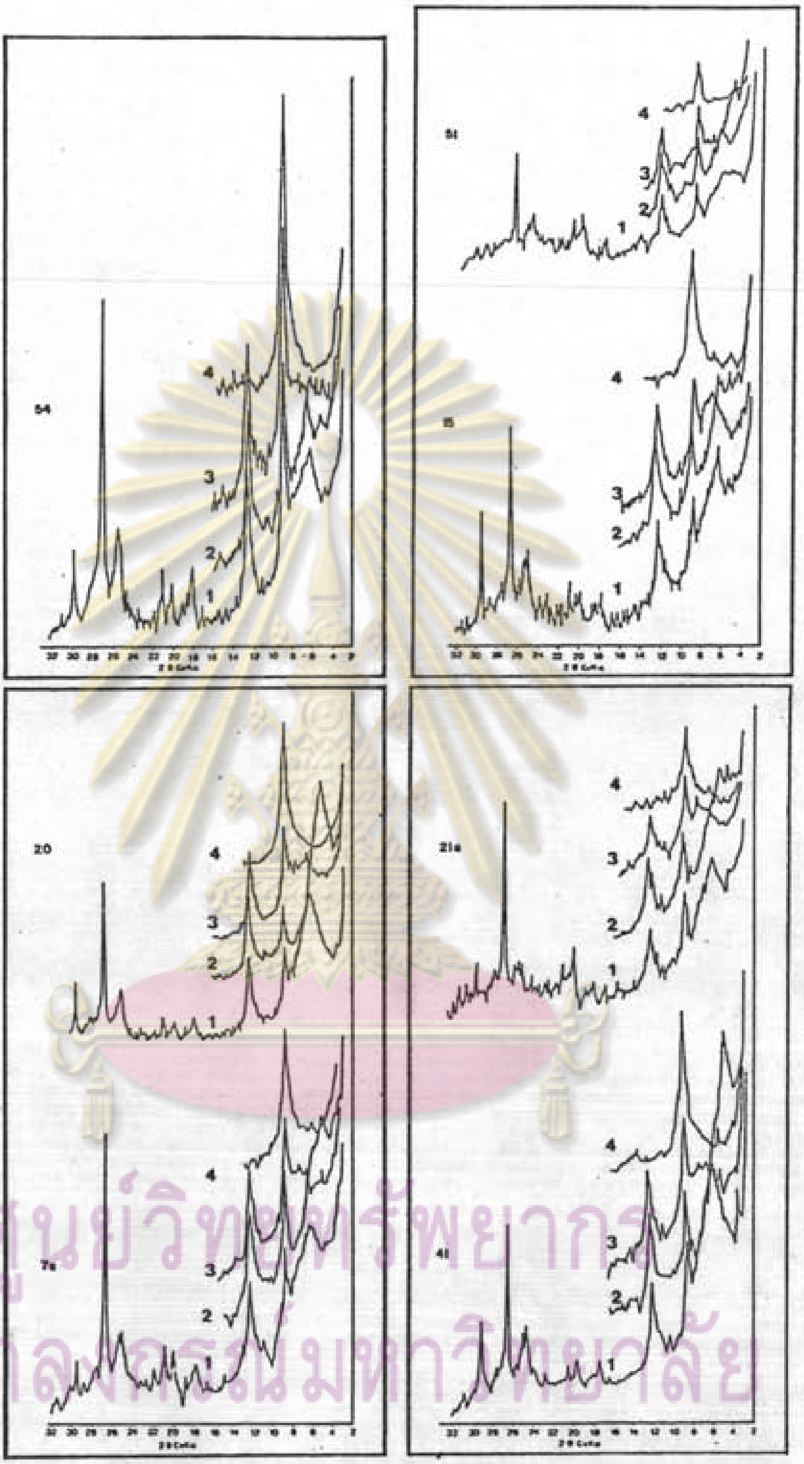


Figure 30 Characteristic peaks of each clay minerals under various treatments in diffractograms from different parts of the Gulf of Thailand.
(1) untreated (2) glycolated
(3) heat at 300 °C (4) heat at 550 °C

APPENDIX M

Table 19 Percentage of oxidizable organic matter in silt and clay fraction, and in total sediment.

Station	in silt & clay fraction	in in total sediment	Station	in silt & clay fraction	in in total sediment
5A	2.864	2.62	18	1.800	0.82
6A	2.494	1.90	19	2.563	0.87
7A	2.468	-	20	2.265	2.25
8A	2.522	1.64	21	1.092	0.63
9A	3.416	3.25	22	1.133	0.90
10A	2.858	2.26	23	1.085	0.69
12A	1.833	0.67	24	1.328	0.69
13A	2.022	0.60	25	1.400	0.96
14A	2.953	2.58	26	1.607	0.86
15A	2.632	1.78	27	2.191	2.18
17A	1.667	0.42	28	1.459	1.41
19A	2.956	1.49	29	1.126	0.80
21A	2.052	0.63	30	0.896	0.82
23A	1.310	0.20	31	2.264	2.24
24A	1.663	0.16	32	1.323	1.14
25A	2.218	0.82	33	1.270	0.78
27A	1.830	0.53	34	0.753	0.51
33A	1.579	0.21	35	1.297	1.21
34A	1.597	-	36	1.315	1.06
35A	1.395	0.18	37	1.376	1.35
36A	1.296	0.23	38	1.186	0.70
1	2.096	1.47	39	1.126	0.49
2	1.381	0.40	40	1.000	0.95
3	1.421	0.20	41	1.200	0.80
4	1.565	0.29	42	1.180	0.69
5	2.506	2.43	43	-	0.21
6	1.604	0.58	44	0.981	0.95
7	1.271	0.51	45	3.956	2.11
8	1.962	1.15	46	1.245	0.79
9	2.446	0.71	47	1.084	0.58
10	2.476	0.35	48	0.745	0.66
11	3.225	2.92	49	1.286	0.87
12	2.291	2.28	50	1.686	1.63
13	1.265	1.16	51	2.442	0.50
14	1.217	0.75	52	1.138	-
15	1.727	1.61	53	0.958	0.70
16	2.405	2.37	54	1.275	0.82
17	1.742	-			

* Station 43 no other chemical data because of lacked in <63 µm fraction.

APPENDIX N

Table 20 Percentage of carbonate content in silt and clay fraction.

Station	Carbonate content
5A	8.97
6A	9.54
7A	10.38
8A	12.94
9A	13.32
10A	13.31
12A	16.23
13A	15.92
14A	18.62
15A	14.46
17A	13.34
19A	24.34
21A	12.96
23A	13.33
24A	15.39
25A	27.13
27A	13.63
33A	8.35
34A	16.93
35A	13.37
36A	10.16
1	7.81
2	6.71
3	14.53
4	14.43
5	8.77
6	15.13
7	12.72
8	14.21
9	13.75
10	15.46
11	7.18
12	12.28
13	14.47
14	15.79
15	21.43
16	14.87
17	12.09
18	9.44
19	7.12
20	10.49
21	13.90
22	14.67
23	17.62
24	16.37
25	12.72
26	7.86
27	6.34
28	13.11
29	17.08
30	13.97
31	4.81
32	8.46
33	13.97
34	16.13
35	5.17
36	10.71
37	11.47
38	15.53
39	7.63
40	8.94
41	13.52
42	20.23
43	-
44	6.89
45	11.44
46	18.82
47	10.03
48	5.22
49	15.09
50	12.18
51	20.60
52	8.34
53	7.27
54	11.71

* Station 43 lacked of <63 μm fraction.

APPENDIX O

Table 21 Leachable metal concentration in sediments of the Gulf of Thailand in ppm (carbonate free basis).

Station	Cd	Zn	Cr	Fe	Mn	Station	Cd	Zn	Cr	Fe	Mn
5A	0.079	22.718	8.573	12302.12	803.71	18	0.056	15.507	13.339	11705.01	406.42
6A	0.071	23.677	11.012	13434.96	757.09	19	0.093	15.900	9.637	7853.94	511.95
7A	0.056	24.466	16.175	16579.71	682.40	20	0.086	29.288	27.245	11987.94	510.85
8A	0.082	27.188	12.946	14703.51	762.92	21	0.105	17.065	17.503	7701.38	519.61
9A	0.102	31.980	20.467	11512.66	831.47	22	0.065	14.778	10.813	7208.68	428.02
10A	0.112	23.394	17.995	15895.43	824.76	23	0.152	14.361	15.891	7902.51	613.80
12A	0.069	19.315	22.074	11478.33	620.82	24	0.133	16.354	18.798	8177.05	493.44
13A	0.081	16.916	13.012	11016.77	542.16	25	0.085	13.349	10.680	8009.72	367.11
14A	0.134	18.160	19.633	11976.28	582.86	26	0.134	15.796	12.245	17632.10	321.42
15A	0.257	19.755	18.255	10366.26	684.56	27	0.057	24.750	7.021	13375.81	493.69
17A	0.631	16.797	15.132	9760.45	425.60	28	0.116	26.227	9.625	10827.61	481.23
19A	0.747	24.915	27.684	7730.10	638.85	29	0.082	15.416	15.720	6791.60	677.08
21A	0.223	18.248	15.561	11246.04	530.47	30	0.097	14.840	7.067	6656.87	477.01
23A	0.423	16.700	12.724	9924.86	447.34	31	0.088	23.860	17.854	14607.85	395.63
24A	0.829	19.226	22.098	12198.31	828.69	32	0.080	21.876	8.102	10451.77	394.97
25A	0.090	19.137	19.331	9104.70	434.94	33	0.409	22.147	18.079	10169.52	480.44
27A	0.202	16.685	11.123	12108.60	595.90	34	0.101	12.889	12.474	6028.86	493.74
33A	0.043	13.591	11.691	9118.94	493.21	35	0.049	12.995	9.996	9162.85	291.55
34A	0.175	15.061	15.213	9493.10	855.75	36	0.089	20.732	12.693	12212.20	449.55
35A	0.214	16.362	14.075	10978.16	462.34	37	0.083	23.888	11.176	9429.56	445.29
36A	0.162	15.079	12.199	11162.47	457.48	38	0.103	17.140	25.393	8252.75	634.83
1	0.356	13.351	6.138	7227.90	517.92	39	0.073	11.316	9.105	9131.27	365.84
2	0.076	11.135	11.519	6527.67	407.98	40	0.072	18.849	19.040	10053.06	285.60
3	0.740	14.900	12.876	9381.42	620.83	41	0.075	18.085	9.274	7277.98	376.77
4	0.188	18.183	10.292	9845.84	407.39	42	0.134	23.106	-	9301.99	814.67
5	0.105	14.119	10.758	7100.08	504.27	43	-	-	-	-	-
6	0.091	14.853	16.906	10397.29	520.77	44	0.040	13.714	13.271	6945.40	221.19
7	0.102	16.508	14.872	12804.76	456.47	45	0.100	24.804	17.591	15145.74	329.83
8	0.135	18.738	14.276	11510.19	468.44	46	0.114	22.875	14.338	8798.20	610.99
9	0.099	15.481	21.640	9538.28	499.39	47	0.037	12.700	15.021	6964.22	281.64
10	0.594	16.744	16.927	9764.56	540.62	48	0.034	11.965	5.697	5572.15	192.29
11	0.114	16.562	14.196	7098.20	561.94	49	0.095	26.568	12.429	10487.27	495.23
12	0.092	27.499	22.483	10376.75	486.41	50	0.104	34.616	13.417	14168.71	553.47
13	0.115	19.743	27.597	9552.77	517.44	51	2.134	21.117	9.822	9380.01	245.55
14	0.063	13.036	18.624	6555.49	372.47	52	0.051	18.372	8.962	7304.11	252.06
15	0.121	21.417	15.352	11237.75	690.85	53	0.033	13.882	6.457	6166.12	282.48
16	0.108	21.889	19.457	10117.77	608.04	54	0.574	25.370	9.951	11686.34	460.38
17	0.109	13.267	12.199	10704.72	428.88						

* Station 43 lacked of <63 um fraction

TEST OF PRECISION

Table 22 Replicate leachable metals concentration in sediments of the Gulf of Thailand in ppm (carbonate free basis).

Station	Cd	Zn	Cr	Fe	Mn
10-1	0.663	17.561	8.869	9791.815	532.163
10-2	0.537	16.762	18.024	9949.049	540.710
10-3	0.572	15.834	14.560	9609.419	545.990
10-4	** 0.959	17.142	23.280	9967.886	555.535
10-5	0.604	16.422	19.905	9504.625	528.726
average	0.594	16.744	16.927	9764.559	540.625
S.D.	0.047	0.593	4.918	183.170	9.636
% of S.D.	7.829	3.541	29.056	1.876	1.782
23-1	0.149	12.699	11.813	7678.443	590.649
23-2	** 0.481	14.925	22.743	7931.607	639.646
23-3	0.141	13.992	14.926	7836.003	594.697
23-4	0.157	14.587	11.308	7666.572	593.990
23-5	0.160	15.600	18.666	8399.900	649.993
average	0.152	14.361	15.891	7902.505	613.795
S.D.	0.007	0.980	4.318	267.783	25.578
% of S.D.	4.706	6.825	27.172	3.389	4.167
54-1	0.767	27.006	6.155	11725.801	461.648
54-2	0.491	21.114	12.707	11436.620	452.699
54-3	0.524	27.026	11.063	12043.220	474.142
54-4	0.516	25.766	10.994	11337.298	463.799
54-5	** 0.906	25.936	8.835	11888.738	449.614
average	0.574	25.370	9.951	11686.335	460.380
S.D.	0.112	2.191	2.262	266.111	8.690
% of S.D.	19.458	8.638	22.729	2.277	1.888

** Likely to be contaminated

APPENDIX P

Table 23 Metal concentration in sediments of the Gulf of Thailand in ppm (carbonate free basis).

Station	Cr	Fe	Mn	Al
5A	73.93	31198.51	1062.29	70526.20
6A	67.65	29405.26	967.28	60468.72
7A	74.09	31466.19	914.27	62039.72
8A	72.02	27567.20	965.48	61796.46
9A	72.57	34148.59	1072.34	81218.27
10A	73.25	31376.17	1094.36	67827.89
12A	66.61	26859.26	789.54	53002.27
13A	70.88	25570.88	734.60	48406.28
14A	69.30	29982.80	833.87	67829.93
15A	68.97	29226.09	904.52	59153.61
17A	70.51	22501.73	521.50	49273.02
19A	66.09	22468.94	806.67	52471.58
21A	75.94	26999.08	705.19	50896.14
23A	71.07	24229.84	602.05	47421.25
24A	49.88	25647.09	1109.80	46212.03
25A	49.27	24289.83	659.39	51461.51
27A	69.47	30566.17	763.00	47238.62
33A	61.87	26623.02	652.48	48663.39
34A	65.97	27928.25	1533.16	47911.40
35A	80.00	35438.07	729.25	52983.95
36A	90.94	41963.49	703.42	54652.72
1	71.48	28419.57	621.54	50547.78
2	63.89	21867.30	490.94	43520.21
3	70.32	26208.03	603.72	54171.05
4	65.68	22788.36	518.87	41720.23
5	61.93	23676.42	633.56	54148.85
6	70.70	27571.58	732.89	56203.61
7	83.87	39184.23	659.95	62442.71
8	80.66	29723.74	678.40	68772.58
9	102.96	26318.84	662.03	60985.51
10	71.45	28625.50	745.21	58079.02
11	64.97	26610.64	770.31	63456.15
12	91.54	31007.75	658.91	87551.30
13	68.28	25488.13	688.65	72255.35
14	66.62	20306.38	597.32	55219.10
15	81.71	30036.91	874.38	78146.88
16	85.28	30658.99	825.80	87160.81
17	74.96	26163.12	536.91	47434.88
18	63.49	27495.58	506.85	43507.07
19	50.93	19595.18	595.39	51894.92
20	84.24	32510.33	702.71	88705.17
21	69.69	30545.88	804.88	75029.04
22	63.99	19688.27	596.51	52384.86
23	63.85	20029.13	748.97	54989.08
24	78.08	20088.48	658.85	58710.99
25	74.47	30247.48	492.67	54307.97
26	63.06	30605.60	452.57	42869.55
27	87.55	28614.14	683.32	80183.64
28	72.51	29807.80	646.79	76188.28
29	66.33	23396.04	906.90	56198.75
30	70.09	18016.97	628.85	49633.85
31	77.42	30780.54	508.46	83307.07
32	62.49	27310.47	539.65	66637.54
33	62.89	29059.63	647.45	66604.67
34	58.54	16454.04	633.12	43162.04
35	59.79	20774.02	398.61	49984.18
36	65.74	26430.73	565.57	66076.83
37	66.42	25189.20	582.85	65175.65
38	67.48	23440.27	807.39	53391.74
39	40.49	18187.72	490.42	40381.08
40	61.94	24928.62	396.44	66329.89
41	77.01	21970.40	524.98	58973.17
42	75.59	25698.88	1094.40	62805.57
43	-	-	-	-
44	59.28	19761.57	307.16	52411.13
45	71.14	33310.75	473.13	63233.97
46	75.23	26237.99	756.34	63562.45
47	47.35	24341.45	384.57	54907.19
48	42.84	16248.15	298.59	44102.13
49	68.78	28382.99	671.30	66541.04
50	74.70	34957.87	699.16	86882.26
51	71.66	24307.30	394.21	60201.51
52	58.80	20401.48	354.57	51931.05
53	49.82	21567.99	387.15	51547.50
54	73.39	34205.46	599.16	70109.87

* Station 43 lacked of <63 um fraction.

Table 24 Enrichment factor of Cr, Fe and Mn in sediments of the Gulf of Thailand

Station	Cr	Fe	Mn	Cr	Fe	Mn	Station	Cr	Fe	Mn	Cr	Fe	Mn
		(1)			(2)				(1)			(2)	
5A	0.93	0.75	1.42	1.47	0.57	1.49	18	1.30	1.08	1.10	2.04	0.82	1.15
6A	0.99	0.83	1.51	1.57	0.63	1.58	19	0.87	0.64	1.08	1.37	0.49	1.13
7A	1.06	0.86	1.39	1.67	0.66	1.46	20	0.84	0.62	0.75	1.33	0.47	0.78
8A	1.04	0.76	1.47	1.63	0.58	1.54	21	0.83	0.69	1.01	1.30	0.53	1.06
9A	0.79	0.72	1.24	1.25	0.54	1.30	22	1.09	0.64	1.07	1.71	0.49	1.13
10A	0.96	0.79	1.52	1.51	0.60	1.59	23	1.03	0.62	1.28	1.63	0.47	1.35
12A	1.12	0.86	1.40	1.76	0.65	1.47	24	1.18	0.58	1.06	1.86	0.44	1.11
13A	1.30	0.90	1.43	2.05	0.68	1.50	25	1.22	0.95	0.85	1.92	0.72	0.90
14A	0.91	0.75	1.16	1.43	0.57	1.21	26	1.31	1.22	0.99	2.06	0.92	1.04
15A	1.04	0.84	1.44	1.63	0.64	1.51	27	0.97	0.61	0.80	1.53	0.46	0.84
17A	1.27	0.78	1.00	2.00	0.59	1.05	28	0.85	0.67	0.80	1.33	0.51	0.84
19A	1.12	0.73	1.45	1.76	0.55	1.52	29	1.05	0.71	1.52	1.65	0.54	1.59
21A	1.33	0.90	1.30	2.09	0.69	1.37	30	1.26	0.62	1.19	1.98	0.47	1.25
23A	1.33	0.87	1.19	2.10	0.66	1.25	31	0.83	0.63	0.57	1.30	0.48	0.60
24A	0.96	0.94	2.26	1.51	0.72	2.37	32	0.83	0.70	0.76	1.31	0.53	0.80
25A	0.85	0.80	1.21	1.34	0.61	1.27	33	0.84	0.74	0.91	1.32	0.56	0.96
27A	1.31	1.10	1.52	2.06	0.84	1.60	34	1.21	0.65	1.38	1.90	0.49	1.45
33A	1.13	0.93	1.26	1.78	0.71	1.33	35	1.06	0.71	0.75	1.67	0.54	0.79
34A	1.22	0.99	3.01	1.93	0.75	3.16	36	0.88	0.68	0.81	1.39	0.52	0.85
35A	1.34	1.14	1.30	2.11	0.86	1.36	37	0.91	0.66	0.84	1.43	0.50	0.88
36A	1.48	1.31	1.21	2.33	0.99	1.27	38	1.12	0.75	1.42	1.77	0.57	1.49
1	1.26	0.96	1.16	1.98	0.73	1.22	39	0.89	0.77	1.14	1.40	0.58	1.20
2	1.30	0.86	1.06	2.06	0.65	1.11	40	0.83	0.64	0.56	1.31	0.49	0.59
3	1.15	0.82	1.05	1.82	0.63	1.10	41	1.16	0.63	0.84	1.83	0.48	0.88
4	1.40	0.93	1.17	2.20	0.71	1.23	42	1.07	0.70	1.64	1.69	0.53	1.72
5	1.02	0.74	1.10	1.60	0.57	1.16	43	-	-	-	-	-	-
6	1.12	0.84	1.23	1.76	0.63	1.29	44	1.01	0.64	0.55	1.58	0.49	0.58
7	1.19	1.07	0.99	1.88	0.81	1.04	45	1.00	0.90	0.70	1.58	0.68	0.74
8	1.04	0.74	0.93	1.64	0.56	0.97	46	1.05	0.70	1.12	1.66	0.53	1.18
9	1.50	0.73	1.02	2.36	0.56	1.07	47	0.77	0.75	0.66	1.21	0.57	0.69
10	1.09	0.84	1.21	1.72	0.64	1.27	48	0.86	0.63	0.64	1.36	0.48	0.67
11	0.91	0.71	1.14	1.43	0.54	1.20	49	0.92	0.73	0.95	1.45	0.55	1.00
12	0.93	0.60	0.71	1.46	0.46	0.74	50	0.76	0.68	0.76	1.20	0.52	0.80
13	0.84	0.60	0.90	1.32	0.46	0.94	51	1.06	0.69	0.62	1.67	0.52	0.65
14	1.07	0.63	1.02	1.69	0.48	1.07	52	1.01	0.67	0.64	1.59	0.51	0.67
15	0.93	0.65	1.05	1.46	0.50	1.11	53	0.86	0.71	0.71	1.35	0.54	0.74
16	0.87	0.60	0.89	1.37	0.45	0.94	54	0.93	0.83	0.80	1.47	0.63	0.84
17	1.40	0.94	1.07	2.21	0.71	1.12							

(1) compare with shale
(2) compare with near-shore muds

Table 25 Metal concentration from each fraction (μg/g).
(carbonate free basis)

Experiment 1

(a) Cd

Sample	Carbonate	Organic	Oxyhydroxide	Sum	Residual	Total
8A (1)	0.049		0.006	0.055	0.062	0.117
(2)	0.046		0.007	0.053	0.049	0.102
27A (1)	0.054		0.008	0.063	0.051	0.113
(2)	0.053		0.008	0.061	0.034	0.095
13 (1)	0.144		0.006	0.150	0.032	0.181
(2)	0.141		0.008	0.150	0.022	0.172
16 (1)	0.173		0.012	0.184	0.039	0.223
(2)	0.167		0.005	0.172	0.034	0.206
37 (1)	0.125		0.010	0.136	0.033	0.168
(2)	0.132		0.005	0.137	0.023	0.159
47 (1)	0.048		0.007	0.054	0.032	0.087
(2)	0.046		0.004	0.050	0.040	0.090

(b) Cr

Sample	Carbonate	Organic	Oxyhydroxide	Sum	Residual	Total
8A (1)	1.149	0.859	2.070	4.078	59.929	64.006
(2)	0.956	0.758	2.332	4.045	68.723	72.768
27A (1)	1.123	0.865	1.369	3.356	55.009	58.365
(2)	1.042	0.873	2.199	4.114	22.881	26.994
13 (1)	1.216	0.977	1.501	3.695	60.477	64.172
(2)	1.096	0.846	1.345	3.287	84.055	87.341
16 (1)	1.183	0.885	2.903	4.970	63.468	68.438
(2)	1.003	1.548	2.506	5.057	95.701	100.758
37 (1)	1.048	0.770	1.282	3.101	49.909	53.009
(2)	0.968	0.793	1.236	2.997	58.676	61.673
47 (1)	0.923	0.688	1.100	2.711	43.582	46.293
(2)	1.004	0.774	1.236	3.013	49.630	52.643

(c) Zn

Sample	Carbonate	Organic	Oxyhydroxide	Sum	Residual	Total
8A (1)	1.177	1.100	3.742	6.020	55.679	61.699
(2)	0.979	1.105	3.689	5.773	60.703	66.476
27A (1)	0.329	0.548	1.083	1.959	51.583	53.542
(2)	0.610	0.724	1.017	2.350	18.144	20.494
13 (1)	0.357	0.608	0.849	1.813	78.086	79.899
(2)	0.320	0.716	0.912	1.948	92.280	94.228
16 (1)	0.347	0.950	1.148	2.444	82.838	85.283
(2)	0.294	0.828	0.991	2.113	77.088	79.201
37 (1)	0.461	0.508	1.159	2.128	73.825	75.953
(2)	0.425	0.829	1.117	2.371	61.633	64.004
47 (1)	0.270	0.152	0.746	1.168	51.163	52.331
(2)	0.295	0.652	0.559	1.506	47.629	49.135

Table 26 Metal concentration from each fraction (µg/g).
(carbonate free basis)

Experiment 2

(a) Cd

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.034	0.002	0.003	0.040	0.042	0.083
(2)	0.032	0.003	0.003	0.039	0.034	0.074
37 (1)	0.066	0.006	0.001	0.072	0.033	0.105
(2)	0.064	0.006	0.001	0.071	0.041	0.112

(b) Cr

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	2.024	1.481	6.986	10.490	67.000	77.490
(2)	1.321	1.467	7.263	10.051	67.032	77.082
37 (1)	1.329	0.971	5.144	7.445	76.141	83.586
(2)	1.302	0.476	5.522	7.300	71.808	79.109

(c) Zn

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.691	3.129	6.669	10.489	69.558	80.047
(2)	0.967	3.213	6.470	10.650	69.778	80.428
37 (1)	0.390	0.912	1.747	3.049	79.127	82.176
(2)	0.286	0.893	1.933	3.112	76.114	79.226

Table 27 Metal concentration from each fraction (μg/g).
(carbonate free basis)

Experiment 3

(a) Cd

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.031	0.005	0.002	0.038	0.040	0.078
(2)	0.028	0.003	0.000	0.031	0.029	0.060
37 (1)	0.067	0.007	0.002	0.076	0.035	0.111
(2)	0.067	0.007	0.001	0.075	0.029	0.104

(b) Cr

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	1.157	1.269	6.849	9.275	53.640	62.915
(2)	1.012	1.506	6.585	9.103	47.757	56.860
37 (1)	1.056	0.792	5.792	7.640	45.954	53.594
(2)	1.054	0.771	5.124	6.949	49.591	56.540

(c) Zn

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.763	2.582	7.040	10.385	67.898	78.283
(2)	0.667	2.651	7.244	10.563	68.022	78.585
37 (1)	0.232	0.743	2.266	3.241	69.245	72.486
(2)	0.232	0.634	2.205	3.070	72.746	75.816

Table 28 Metal concentration from each fraction (µg/g).
(carbonate free basis)

Experiment 4

(a) Cd

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.026	0.006	0.006	0.038	0.038	0.076
(2)	0.026	0.008	0.006	0.040	0.042	0.083
37 (1)	0.055	0.010	0.002	0.068	0.038	0.106
(2)	0.053	0.011	0.002	0.067	0.035	0.102

(b) Cr

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.347	1.246	5.720	7.313	70.190	77.503
(2)	0.749	1.342	5.894	7.984	73.106	81.090
37 (1)	0.337	0.724	4.578	5.639	78.716	84.354
(2)	0.306	0.660	4.391	5.356	77.985	83.341

(c) Zn

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.232	2.489	7.041	9.762	71.431	81.193
(2)	0.249	2.557	6.795	9.601	71.458	81.059
37 (1)	0.056	0.560	1.856	2.473	76.265	78.737
(2)	0.103	0.511	1.592	2.205	75.914	78.119

Table 29 Metal concentration from each fraction (μg/g).
(carbonate free basis)

Experiment 5

(a) Cd

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.023	0.018	0.009	0.051	0.032	0.083
(2)	0.030	0.018	0.010	0.059	0.039	0.098
37 (1)	0.050	0.030	0.007	0.087	0.044	0.131
(2)	0.042	0.029	0.007	0.078	0.032	0.110

(b) Cr

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.338	2.351	6.230	8.919	72.433	81.352
(2)	0.363	2.501	5.677	8.540	71.867	80.407
37 (1)	0.326	1.925	4.359	6.610	78.144	84.754
(2)	0.297	1.915	3.821	6.033	68.415	74.448

(c) Zn

Sample	Carbonate	Oxyhydroxide	Organic	Sum	Residual	Total
8A (1)	0.207	2.457	6.638	9.302	71.210	80.511
(2)	0.165	2.862	6.764	9.792	70.319	80.111
37 (1)	0.058	0.703	1.453	2.213	78.076	80.289
(2)	0.114	0.699	1.327	2.141	67.815	69.956

Table 30 Leacheable and total metal concentrations (µg/g).
(carbonate free basis)

(a) Cd

Sample	Leach	Total (1)	Total (2)
8A (1)	0.039	0.086	0.077
(2)	0.041	0.080	0.080
27A (1)	0.044	0.075	
(2)	0.051	0.074	
13 (1)	0.098	0.143	
(2)	0.102	0.112	
16 (1)	0.137	0.182	
(2)	0.133	0.182	
37 (1)	0.069	0.134	0.108
(2)	0.078	0.159	0.102
47 (1)	0.034	0.089	
(2)	0.034	0.083	

(b) Cr

Sample	Leach	Total (1)	Total (2)
8A (1)	31.479	62.569	88.469
(2)	32.596	52.606	86.415
27A (1)	32.605	44.643	
(2)	37.256	44.433	
13 (1)	40.022	51.640	
(2)	46.445	51.150	
16 (1)	62.997	57.875	
(2)	68.502	51.134	
37 (1)	36.210	49.411	97.271
(2)	38.808	49.610	97.059
47 (1)	33.939	62.901	
(2)	40.111	58.637	

(c) Zn

Sample	Leach	Total (1)	Total (2)
8A (1)	28.763	92.099	100.326
(2)	25.827	88.647	103.496
27A (1)	14.013	59.789	
(2)	16.286	61.488	
13 (1)	18.768	91.465	
(2)	20.341	91.036	
16 (1)	21.981	101.649	
(2)	23.751	96.374	
37 (1)	21.300	93.619	102.510
(2)	21.127	86.882	101.416
47 (1)	15.085	68.861	
(2)	15.127	70.925	

BIOGRAPHY

Miss Penjai Sompongchaiyakul was born on 6th November 1962 in Bangkok. She graduated with a B.Sc. in Marine Science from Chulalongkorn University in 1984. She joined student activities in Faculty of Science during her undergraduate study which later she had an occasion to be a President of Science Study Club in 1983. In her last year of undergraduate study she was awarded Certificate of Good Behavior by the Buddhist Society of Thailand. After graduation she enrolled in a Master Degree Course in the same Department and act as a part-time research assistant in some field works and laboratory analysis of field samples. The research projects she have been involved in are

1. The Eastern Seaboard Project 1984-1985
2. Behaviour of some trace elements during river-sea water mixing in the Bang Pakong Estuary 1983-1985 co-operative research with the U.S. National Science Foundation through Prof. H.L. Windom, from Skidaway Institute of Oceanography
3. The chemistry of the Mae Klong River and its influence on the ecosystem of razor shells at Don Hoi Lord, Samut Songkram 1985-1987
4. Impact of human activities on the mangrove ecosystem 1985-1986
5. Assessment of the coastal environment of the Upper South area 1986-1989

In 1986 she got a Somdejpharmahittalhathibeth scholarship.

In July 1984 she was awarded the fellowship to attend the International Seminar for Youth at Republic of China (Taiwan), which she had an opportunity to communicate with students from several countries.

During July-August 1985, she was awarded a fellowship to attend the Training Course on Marine Pollution at Bermuda Biological

Station where she gained extensive experience on analysis of trace metals, chlorinated hydrocarbons and petroleum hydrocarbons, technique of "Clean Room " analysis, etc.

During April-May 1986, a Regional training Workshop in Riverine Input to the Coastal Zones was held at the Department of marine Science by IOC Expert Group on Method, Inter-calibration and Standardization (GEMSI). She attended the lectures and worked as a technical assistant for the expert group. she gained further experience on river input systems and methodology associated with the planning, field work and laboratory analysis.

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