Chapter 4
Results

4.1 Interstitial nutrient concentration at different depths

Sediment samples from Klong Lat Khao Kao were analyzed for concentrations of interstitial nutrients at different depths. Results are summarized below.

4.1.1 pH at different depths

Results of analysis are given in Table 4.1. In March 1990 (dry season) pH ranged from 6.4 to 6.7 (Station 1), 6.3 to 6.6 (Station 2), 6.3 to 6.7 (Station 3), and 6.3 to 6.6 (Station 4). In October 1990 (wet season) pH ranged from 6.3 to 6.7 (Station 1), 6.4 to 6.8 (Station 2), 6.3 to 6.9 (Station 3), and 6.3 to 6.8 (Station 4). The pH value averaged 6.4 in March 1990 and 6.5 in October 1990 (Table 4.1) Vertical distributions at each station at different depths are presented in Figure A1 for dry season and Figure A9 for wet season. Figure 4.1 details vertical pH profiles for March 1990 and October 1990, as can be seen, in March, pH values are higher at the surface and the profile decreased with increasing depth. In October, pH values were less at the surface and lowest at the depth of 10 cm then pH values was not change with depth. The study also found mangrove sediment in this area were weak acid.

4.1.2 Redox potential at different depths

Results of analysis of redox potential at different depths are given in Table 4.1 and Figure 4.2. In March 1990 (dry season) Eh values ranged from 221 at the surface to -66 mV at a depth of 60 cm (Station 1), 137 at the surface to -140 mV at a depth of 60 cm (Station 2), 92 at the surface to -149 mV at a depth of 70 cm (Station 3), 69 at the surface to -102 mV at a depth of 60 cm (Station 4). In October 1990 (wet season) they ranged from 201 at the surface to -161 mV at a depth 70 cm (Station 1), 123 at the surface to -120 at a depth of 70 cm (Station 2), 96 at the surface to -136 mV at a depth of 70 cm (Station 3), 152 at the surface to -49 mV at a depth of 70 cm a depth of 70 cm (Station 4). The redox potential of each station is presented in Figure A2 for March 1990 and Figure A10 for October 1990.

As can be seen in Figure 4.2, in March, showed positive values of Eh at the surface (over +100 mV) and decreased to negative at the depth of 15 cm, then decreased with depth. In October, vertical distribution of Eh was similarly to March. However, positive were found at the surface of the sediment. Eh values were negative between the depth of 25-30 cm the decreased with depth.

4.1.3 Water content at different depths

Average of water content are presented in Table 4.1 and Figure 4.3. In March 1990, the content ranged from 43 to 51% (Station 1), 42 to 49% (Station 2), 42 to 48% (Station 3), and 41 to 52% (Station 4). In October 1990, it ranged from 42 to 56% (Station 1), 43 to 52% (Station 2), 42 to 58% (Station 3), and 42 to 52% (Station 4). Average water content was 45% in March and 48% in October. Vertical distributions at each stations in March 1990 are indicated in Figure A3 and for October 1990 in Figure A11.

Water content of sediment at the surface was generally higher than at lower depths for both seasons (Figure 4.3). In March, the highest of water content were found at the depth of 10 cm (49%) and lowest at the depth of 55 cm (43%). In October, the highest water content were found at the depth of 10 and 15 cm (51.5%) and lowest at the depth od 35 cm.

4.1.4 Concentration of dissolved nitrate plus nitrite at different depths

Average concentrations of interstitial nitrite plus nitrate are given in Table 4.2. In March, values ranged from 28.6 to 118.1 μg-at/l (Station 1), 23.2 to 124.4 μg-at/l (Station 2), 14.5 to 67.3 μg-at/l (Station 3), and 14.6 to 51.9 μg-at/l (Station 4). Means were 56.14 μg-at/l (Station 1)(Table A.5), 45.77 μg-at/l (Station 2)(Table A.6), 29.88 μg-at/l (Station 3)(Table A.7), and 26.67 μg-at/l (Station 4)(Table A.8). The study found concentration of nitrite plus nitrate highest at Station 1 (mean =56.14 μg-at/l) in March, which Station 1 was located at the mouth of the river.

Table 4.1 *Average values (pH, redox potential and water content) of mangrove sediment at different depths: March 1990 (dry season) and October 1990 (wet season)*

	March			October		
Depth (cm)	pH	Eh (mV)	Water content (%)	pH	Eh (mV)	Water content (%)
0-5	6.6	129.7	47.2	6.5	143.0	49.7
5-10	6.5	86.7	48.7	6.4	144.0	51.5
10-15	6.6	4.7	46.5	6.6	100.5	51.5
15-20	6.5	-11.2	45.2	6.5	72.0	50.2
20-25	6.5	-38.7	45.0	6.5	12.7	48.0
25-30	6.5	-54.5	44.7	6.7	-24.5	45.5
30-35	6.4	-53.5	45.7	6.5	-63.0	45.2
35-40	6.4	-80	47.2	6.5	-37.2	47.0
40-45	6.4	-105	46.0	6.6	-71.7	47.0
45-50	6.4	-118.7	45.2	6.5	-87.0	49.2
50-55	6.4	-133.2	43.5	6.6	-119.7	49
55-60	6.5	-104	45.0	6.5	-144.5	47.5
Range	6.3-6.7	(-77) -221	43-51	6.4-6.7	(-189)-201	42-56
Average	6.4	-	45.9	6.5	-	48.1

***Table 4.2** Average concen-trations of nutrients in interstitial water: March 1990 (dry season) and October 1990 (wet season)*

	March					October					
Depths (cm)	NO_2+NO_3 (µM)	NH_4 (µM)	DON (µM)	PO_4 (µM)	DOP (µM)	NO_2+NO_3 (µM)	NH_4 (µM)	DON (µM)	PO_4 (µM)	DOP (µM)	SiO_4 (µM)
0-5	30.1	344.4	471.8	4.83	20.9	55.9	194.6	575.0	4.07	12.9	35.8
5-10	32.1	398.9	155.3	3.77	19.4	77.6	234.5	527.9	4.17	10.3	46.2
10-15	31.8	350.2	589.6	4.98	25.2	79.5	239.3	424.0	3.64	13.2	33.1
15-20	55.3	314.17	346.5	3.64	20.8	77.5	262.2	506.4	4.94	10.3	40.6
20-25	40.1	232.4	310.4	3.53	15.2	76.3	270.0	271.4	6.41	9.29	37.1
25-30	36.6	230.5	357.7	4.12	17.1	47.5	250.3	428.8	7.05	11.5	64.5
30-35	42.7	283.8	269.9	5.03	20.7	77.0	237.9	486.1	7.82	11.6	54.4
35-40	38.6	297.9	398.8	5.49	28.2	64.1	245.6	552.5	9.10	11.8	59.6
40-45	43.1	321.0	333.7	5.32	28.6	43.2	285.1	335.6	6.68	13.5	51.2
45-50	38.9	318.6	423.9	3.48	26.5	61.3	255.4	364.1	8.04	12.8	58.1
50-55	32.0	334.3	535.1	3.15	20.4	73.9	296.7	355.5	6.27	15.4	56.2
55-60	24.6	331.9	512.3	3.85	17.6	56.8	254.4	435.1	8.57	13.8	45.7
Average	**34.56**	**313.16**	**392.08**	**4.26**	**21.71**	**65.88**	**252.16**	**438.53**	**6.39**	**12.19**	**48.54**

In wet season, values ranged from 42.3 to 115.3 μg-at/l (Station 1), 43.8 to 92.4 μg-at/l (Station 2), 29.8 to 131.8 μg-at/l (Station 3), 34.2 to 70.05 μg-at/l (Station 4). Means were 65.7 μg-at/l for Station 1 (Table A.9), 70.37 μg-at/l for Station 2(Table A.10), 76.7 μg-at/l for Station 3 (Table A.11), and 45.96 μg-at/l for Station 4 (Table A.12). The highest concentration of nitrite plus nitrate found at Station 3 (mean = 76.7 μg-at/l).

As can be seen in Figure 4.4, vertical interstitial nitrite plus nitrate profiles were higher at the surface than at a lower depths. Average concentrations of interstitial nitrite plus nitrate were significantly different (∝=.05) in between season (Table 4.3) The range was 34.56 μg-at/l in March and 65.88 μg-at/l in October (Table 4.2).

4.1.5 Concentration of interstitial ammonia at different depths

Results of the chemical analysis of interstitial ammonia in the sediment are given in Table 4.2. In March, the range was 185.2 μg-at/l to 399.8 μg-at/l (Station 1), 63.88 μg-at/l to 460.75 μg-at/l (Station 2), 132.6 μg-at/l (Station 3), 391.1 μg-at/l (Station 4). Means were 249.6 μg-at/l (Station 1)(Table A.5), 285.91 μg-at/l (Station 2)(Table A.6), 242.38 μg-at/l (Station 3)(Table A.7), and 513.01 μg-at/l (Station 4)(Table A.8). As result, concentration of ammonia are highest at Staion 4 (mean =513.01 μg-at/l).

In October, the range was 160.8 μg-at/l to 1234.5 μg-at/l (Station 1), 178.91 μg-at/l to 308.1 μg-at/l (Station 2), 208.9 μg-at/l to 348.4 μg-at/l (Station 3), 188.9 μg-at/l to 451.36 μg-at/l (Station 4). Means were 189.2 μg-at/l (Station 1)(Table A.9), 246.68 μg-at/l (Station 2)(Table A.10), 288.78 μg-at/l (Station 3)(Table A.11), and 308.69 μg-at/l (Station 4)(Table A.12).

As can be seen in Figure 4.5, generally, ammonia concentrations increased with depth, but the lowest concentrations were observed at a depth of 30-40 cm in October (ammonia distributions at different depths in each station are presented in Figure A.5-A.13). Average concentrations of interstitial ammonia were significantly different (∝=.05) in between seasons (Table 4.3). It was 313.16 μg-at/l in dry season and 252.16 μg-at/l in wet season (Table 4.2). Vertical profiles for both seasons were releated to those for nitrite plus nitrate.

4.1.6 Concentration of dissolved organic nitrogen at different depths

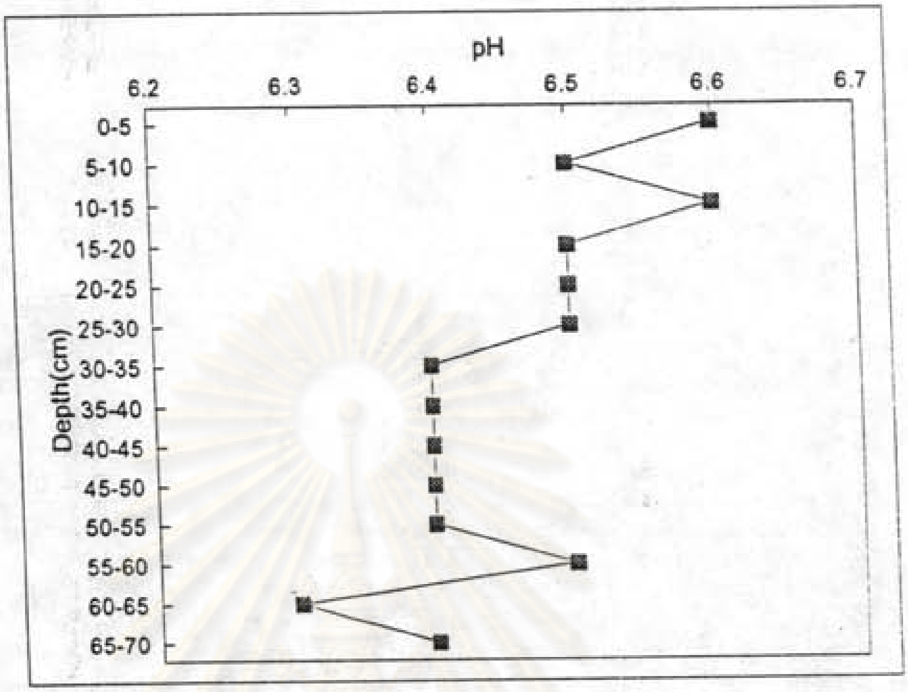
Results of the chemical analysis of dissolved organic nitrogen in interstitial water are given in Table 4.2. The study found non-significant ($\propto$=.05) in between season. Average concentrations of dissolved organic nitrogen were 392.08 µg-at/l in March and 438.53 µg-at/l in October. As can be seen in Figure 4.6, in March, concentrations of dissolved organic nitrogen were high at the surface then decreased to a depth of 35 cm (mean =269.9 µg-at/l (lowest)) and then increased with highest concentration at a depth of 55 cm (535.1 µg-at/l). In October, concentrations of dissolved organic nitrogen were high at the surface (mean=575 µg-at/l) then decreased sharply to a depth of 25 cm (mean = 271.1 µg-at/l), then increased slightly with depth.

4.1.7 Concentration of dissolved phosphate at different depths

Results of the chemical analysis of interstitial phosphate in the sediment are given in Table 4.2. Phosphate analyses indicated that concentrations of phosphate at different depths ranged from 1.54 µg-at/l to 4.26 µg-at/l (Station 1), 1.84 µg-at/l to 6.02 µg-at/l (Station 2), 1.85 µg-at/l to 6.72 µg-at/l (Station 3), 4.93 µg-at/l to 11.19 µg-at/l (Station 4) in March. In October, they ranged from 3.21 µg-at/l to 14.02 µg-at/l (Station 1), 1.26 µg-at/l to 9.31 µg-at/l (Station 2), 1.64 µg-at/l to 8.59 µg-at/l (Station 3), 4.05 µg-at/l to 12.99 µg-at/l (Station 4). Mean concentrations were 2.53 µg-at/l for Station 1(Table A.5), 3.78 µg-at/l for Station 2(Table A.6), 4.03 µg-at/l for Station 3(Table A.7), and 7.05 µg-at/l for Station 4(Table A.7) in March. In October , means were 7.48 µg-at/l for Station 1(Table A.9), 7.05 µg-at/l for Station 2(Table A.10), 6.5 µg-at/l for Station 3(Table A.11), and 8.88 µg-at/l for Station 4(Table A.12).

As can be seen in Figure 4.7, concentrations of phosphate generally increased with depth in both of March and October (obviously in October). Average concentrations were significantly different ($\propto$ = .05) between seasons. The concentrations of phosphate were 4.26 µg-at/l (March) and 6.39 µg-at/l (October).

March 1990



October 1990

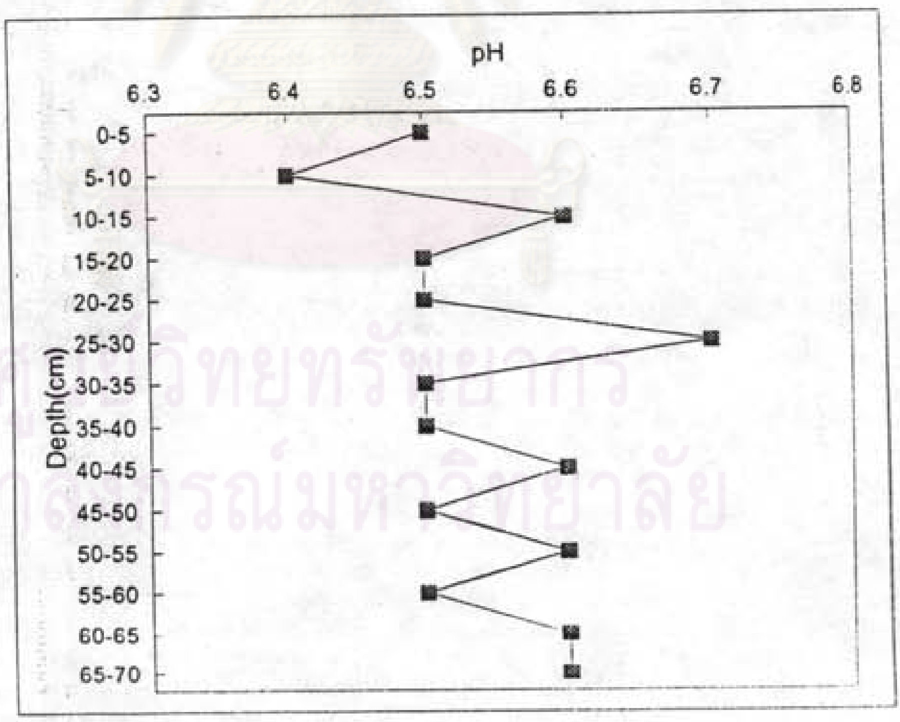
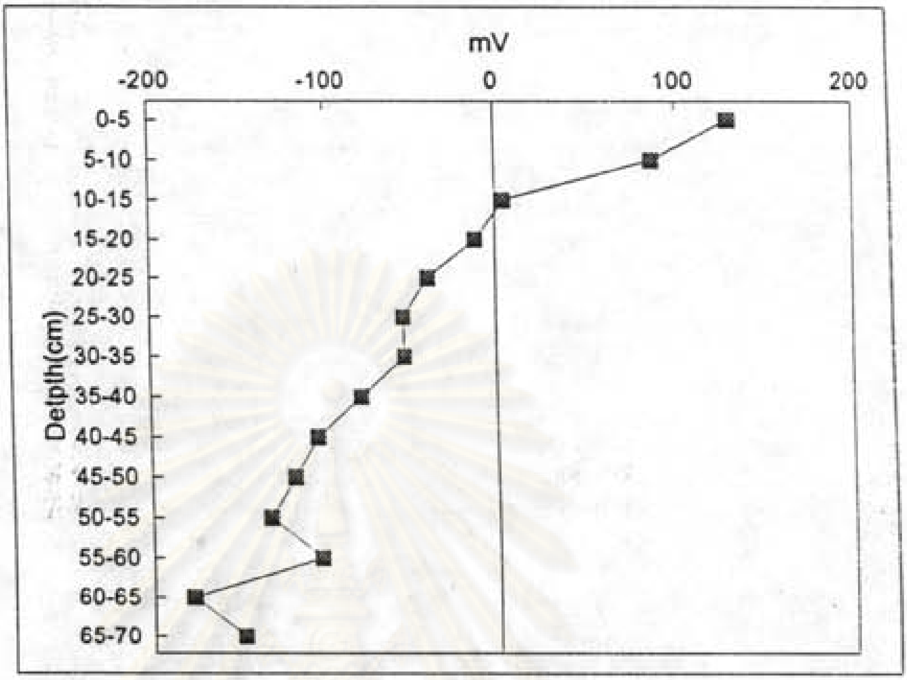


Figure 4.1 Average pH in sediment at different depths in March 1990 (dry season) and October 1990 (wet season)

March 90



October 1990

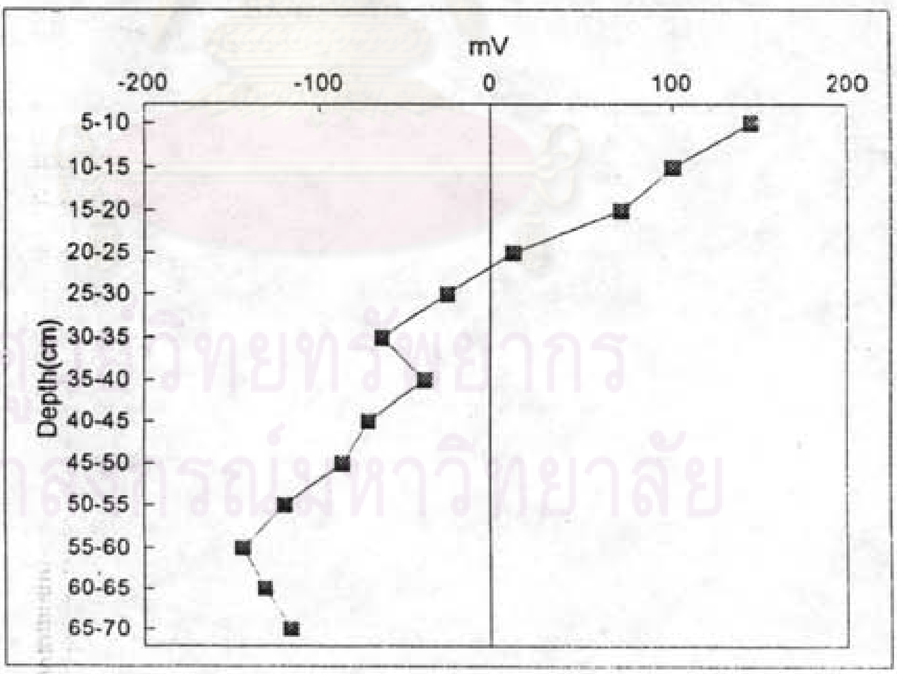
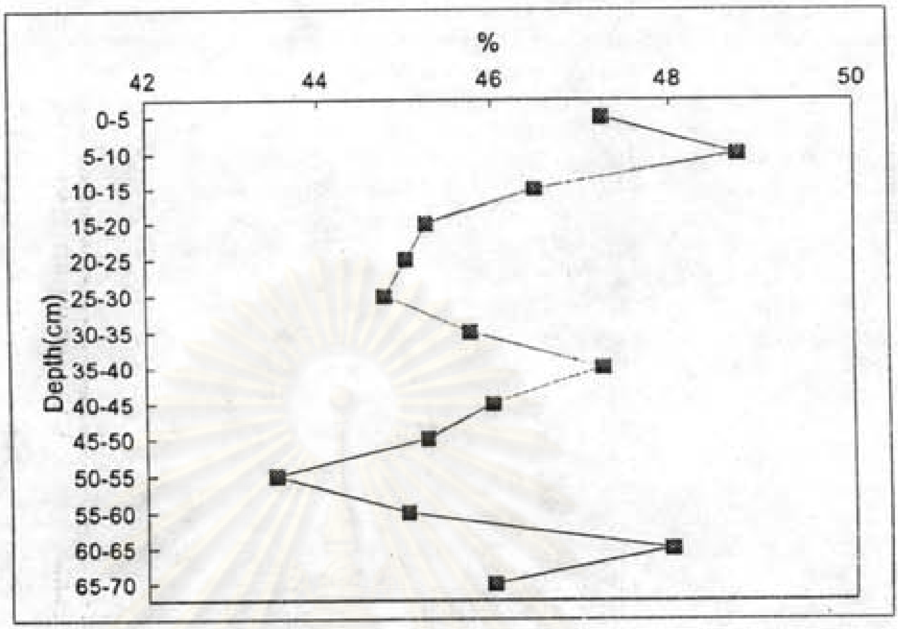


Figure 4.2 Average redox potential in sediment at different depths in March 1990 (dry season) and October 1990 (wet season)

March 1990



October 1990

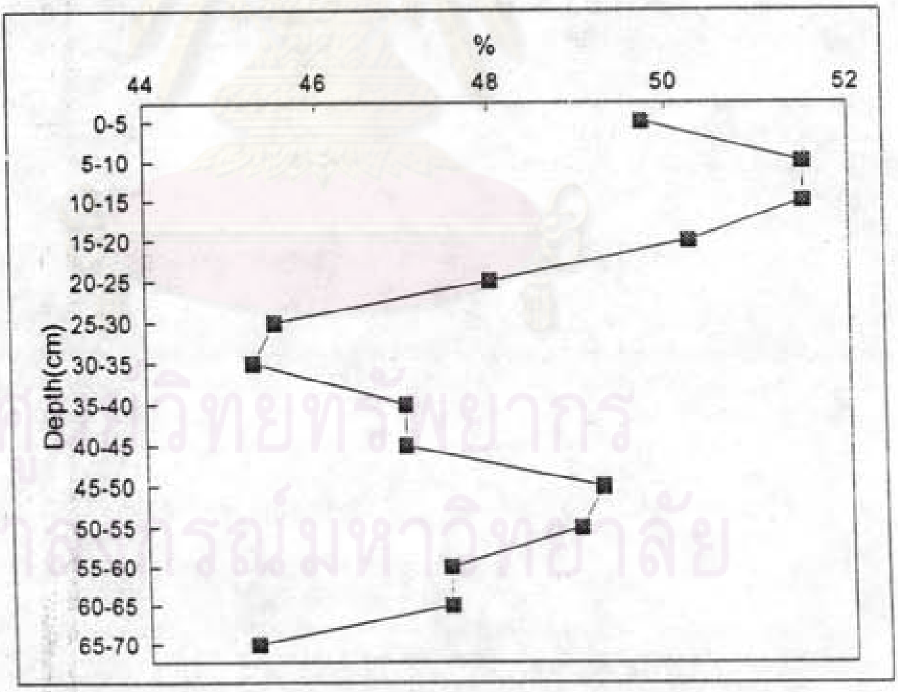
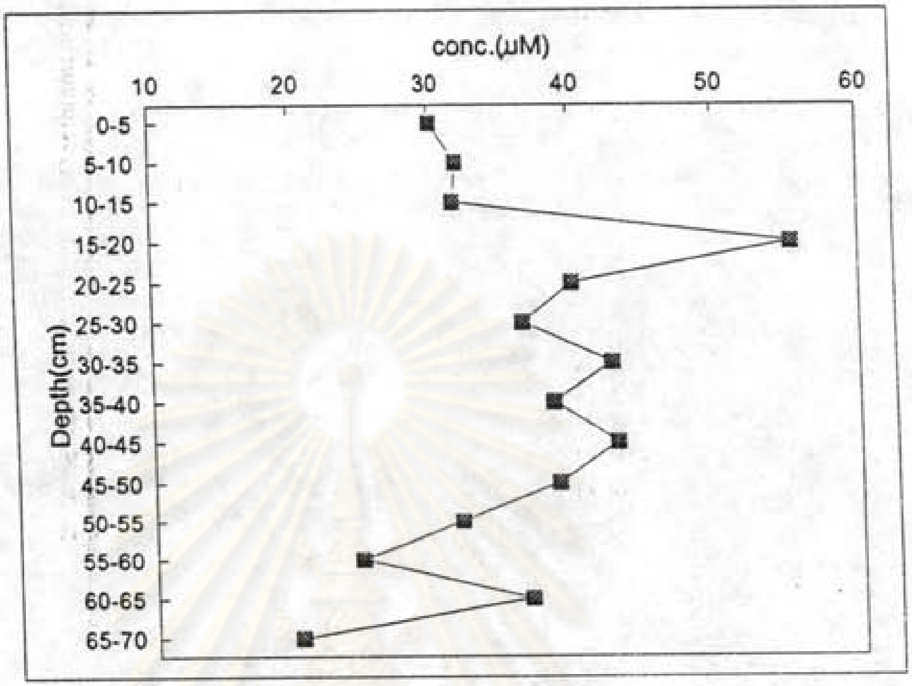


Figure 4.3 Average water content of sediment at different depths in March 1990 (dry season) and October 1990 (wet season)

March 1990



October 1990

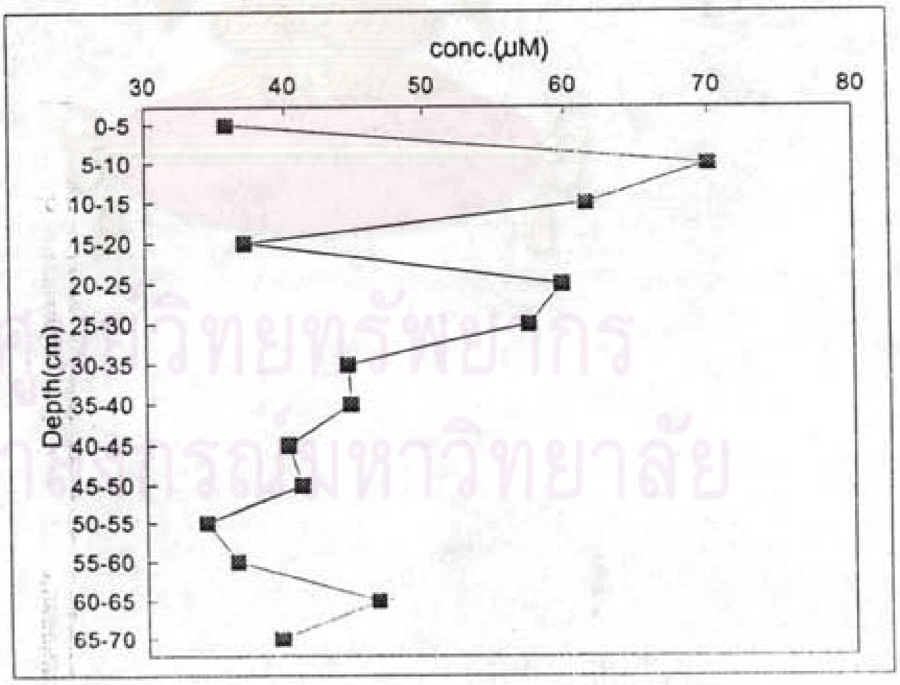
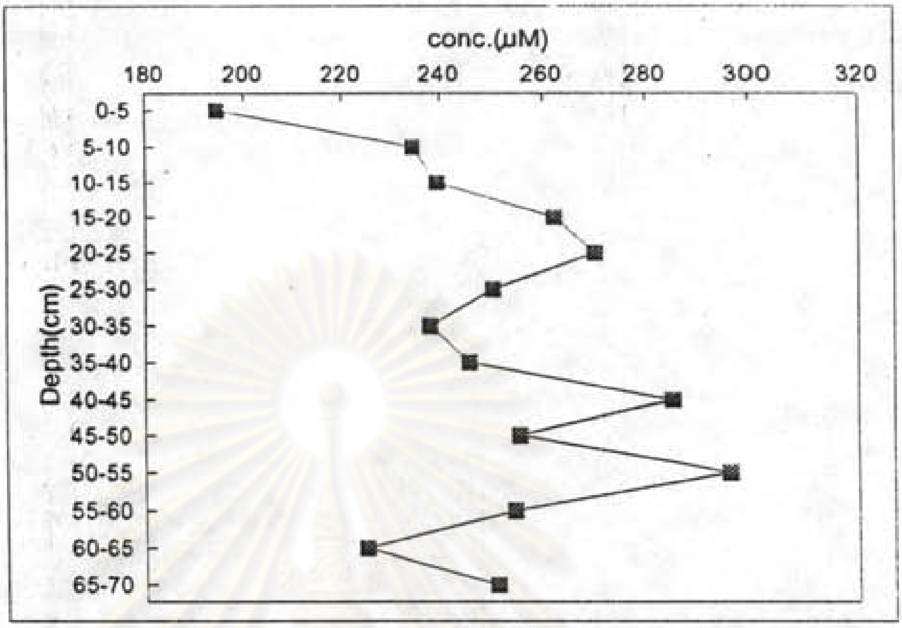


Figure 4.4 Average concentration of interstitial nitrite plus nitrate at different depths in March 1990 (dry season) and October 1990 wet season)

March 1990



October 1990

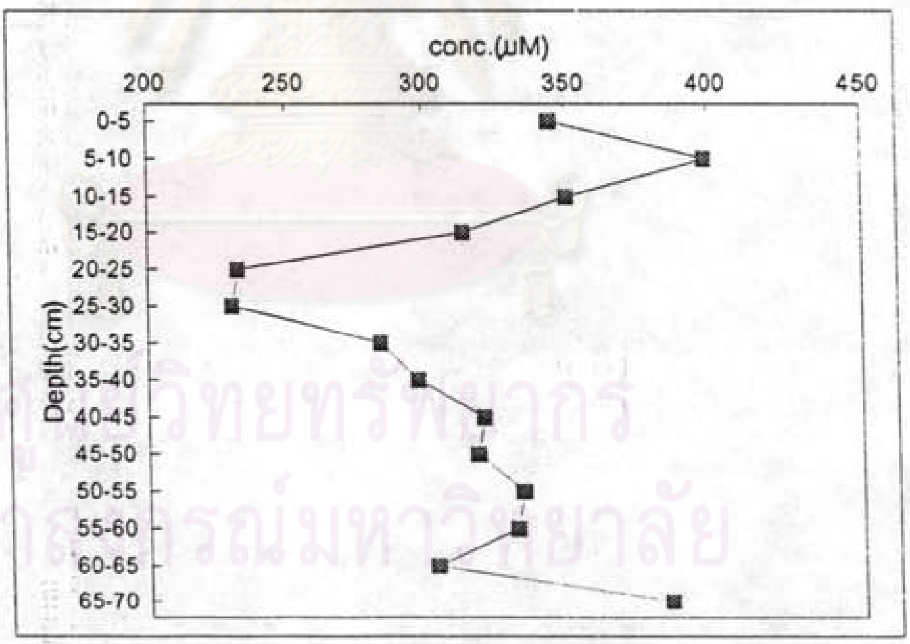
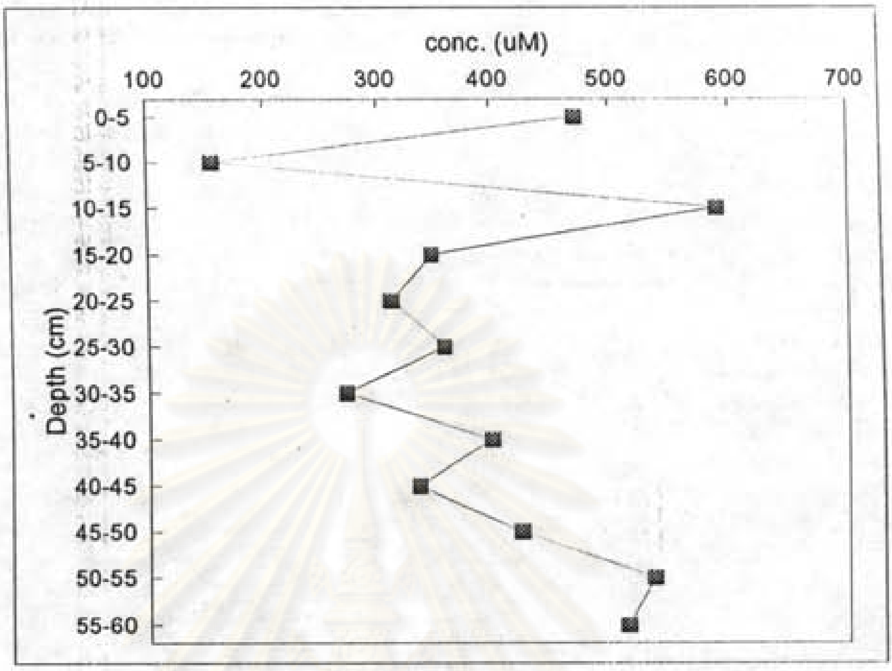


Figure 4.5 Average concentration of interstitial ammonia at different depths in March 1990 (dry season) and October 1990 (wet season)

March 1990



October 1990

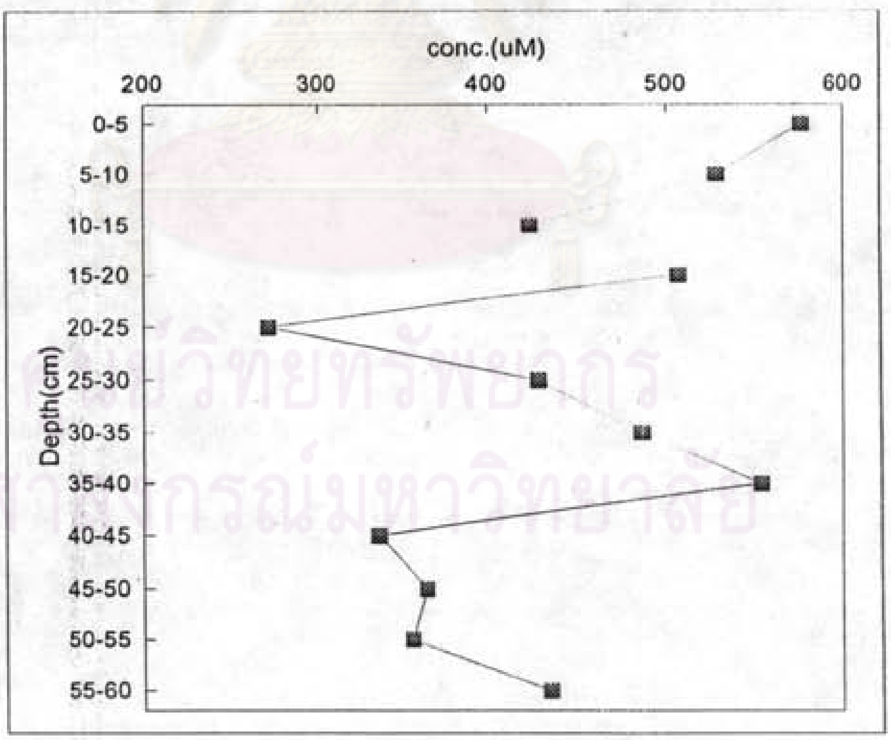
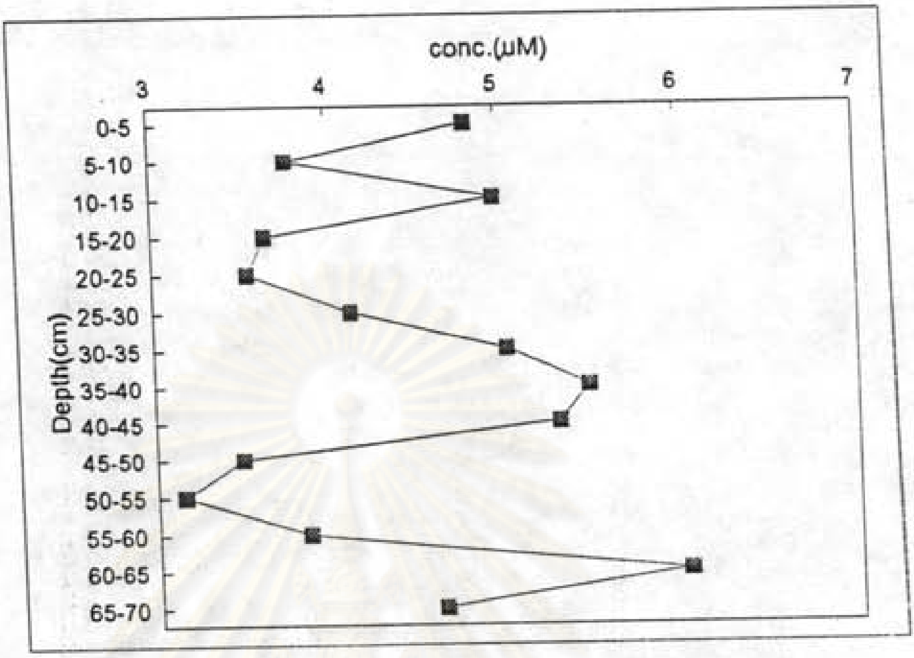


Figure 4.6 Average concentration of dissolved organic nitrogen at the different depths in March(dry season) and October 1990 (wet season)

March 1990



October 1990

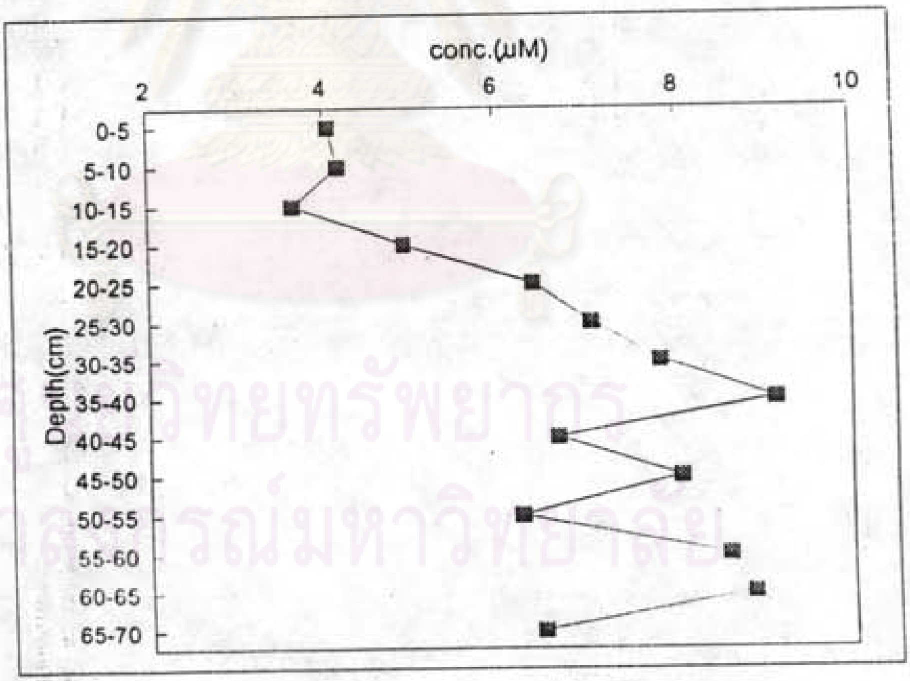
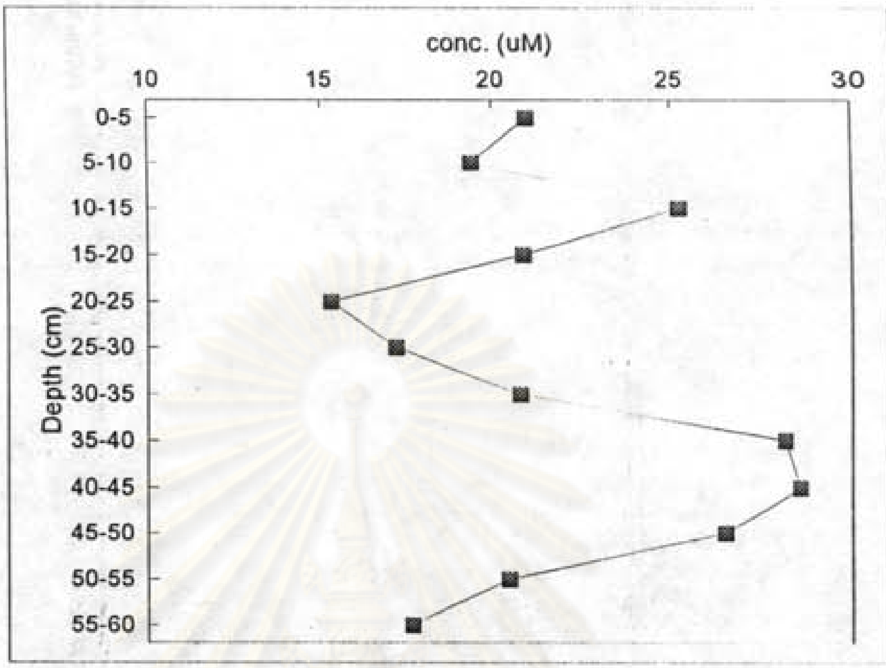


Figure 4.7 Average concentration of interstitial phosphate at different depths in March 1990 (dry season) and October 1990 (wet season)

March 1990



October 1990

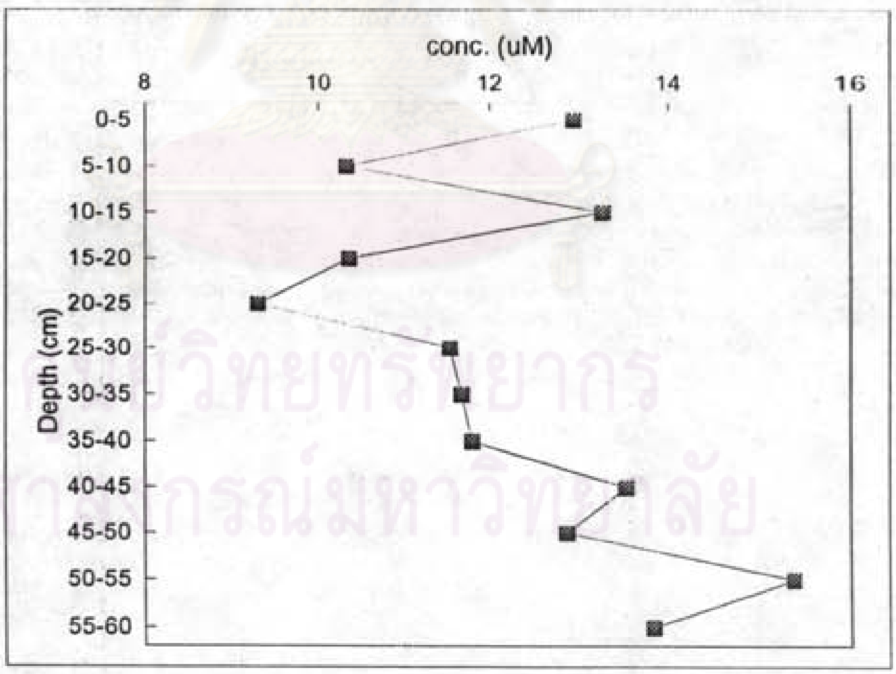


Figure 4.8 Average concentration of dissolved organic phosphorus at different depths in March (dry season) and October 1990 (wet season)

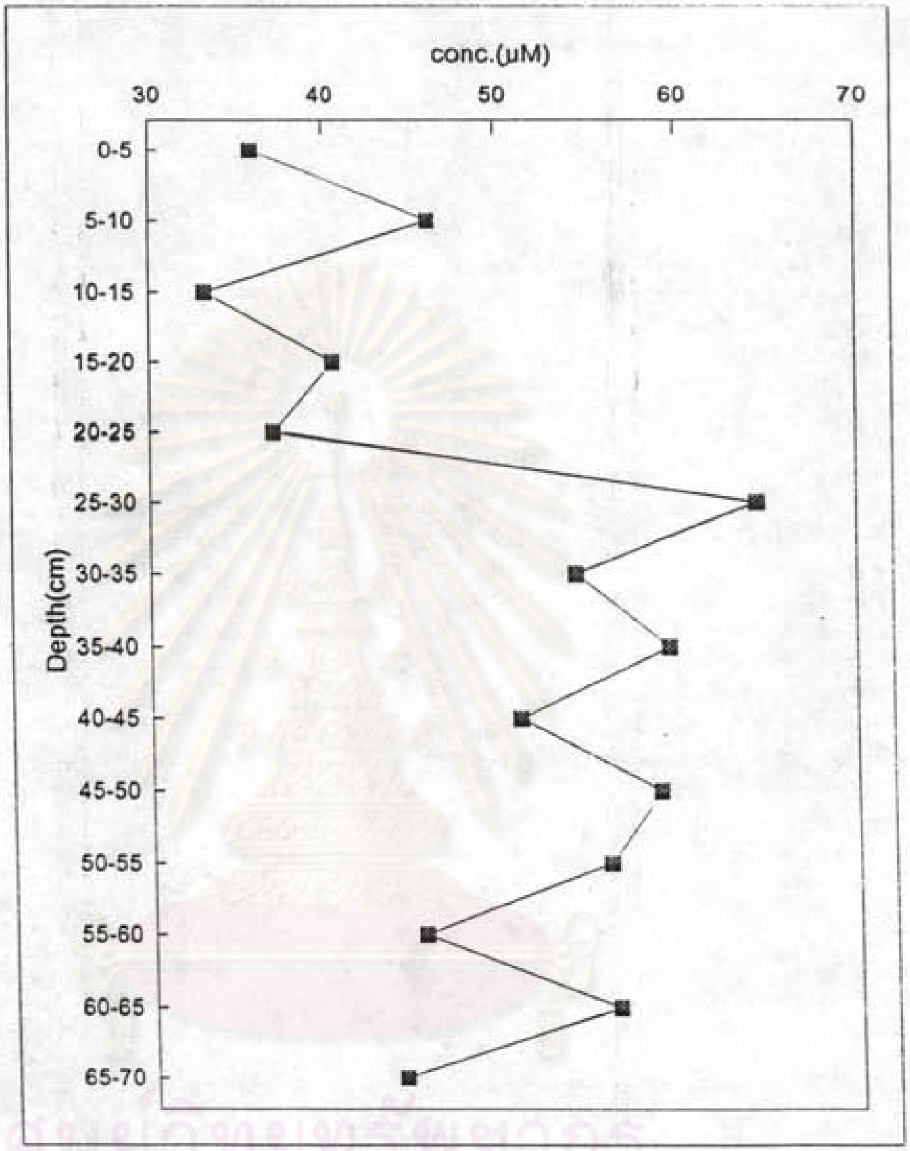


Figure 4.9 Average concentration of interstitial silicate at differen depths in October 1990

4.1.8 Concentration of dissolved organic phosphorus at different depths

Results of the chemical analysis of dissolved organic phosphorus are given in Table 4.2. Average concentrations were 21.71 µg-at/l (March) and 12.19 µg-at/l (October) (Table 4.2).

As can be seen in Figure 4.8, vertical distribution of dissolved organic phosphorus in interstitial water was similar in March and October, increasing with depth. Moreover, the study found the concentration of dissolved organic phosphorus significant between seasons ($\propto$=.05) (Table 4.3).

4.1.9 Concentration of dissolved silicate at different depths

Details of this analysis for October 1990 are presented in Table 4.2. Silicon concentrations in interstitial water ranged from 12.66 µg-at/l to 94.03 µg-at/l (Station 1), 24.63 µg-at/l to 52.59 µg-at/l (Station 2), 16.45 µg-at/l to 62.39 µg-at/l (Station 3), 38.56 µg-at/l to 84.59 µg-at/l (Station 4). Means were 54.31 µg-at/l (Station 1), 39.38 µg-at/l (Station 2), 13.24 µg-at/l (Station 3), and 33.93 µg-at/l (Station 4). Average concentration at all station was 48.54 µg-at/l. Vertical distribution of dissolved silicate at each station are presented in Figure A17.

Generally, the concentration of silicate in interstitial water was not different from the surface to a depth of 25 cm, then increased sharply to approximately 60 µg-at/l at a depth of 30 cm, then decreased slightly with depth (Figure 4.9).

Table 4.3 *T-test analysis ofr nitrients in interstitial water in different seasons (March 1990 and October 1990)*

	March (dry season)		October(wet season)			
Parameter	n	mean	n	mean	T(calculate)	T(table)
$NO_2^-+NO_3^-$	12	34.56	12	65.88	-5.63	-2.069^{s}
NH_4^+	12	313.16	12	252.16	3.54	2.069^{s}
DON	12	392.08	12	438.53	-0.98	-2.069^{ns}
PO_4^{3-}	12	4.26	12	6.39	-3.77	-2.069^{s}
DOP	12	21.71	12	12.19	7.99	2.069^{s}

Note : ^{ns} = Non significant

^{s} = Significant

4.2 Nutrients released from sediment *in situ*

Water samples were collected in October 1990 and March 1991. Released rates of nutrients in each tube were calculated directly from the changes in nutrient concentrations over time and area. The physicochemical characteristics of mangrove water are presented in Table 4.4 and relationships between nutrient concentrations and tidal cycle plotted in Figures 4.10-4.19. Concentrations of nutrients in water are presented in Table 4.5. and Figures 4.10-4.13.

4.2.1 Salinity over time

Salinity ranged from 27 to 30 ppt for March 1991 and 27 to 30 ppt for October 1990. Mean concentrations were approximately 28 ppt for both months (Table 4.4 and Figure 4.10). Salinity was correlated with the tide cycle. The highest concentration being at high tide and the lowest corresponding with fresh water run off.

Table 4.4 *Average values (salinity, DO, and temperature) of water: October 1990 (wet season) and March 1991 (dry season)*

	October (wet season)		March (Dry season)	
Parameters	Range	Average	Range	Average
Salinity (ppt)	27-30	28.66	27-30	28.66
DO (mg/L)	5.3-6.5	5.97	5.2-6.8	5.61
pH	7.3-8.0	7.67	7.1-7.8	7.47
Temperature (°C)	28-29	28.38	28	28

Table 4.5 *Concentration of nutrients in water: October 1990 and March 1991*

	October (wet season)		March (Dry season)	
Parameters	Range (μg-at/l)	Average (μg-at/l)	Range (μg-at/l)	Average (μg-at/l)
NO_2-	.102-.391	.225	.046-.214	.181
NO_3^-	.194-.781	.345	.120-.925	.445
NH_4^+	.730-1.97	1.30	.730-3.69	1.3
DON	26.5-268.9	123.2	91.1-407.3	184.5
PO_4^{3-}	.106-.295	.166	.144-.753	.264
DOP	.122-.457	.297	.906-1.94	1.23

***Table 4.6** Average rates of nutrients released from sediment in each tube: October 1990 (wet season) and March 1991(dry season)*

	Wet season(October) mmol $m^{-2}h^{-1}$				Dry season(March) mmol $m^{-2}h^{-1}$			
Tube	1	2	3	Average	1	2	3	Average
NO_2^-	.006	.007	0.002	0.005	.003	.003	.003	.003
NO_3^-	-.007	-.010	0.001	-0.005	-.011	-.011	-.011	-.011
NH_4^+	.181	.187	.162	0.177	.009	.009	.009	.009
DON	28.20	17.90	28.19	24.76	4.468	4.466	4.466	4.466
PO_4^{3-}	.027	.027	.013	.022	-.001	-.001	-.001	-.001
DOP	.011	.011	.011	.011	.039	.039	.039	.039

Note: DON= Dissolved organic nitrogen
DOP = Dissolved organic phosphorus

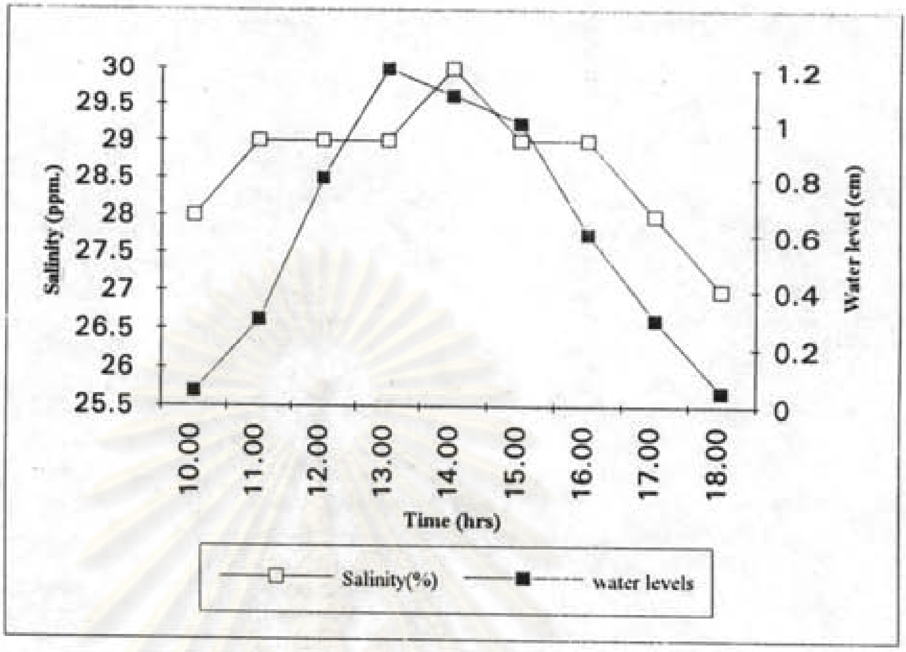
4.2.2 Dissolved oxygen over time

Dissolved oxygen (DO) ranged from 5.2 to 6.8 mg/L in March 1991 and 5.3 to 6.5 mg/L in October 1990. Means were 5.61 and 5.97 mg/L in March 1991 and October 1990, respectively. As can be seen in Figure 4.10, dissolved oxygen in water in both season was similar. Dissolved oxygen in the first hour (10.00 am) did not change much over time.

4.2.3 pH over time

pH ranged from 7.1 to 7.8 in March 1991 (dry season) and 7.3 to 8.0 in October 1990 (wet season). Means were 7.47 during March 1991 and 7.67 during October 1990 (Table 4.4). As can be seen in Figure 4.13, in October 1990 pH was low in the first hour then increased slightly with high tide, finally decreasing a little during ebb tide. In March 1991, the pH profile was similar to the pH profile in October, lower in the first hour then increasing slightly with tide cycle. pH profiles

Oct-90



Mar-91

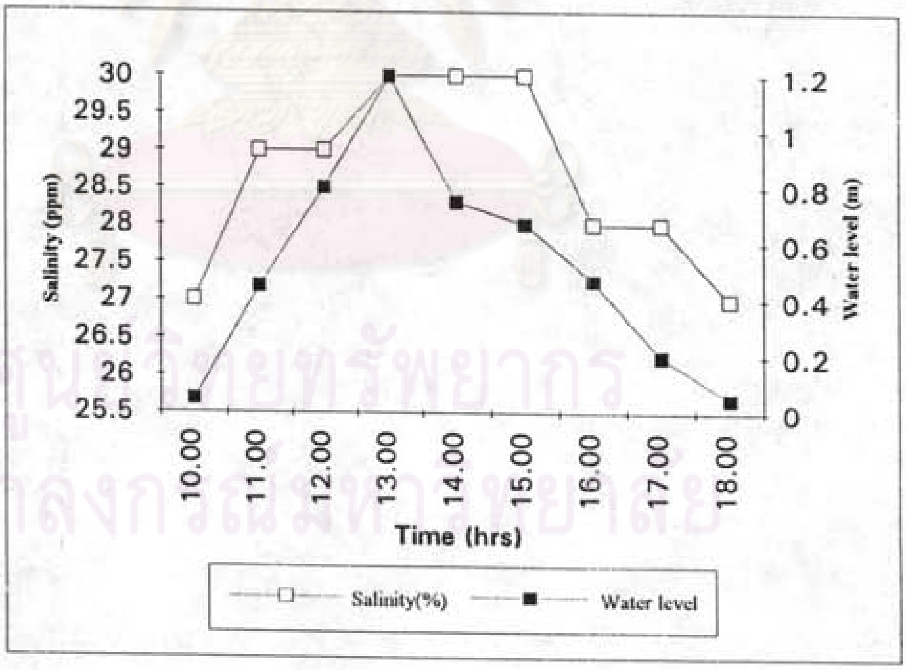
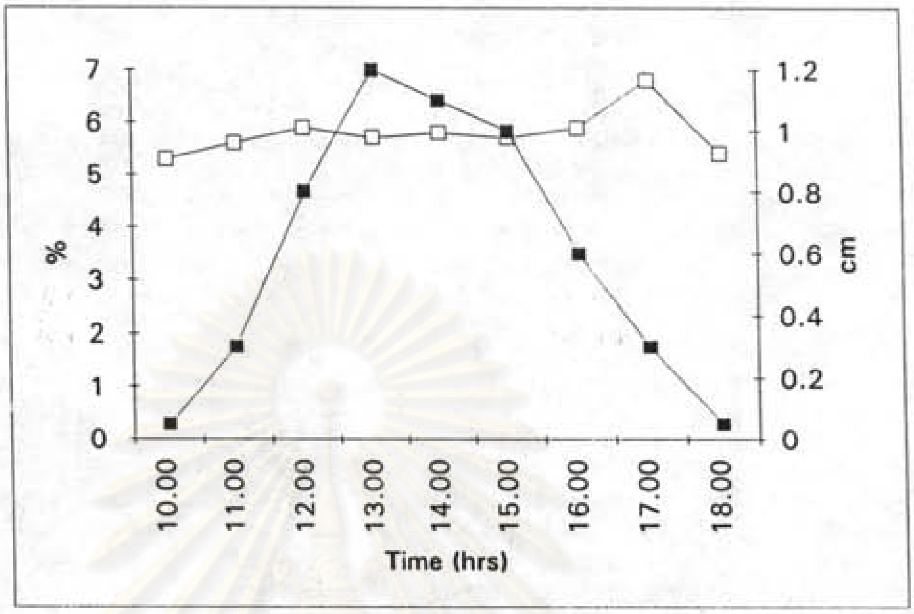


Figure 4.10 Relationship between salinity and one tide cycle: October 1990 (wet season) and March 1991 (dry season)

Oct-90



Mar-91

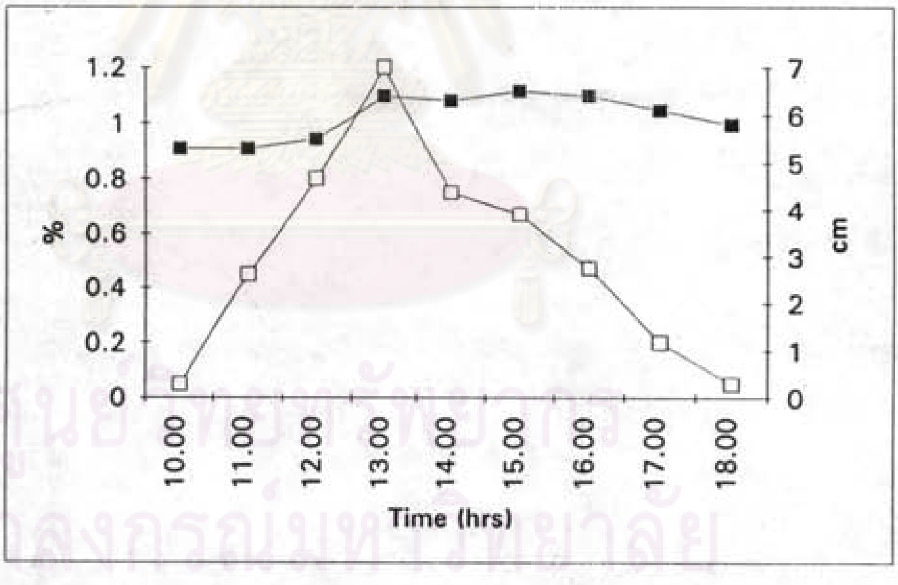
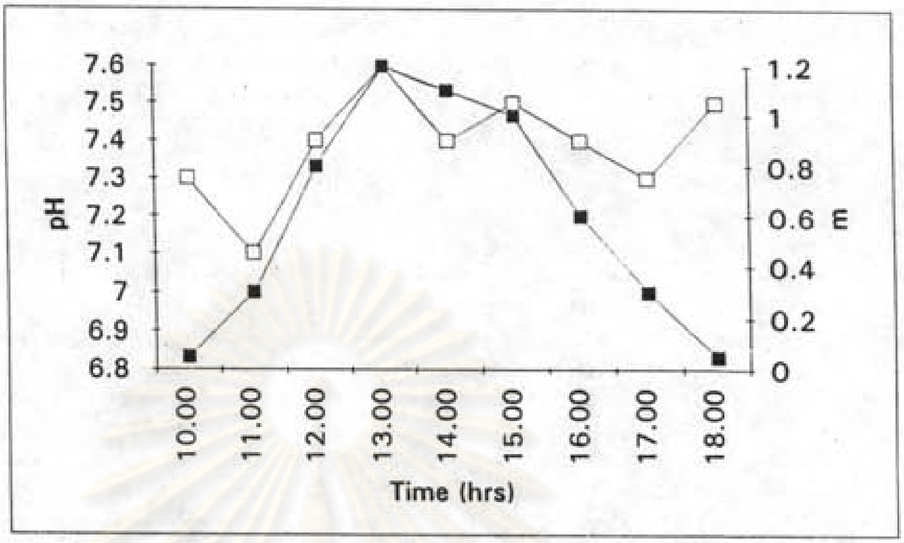


Figure 4.11 Relationship between dissolved oxygen and tide cycle: October 1990 (wet season) and March 1991 (dry season)

Oct-90



Mar-91

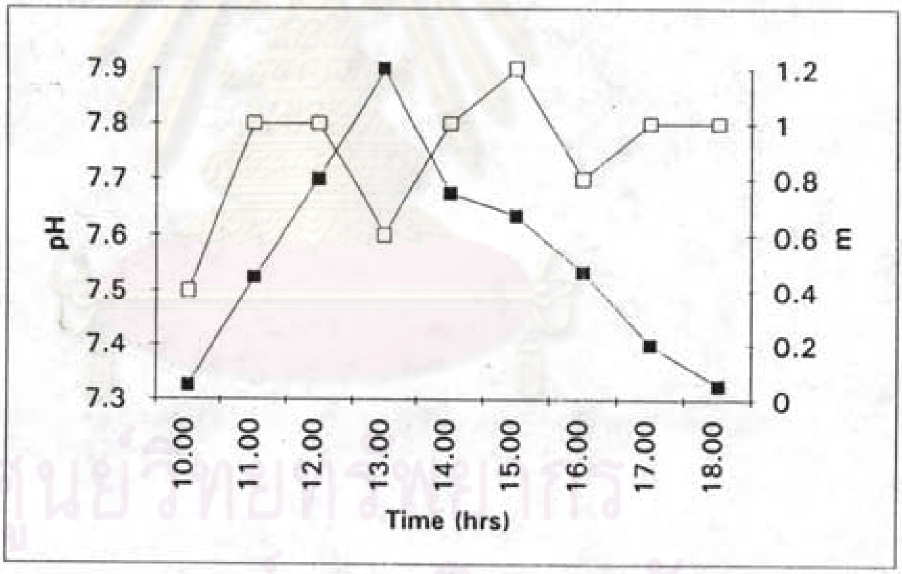
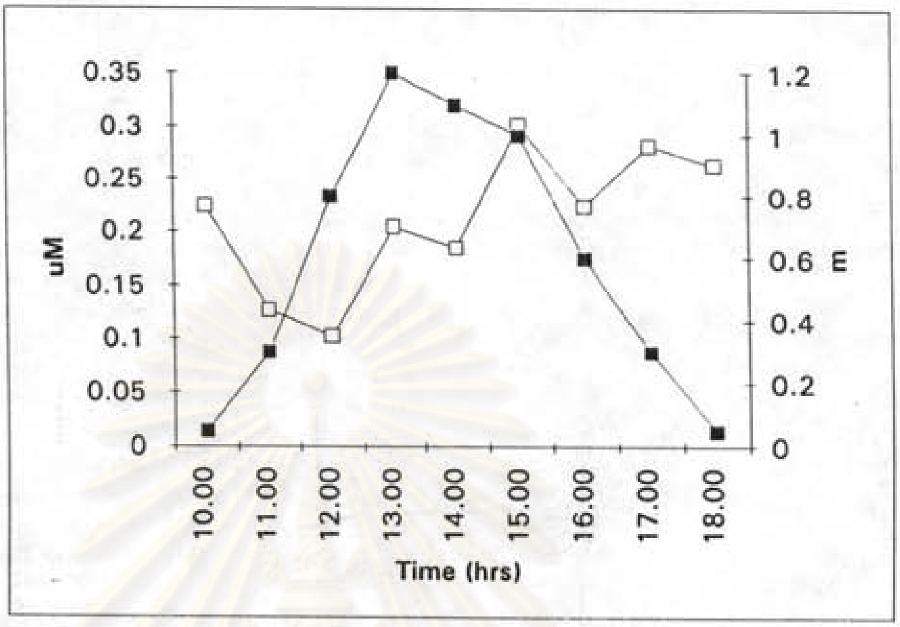


Figure 4.1 2 Relationship between pH and tide cycle: October 1990 (wet season) and March 1991 (dry season)

Oct-90



Mar-91

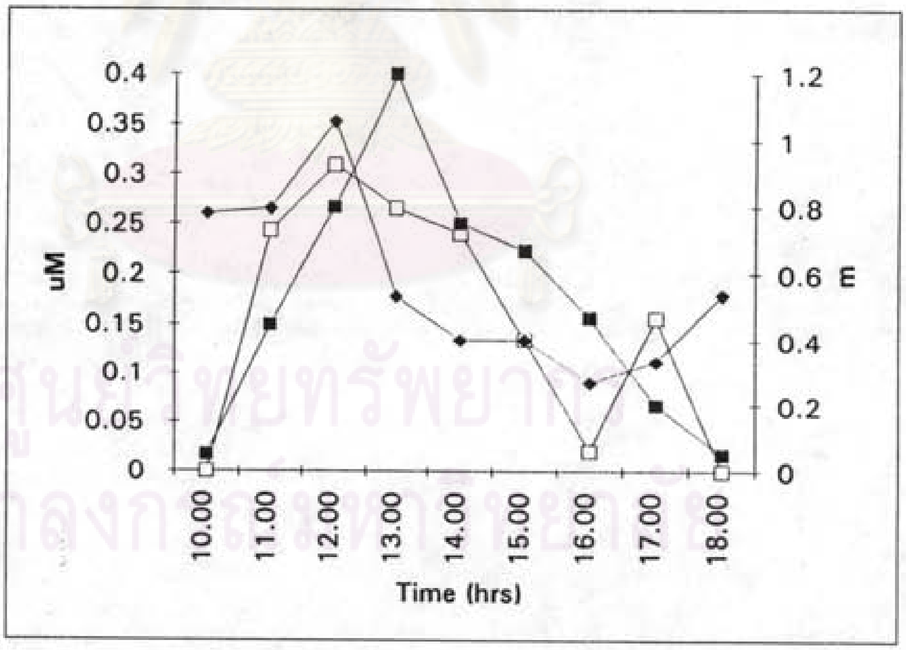
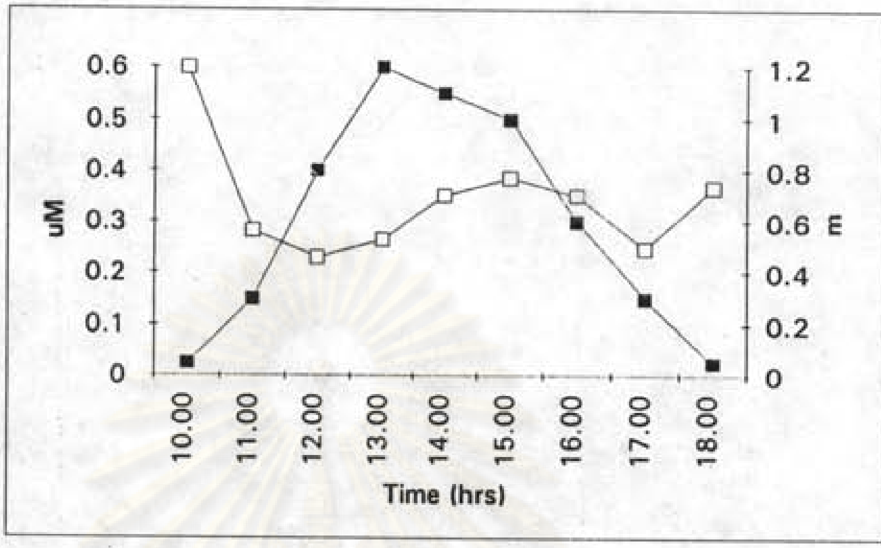


Figure4.13 Relationship between nitrite concentration and tide cycle: October 1990 (wet season) and March 1991 (dryseason)

Oct-90



Mar-91

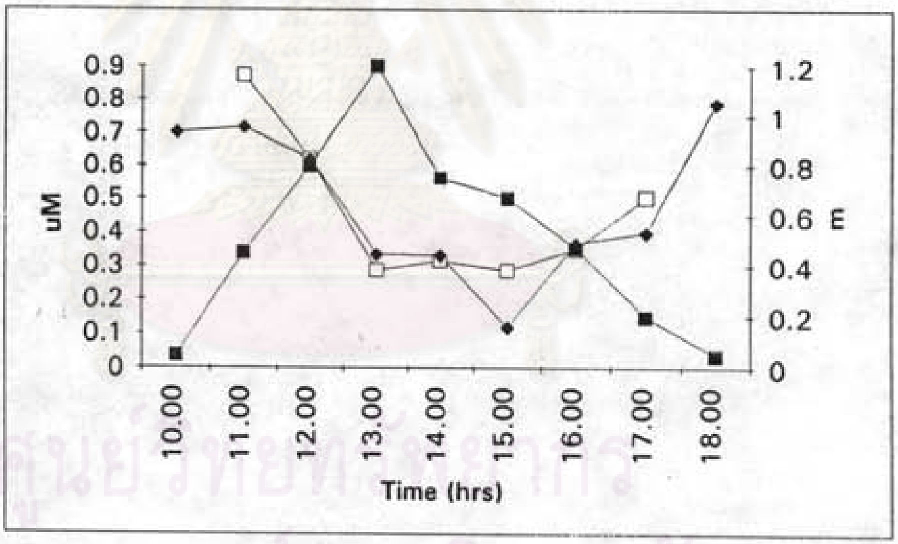
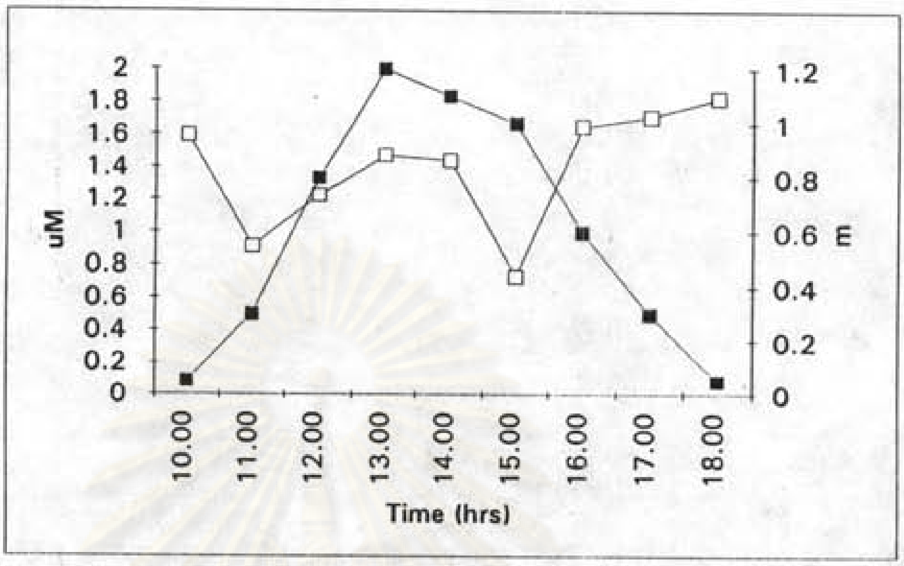


Figure 4.14 Relationship between nitrate concentration and tide cycle:October 1990 (wet season) and March 1991 (dryseason)

Oct-90



Mar-91

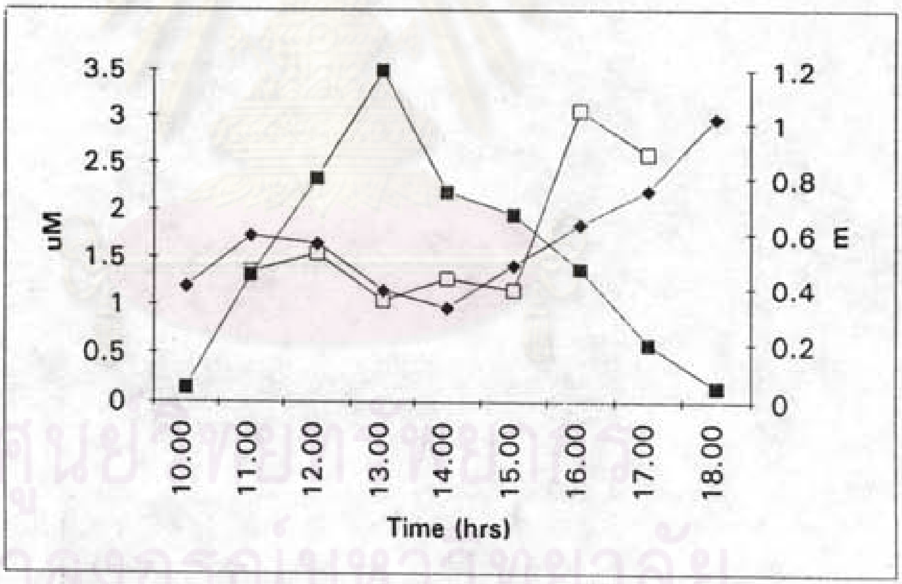
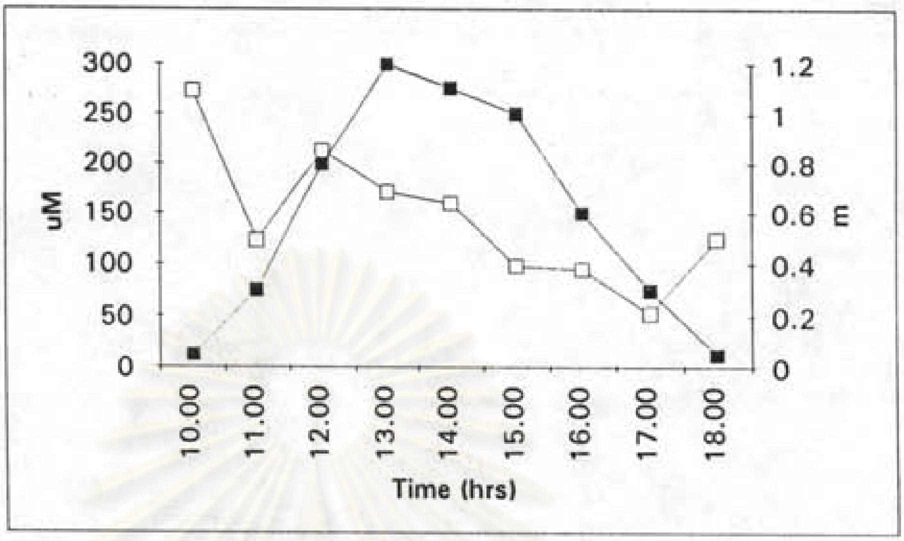


Figure 4.15 Relationship between ammonia concentration and tide cycle: October 1990 (wet season) and March 1991 (dryseason)

Oct-90



Mar-91

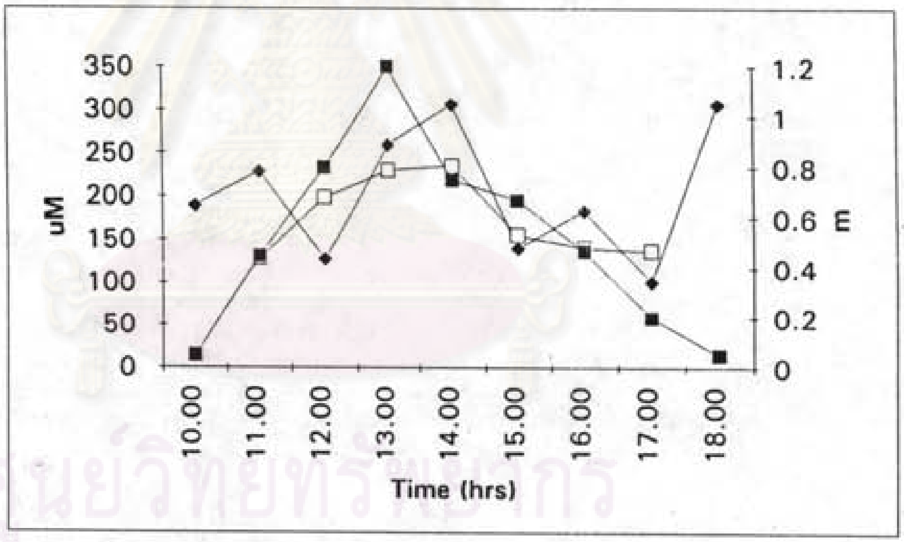
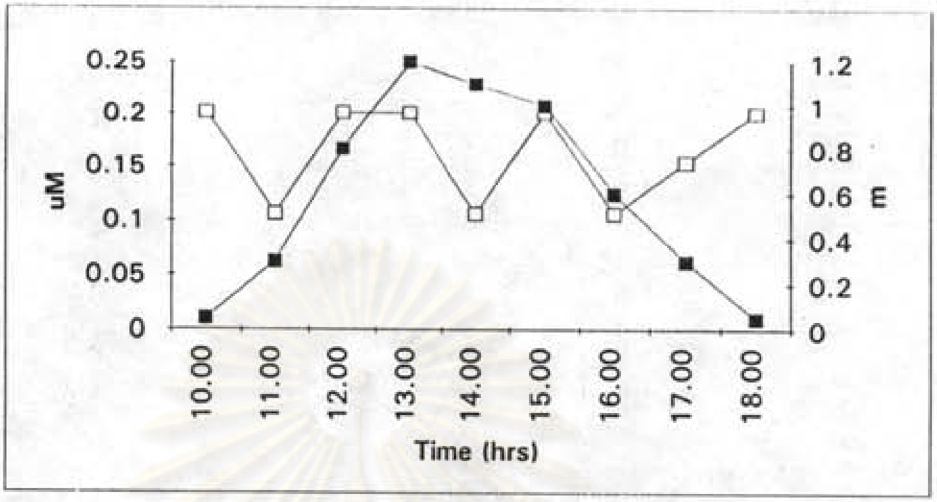


Figure 4.16 Relationship between dissolved organic nitrogen concentration and tide cycle:October 1990 (wet season) and March 1991 (dry season)

Oct-90



Mar-91

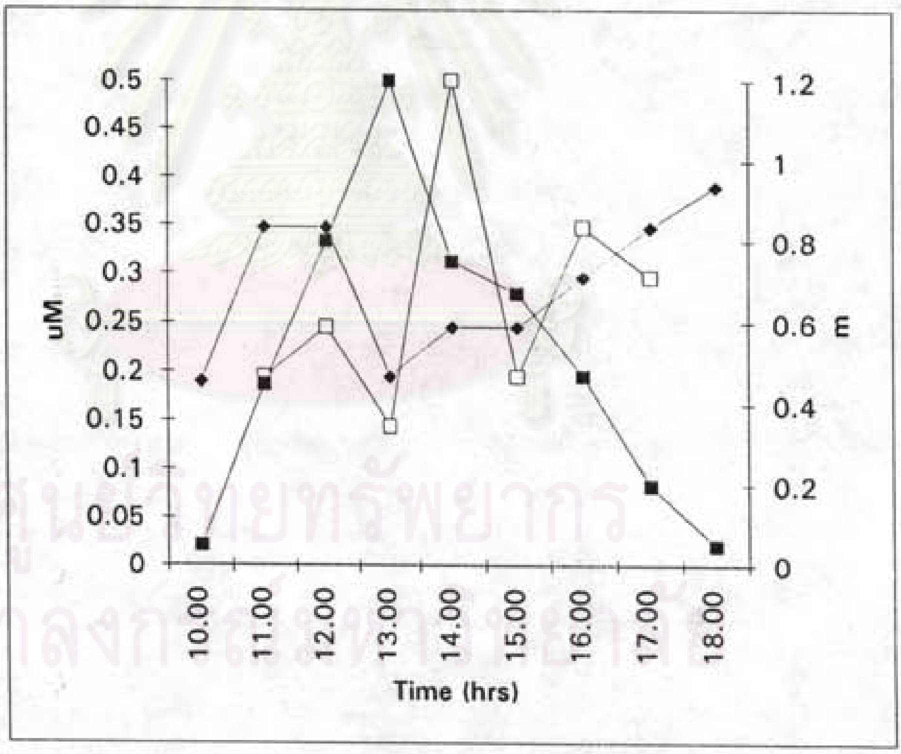
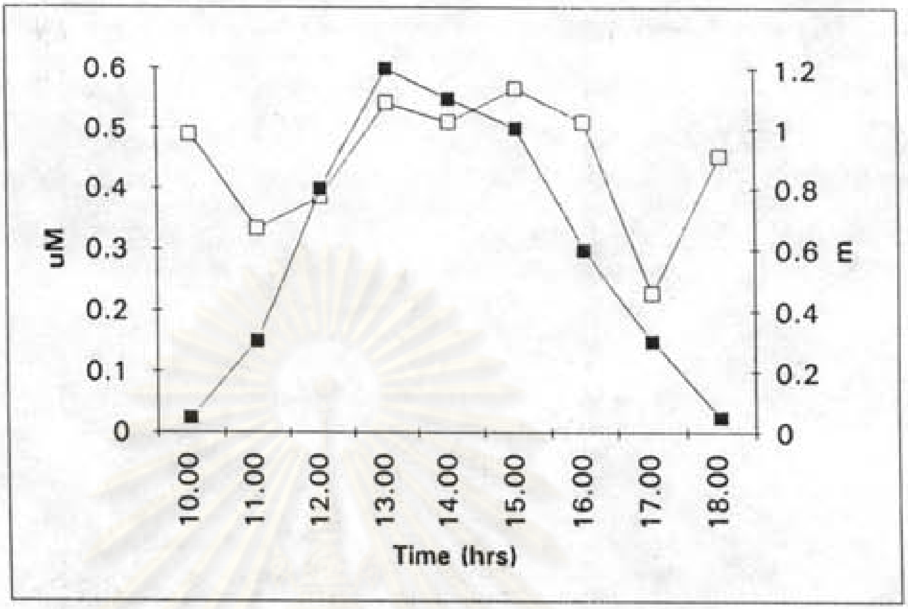


Figure 4.17 Relationship between phosphate concentration and tide cycle:October 1990 (wet season) and March 1991 (dryseason)

Oct-90



Mar-91

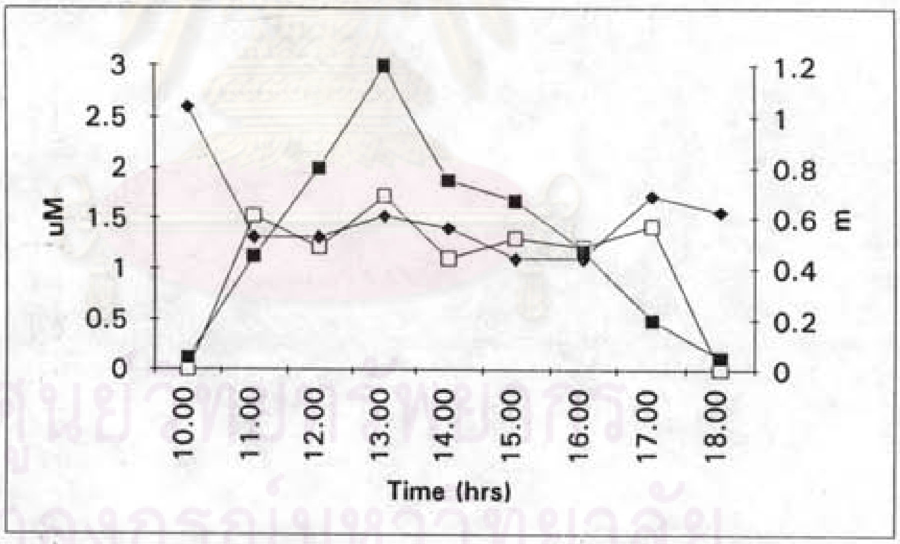
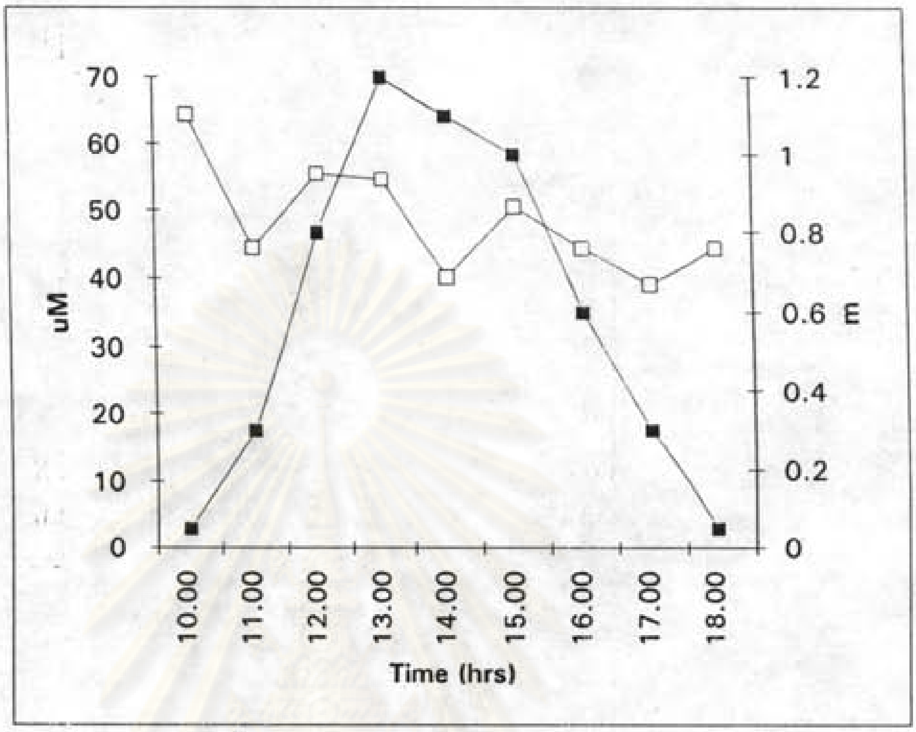


Figure4.18 Relationship between dissolved organic phosphorus and tide cycle:October 1990 (wet season) and March 1991 (dry season)

Oct-90



Mar-91

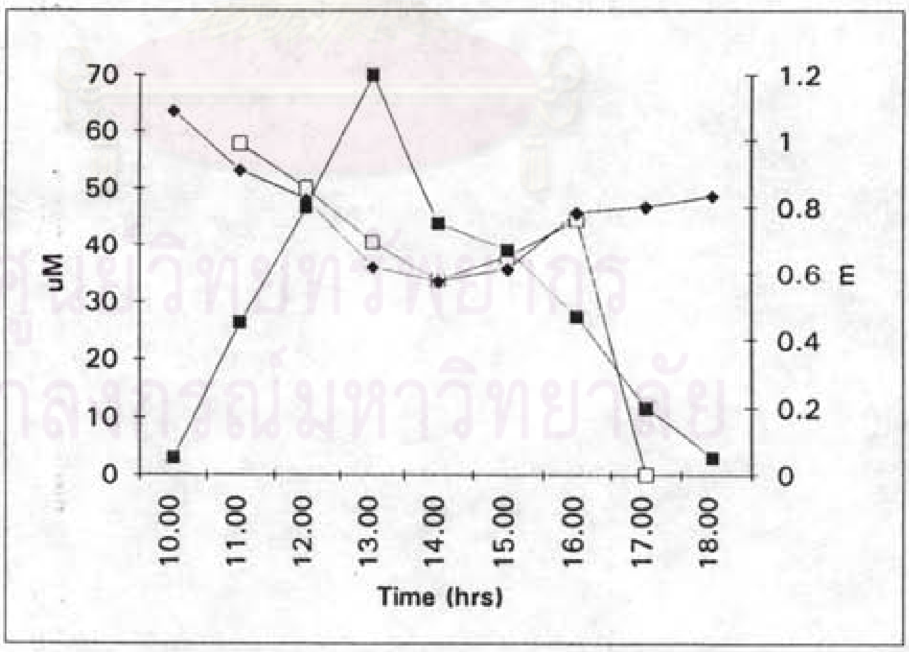


Figure 4.19 Relationship between silicate concentration and tide cycle:October 1990 (wet season) and March 1991 (dryseason)

for both seasons showed positive relationship with tide cycle. This is probably due to the effect of fresh water.

4.2.4 Amount of nitrite released from sediment over time

Results of the chemical analysis of nitrite concentrations in water are given in Table 4.5 and Figure 4.13 showed profile of nitrite concentration in water with tidal cycle. Amounts of nitrite released from sediment in October 1990 and March 1991 are given in Table 4.6. In October 1990, measurements were taken at mid-water level, whereas in March 1991, they were taken at the surface and at the bottom. Concentrations ranged from 0.102 μg-at/l to 0.391 μg-at/l in October. In March , they ranged from 0.046 μg-at/l to 0.331 μg-at/l. Mean concentration was 0.255 μg-at/l in October. In March mean concentration was .181 μg-at/l. Figure 4.13 shows concentration profiles of nitrite in October and March. In October, during low tide (first hour), nitrite concentration was low, then increased slightly with high tide. In March, concentrations of nitrite were similar at the surface and bottom. During low tide, nitrite concentration was low, then increased with high tide. The highest concentration was at the 6th hour, then decreased sharply during ebb tide. As can be seen, concentrations of nitrite profile were similar In October 1990 and March 1991.

Table 4.6 compares released rates of nitrite in each tube in October and March. Mean rates for nitrite were 0.006 mmol m^{-2} h^{-1} in tube 1, 0.007 mmol m^{-2} h^{-1} in tube 2 and 0.002 mmol m^{-2} h^{-1} in tube 3. The rate of change was positive 0.005 mmol m^{-2} h^{-1}. In March 199, mean rates for nitrite were 0.003 mmol m^{-2} h^{-1} in tube 1, 0.003 mmol m^{-2} h^{-1} and 0.003 mmol m^{-2} h^{-1} in tube 3. The rate of change was positive 0.003 mmol m^{-2} h^{-1}. The positive indicated nitrite released from sediment to the overliying water in both seasons.

4.2.5 Amount of nitrate released from sediment over time

Results of the chemical analysis of nitrate concentrations in water are given in Table 4.5. Figure 4.14 shows relationship between nitrate and tidal cycle in October and March. Amounts of nitrate released from sediment in October 1990 and March

1991 are given in Table 4.6.

In October, measurements were taken at mid-water level, whereas in March, they were taken at the surface and bottom. Concentration of nitrate in October ranged from 0.194 μg-at/l to 0.781 μg-at/l, and in March from .120 μg-at/l to .925 μg-at/l. Mean concentrations were 0.345 μg-at/l in October and 0.445 μg-at/l in March. Nitrate concentration were generally highest at low tide (first hour) then decreased slightly to a hour of 4th and increase during ebb tide (Figure 4.14).

Table 4.6 indicates rates of nitrate released from the sediment were -0.007 mmol m^{-2} h^{-1} in Tube 1, -0.010 mmol m^{-2} h^{-1} in Tube 2 and 0.001 mmol m^{-2} h^{-1} in Tube 3. Net nitrate flux was negative -0.005 mmol m^{-2} h^{-1}. In March 1990, released rates were -0.011 mmol m^{-2} h^{-1} in Tube 1, -0.011 mmol m^{-2} h^{-1} in Tube 2 and -0.011 mmol m^{-2} h^{-1} in Tube 3. Net nitrate flux was -0.011 mmol m^{-2} h^{-1}.

4.2.6 Amount of ammonia released from sediment over time

Results of the chemical analysis of ammonia concentrations in water are given in Table 4.5 and Figure 4.15 shows relationship between ammonia concentration in water with tidal cycle. Amount of ammonia released from sediment in October 1990 and March 1991 are given in Table 4.6.

In October, measurements were taken at mid-water level, whereas in March 1991 they were taken at the surface and at the bottom. Concentration ranged from 0.730 μg-at/l to 1.97 μg-at/l in October 1990. In March 1991 concentration ranged from 0.730 μg-at/l to 3.69 μg-at/l. Mean concentrations were 1.303 μg-at/l in October 1990 and 1.30 μg-at/l in March 1991. The relationship between ammonia and tide cycle is shown in Figure 4.15. As can be seen, concentration of ammonia was higher during ebb tide than flood tide in both months.

Table 4.6 shows released rates of ammonia in each tube in October and March. Fluxes of ammonia released from sediment were 0.181 mmol m^{-2} h^{-1} in Tube 1, 0.187 mmol m^{-2} h^{-1} in Tube 2 and 0.162 mmol m^{-2} h^{-1} in Tube 3. Net flux of ammonia was positive 0.177 mmol m^{-2} h^{-1}. In March, fluxes of ammonia were 0.009 mmol m^{-2} h^{-1} in Tube 1, 0.009 mmol m^{-2} h^{-1} in Tube 2 and 0.009 mmol m^{-2} h^{-1} in

Tube 3. Net flux of ammonia was positive 0.009 mmol m^{-2} h^{-1}.

4.2.7 Amount of dissolved organic nitrogen (DON) released from sediment over time

Results of chemical analysis of dissolved organic nitrogen are given in Table 4.5 and Figure 4.16 shows relationship between dissolved organic nitrogen (DON) with tide cycle. Fluxes of dissolved organic nitrogen released from the sediment in October 1990 and March 1991 are persented in Table 4.6.

In October 1990, measurements were taken at mid-water level, whereas in March 1991 they were taken at the surface and at the bottom. Concentrations ranged from 27.56 μg-at/l to 272.17 μg-at/l in October. In March they were 91.39 μg-at/l to 412.36 μg-at/l. As can be seen in Figure 4.16, concentrations of dissolved nitrogen were high at the first hour of low tide then decreased with time (October). In March they were low at the first hour then increased with high tide and decreased slightly during ebb tide.

Table 4.6 shows released rates of dissolved organic nitrogen in different month (October and March). The released rates of DON were 28.20 mmol m^{-2} h^{-1} in Tube 1, 17.90 mmol m^{-2} h^{-1} in Tube 2 and 28.19 mmol m^{-2} h^{-1}. Net released rate of DON was 24.76 mmol m^{-2} h^{-1}. In March, average rates of DON were 4.468 mmol m^{-2} h^{-1} in Tube 1, 4.466 mmol m^{-2} h^{-1} tin Tube 2 and 4.466 mmol m^{-2} h^{-1} in Tube 3. The average rate of DON released was 4.466 mmol m^{-2} h^{-1}.

4.2.8 Amount of phosphate released from sediment over time

Results of chemical analysis of phosphate concentrations in water are given in Table 4.5 and Figure 4.17 showed relationship between concentrations of phosphate with tidal cycle. Fluxes of phosphate released from the sediment in October 1990 and March 1991 are given in Table 4.6

In October, measurements were taken at the mid-water level, whereas in March they were taken at the surface and bottom. Concentrations of phosphate in the water ranged from 0.106 μg-at/l to 0.295 μg-at/l in October. In March 1991, they ranged from 0.144 μg-at/l to 0.753 μg-at/l. Mean concentration was 0.166 μg-at/l in October. In March 1991, it was .264 μg-at/l. As can be seen, in Figure 4.17, phosphorus concentration is low in the first hour and higher during ebb tide than flood tide. The phosphorus concentration profile was similar to the profile in October and March.

Table 4.6 shows released rates of phosphate from sediment to overlying water in each tube in October and March. Averages released were 0.027 mmol m^{-2} h^{-1} in Tube 1, 0.027 mmol m^{-2} h^{-1} in Tube 2 and 0.013 mmol m^{-2} h^{-1} in Tube 3. Net released rate was 0.022 mmol m^{-2} h^{-1}. Whereas in March 1991, released rateds were -0.001 mmol m^{-2} h^{-1} in Tube 1, 0.001 mmol m^{-2} h^{-1} in Tube 2 and 0.001 mmol m^{-2} h^{-1} in Tube 3. Net released rate was 0.001 mmol m^{-2} h^{-1}.

4.2.9 Amount of dissolved organic phosphorus (DOP) released from sediment over time

Results of chemical analysis of dissolved organic phosphorus in the water are presented in Table 4.5 and Figure 4.18 shows relationship between dissolved organic phosphorus with tidal cycle. Fluxes of dissolved organic phophorus released from the sediment in October 1990 and March 1991 are given in Table 4.6.

In October 1990, measurements were taken at the mid-water level, whereas in March they were taken at the surface and the bottom. Concentration of DOP ranged from 0.122 μg-at/l to 0.457 μg-at/l in October. In March, from 0.906 μg-at/l to 1.94 μg-at/l. Mean concentration was 0.297 μg-at/l in October. In March, it was 1.23 μg-at/l. As can be seen in Figure 4.18 concentrations of dissolved organic phosphorus were low during the first hour of low tide and decreased with time.

In Table 4.6, showed released rate of dissolved organic phosphorus in each tube in October and March. The released rates were 0.011 mmol m^{-2} h^{-1} in Tube 1, 0.011 mmol m^{-2} h^{-1} in Tube 2 and 0.011 mmol m^{-2} h^{-1} in Tube 3. Net flux was -0.011 mmol m^{-2} h^{-1}. In March 1991, average rates of dissolved organic phosphorus released from the sediment were 0.039 mmol m^{-2} h^{-1} in Tube 1, 0.039 mmol m^{-2} h^{-1} in Tube 2 and 0.039 mmol m^{-2} h^{-1} in Tube 3. Net flux of dissolved organic phosphorus released from sediment was .039 mmol m^{-2} h^{-1}.

4.3 Nutrients released from stirred and unstirred sediment in Laboratory

Results of the investigation are presented in Table 4.7-4.9, and Figures 4.20-4.27

***Table 4.7** Physicochemical characteristics of unstirred and stirred water:Laboratory*

	Stirred		Unstirred	
parameter	Range	Average	Range	Average
DO (mg/l)	4.1 -5.5	4.75	4.2 -5.9	5.04
pH	7.03-7.92	7.41	7.03-7.85	7.36

Note: Salinity = 33 ppt
temperature = 28 °C

***Table 4.8** Concentration of nutrients in water from stirred and unstirred sediment: Laboratory*

	Stirred		unstirred	
Parameter	Range (μg-at/l)	Average (μg-at/l)	Range (μg-at/l)	Average (μg-at/l)
NO_2^-	.010-.048	.026	.012-.051	.029
NO_3^-	.109-.410	.247	.040-.452	.235
NH_4^+	.206-.634	.458	.206-.634	.367
DON	28.7-58.6	46.2	35.04-67.56	49.7
PO_4	.001-.076	.017	.003-.025	.011
DOP	.086-.772	.453.	.098-.526	.253

***Table 4.9** Average of nutrients released from unstirred and stirred sediment: Laboratory*

	Stirred μmol $m^{-2}h^{-1}$					Unstirred μmol $m^{-2}h^{-1}$		
Tube	1	2	3	4	Average	1	2	Average
NO_2^-	.063	.014	-.044	-.047	.035	-.073	-.030	-.051
NO_3^-	1.29	.196	-1.03	-.907	-.010	-.629	.117	-.256
NH_4^+	-.440	-.560	-.523	.290	-.243	-.243	-.989	-.616
DON	-124.2	-77.9	16.6	-86.9	-68.0	41.2	-23.7	8.73
PO_4^{3-}	-.218	.397	.116	.018	.078	-.054	-.099	-.076
DOP	2.62	-2.38	-5.59	1.33	-1.00	-.643	-.241	-.442

Note: DON= Dissolved organic nitrogen

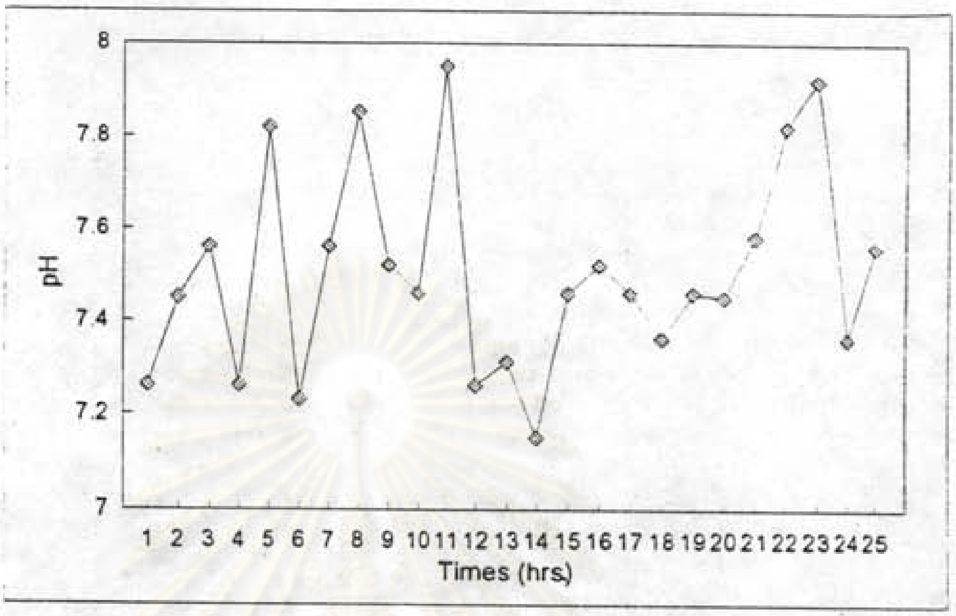
DOP = Dissolved organic phosphorus

4.3.1 Amount of nitrite released in water from stirred and unstirred sediment

Results of the chemical analysis of nitrite concentration in water are given in Table 4.8 and Figure 4.12 shows concentrations of nitrite in water over time. Amounts of nitrite released from the sediment in unstirred sediment and stirred sediment are given in Table 4.9. In stirred sediment, nitrite concentration ranged from 0.010 μg-at/l to 0.048 μg-at/l. In unstirred, they ranged from 0.012 μg-at/l to 0.051 μg-at/l. Mean concentration was 0.026 μg-at/l in stirred sediment and 0.029 μg-at/l in unstirred sediment. Figure 4.22, shows similar nitrite profiles for stirred and unstirred sediment. Concentrations were higher at the beginning trending to decreased over time.

Table 4.9 indicates that nitrite release rates were0 .063 μmol m^{-2} h^{-1} in Container 1, 0.014 μmol m^{-2} h^{-1} in Container 2, -0.044 μmol m^{-2} h^{-1} in Container 3 and -0.047 μmol m^{-2} h^{-1} in Container 4. Net released rate was 0.035 μmol m^{-2} h^{-1}. In unstirred sediment, released rate were -0.073 μmol m^{-2} h^{-1} in Container 1 and -0.030 μmol m^{-2} h^{-1} in Container 2. Net released rate was -0.051 μmol m^{-2} h^{-1}.

Unstirred sediment



Stirred sediment

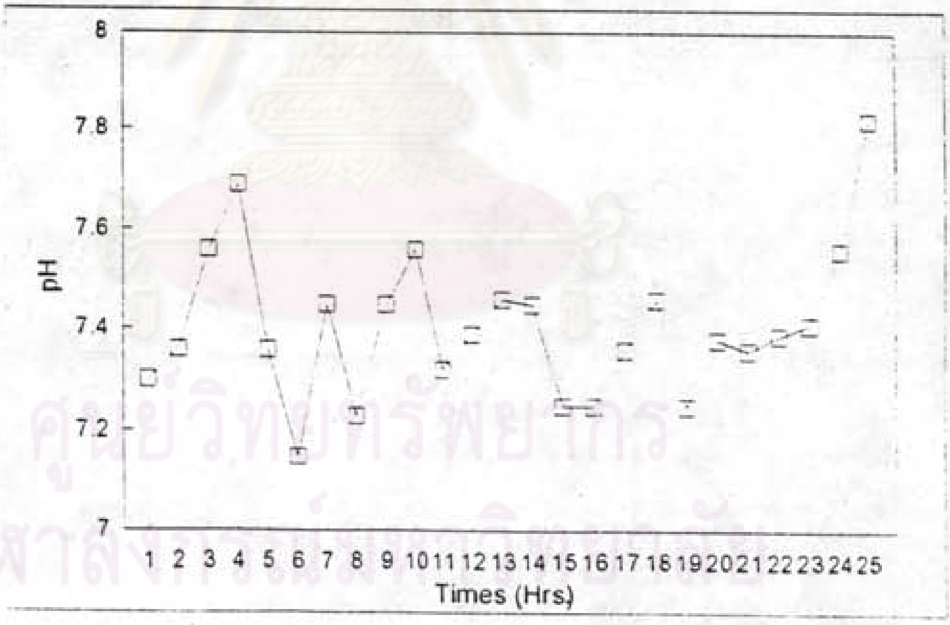
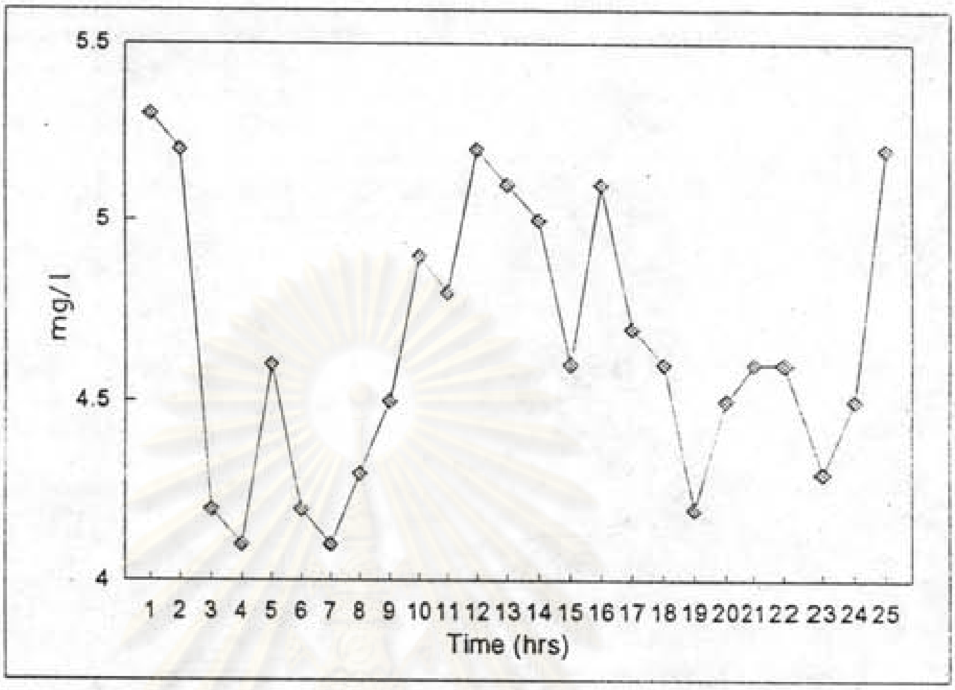


***Figure** 4.20 pH in water from unstirred sediment and stirred sediment*

Unstirred sediment



Stirred sediment

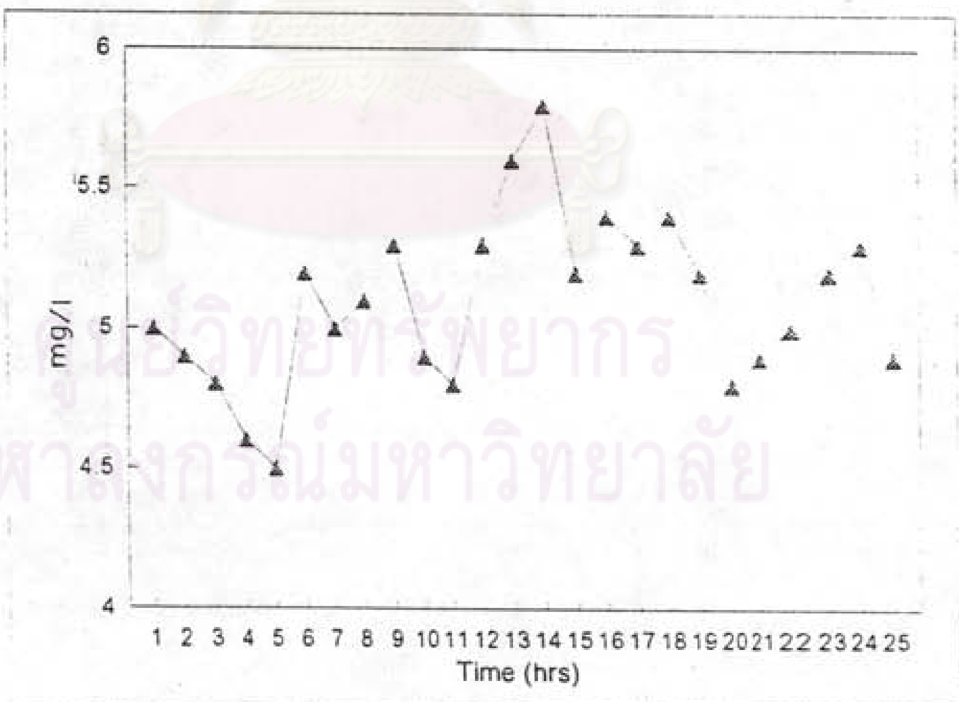
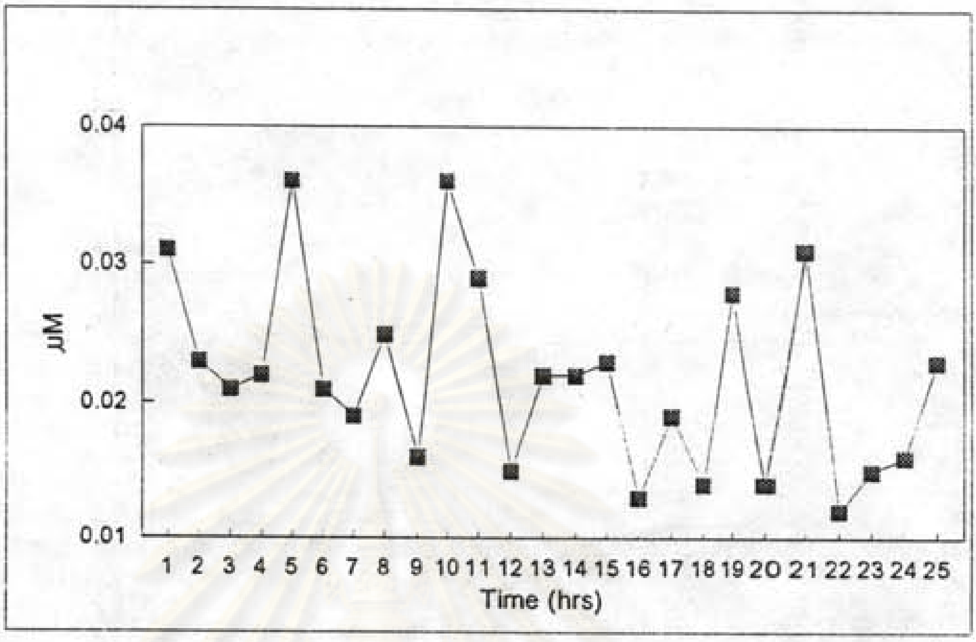


Figure 4.21 Dissolved oxygen in water from unstirred andstirred sediment.

Unstirred sediment



Stirred sediment

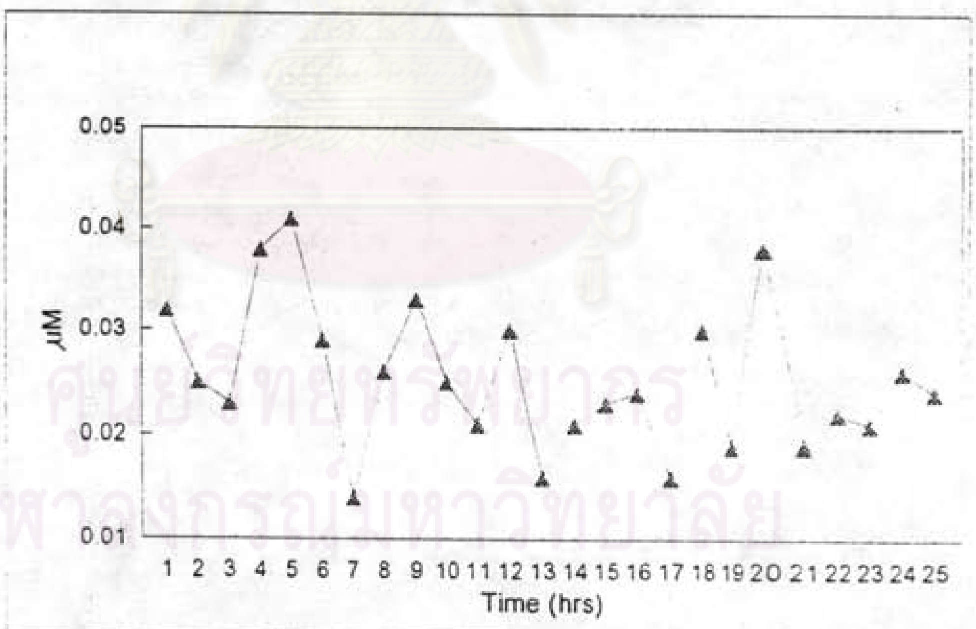
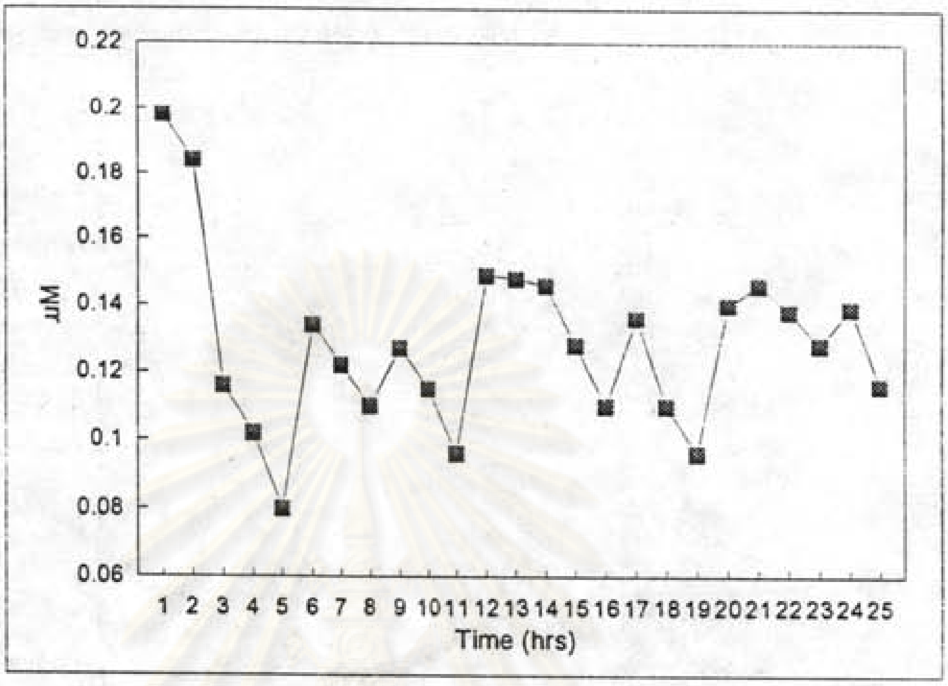


Figure 4.22 Concentration of nitrite in water from unstirred and stirred sediment

Unstirred sediment



Stirred sediment

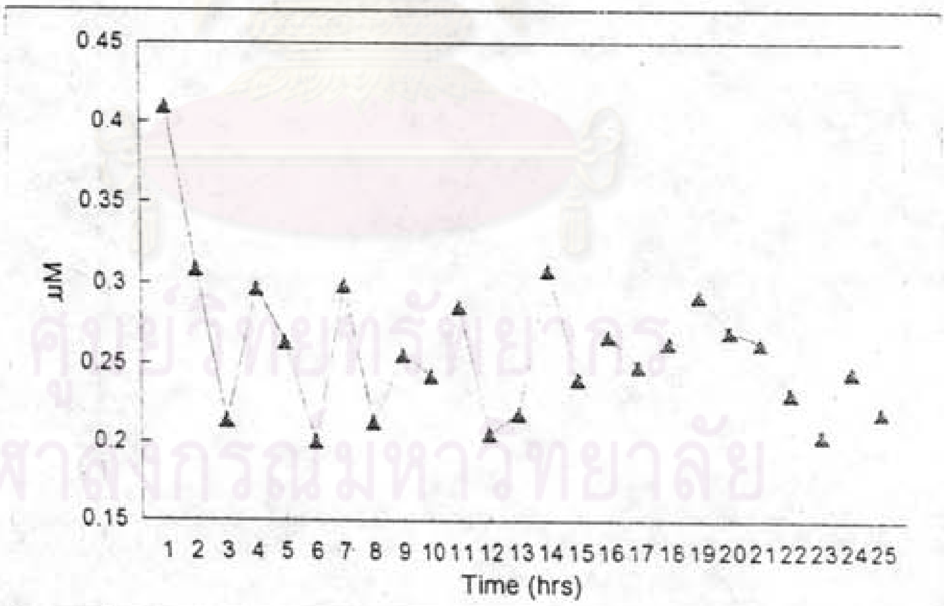
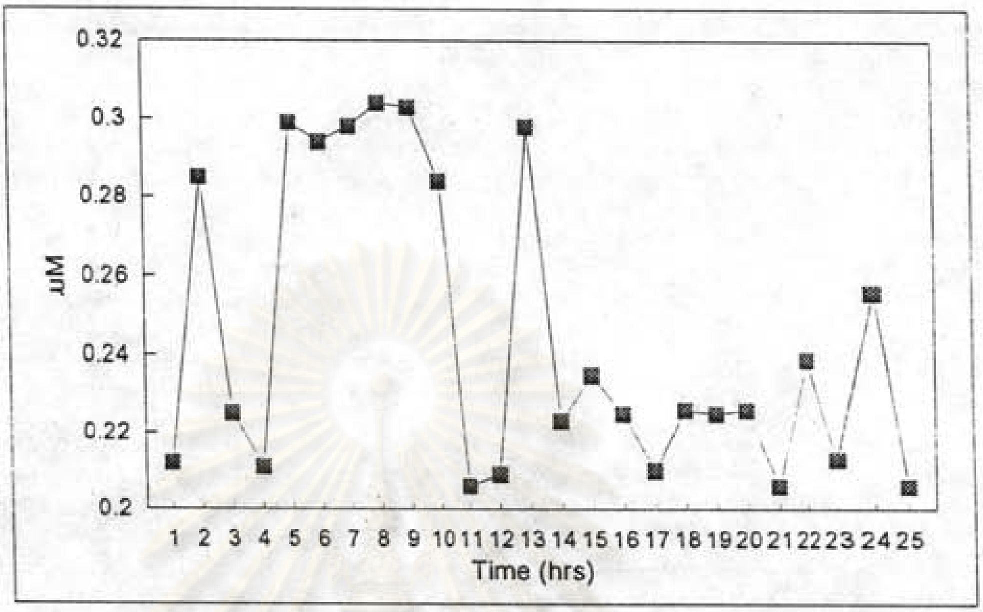


***Figure 4.23** Concentration of nitrate in water from unstirred and stirred sediment.*

Unstirred sediment



Stirred sediment

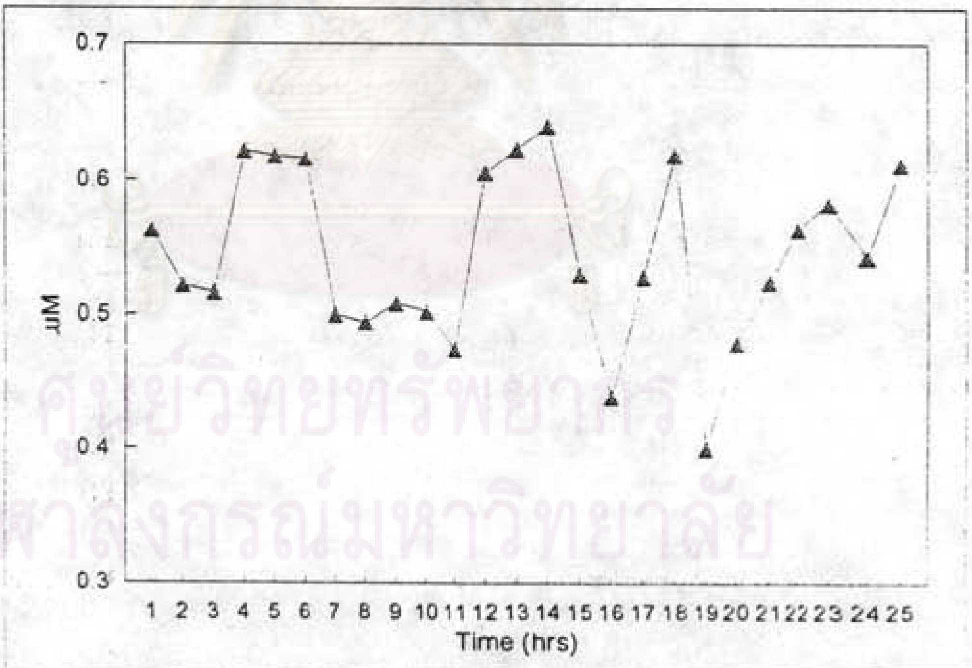
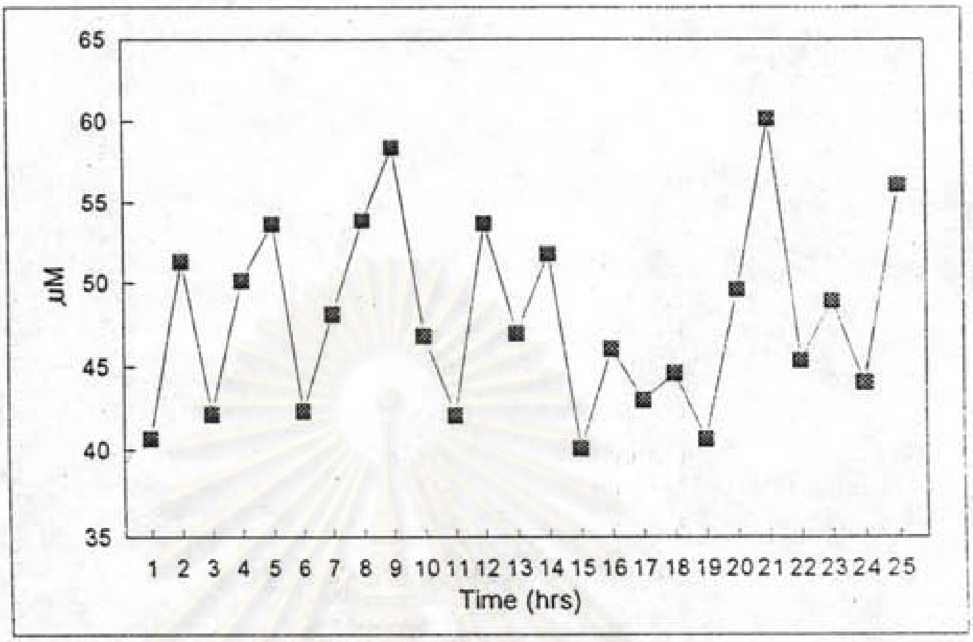


***Figure** 4.24 Concentration of ammonia in water from unstirred and stirred sediment.*

Unstirred sediment



Stirred sediment

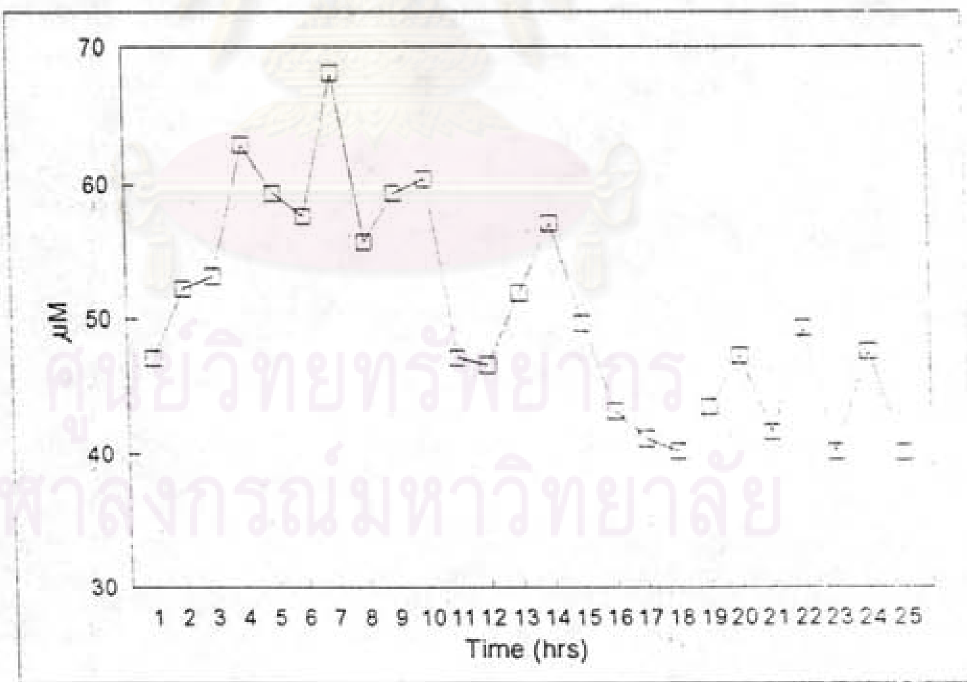
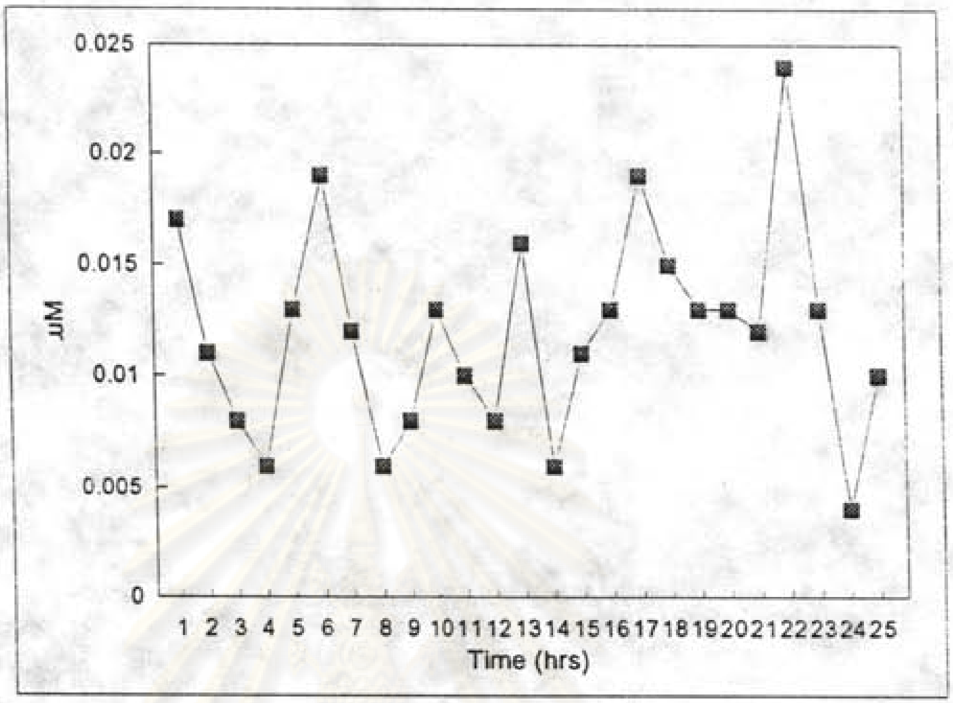


Figure 4.25 *Concentration of dissolved organic nitrogen in water from unstirred and stirred sediment.*

Unstirred sediment



Stirred sediment

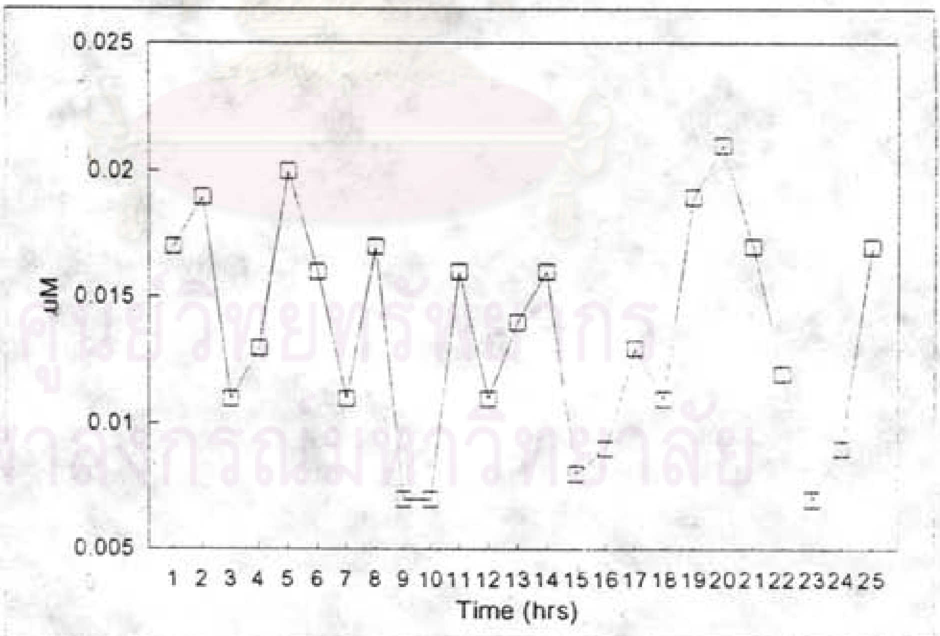
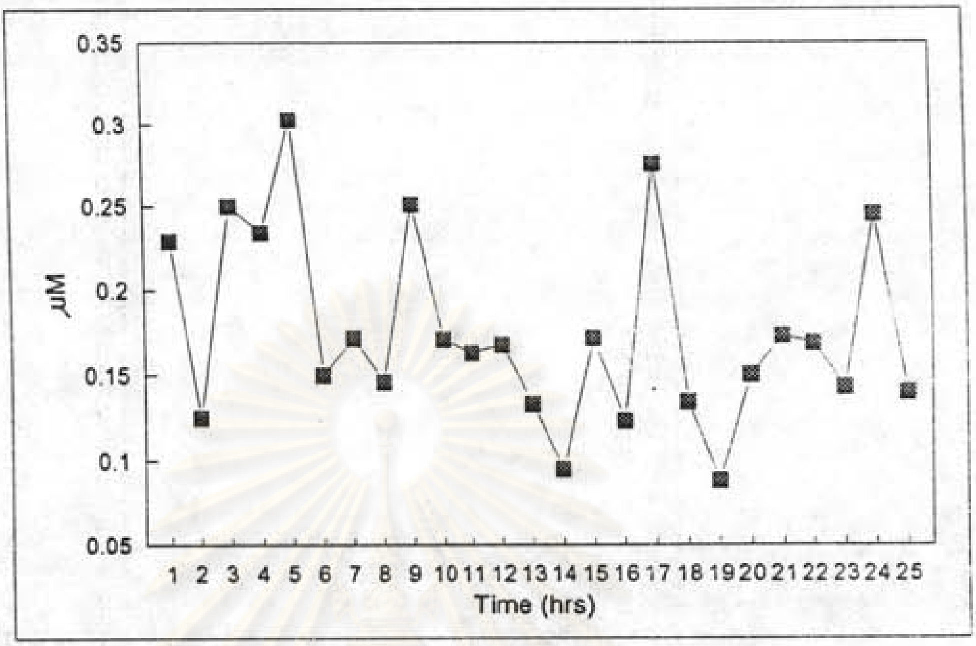


Figure 4.26 *Concentration of phosphate in water from unstirred and stirred sediment.*

unstirred sediment



Stirred sediment

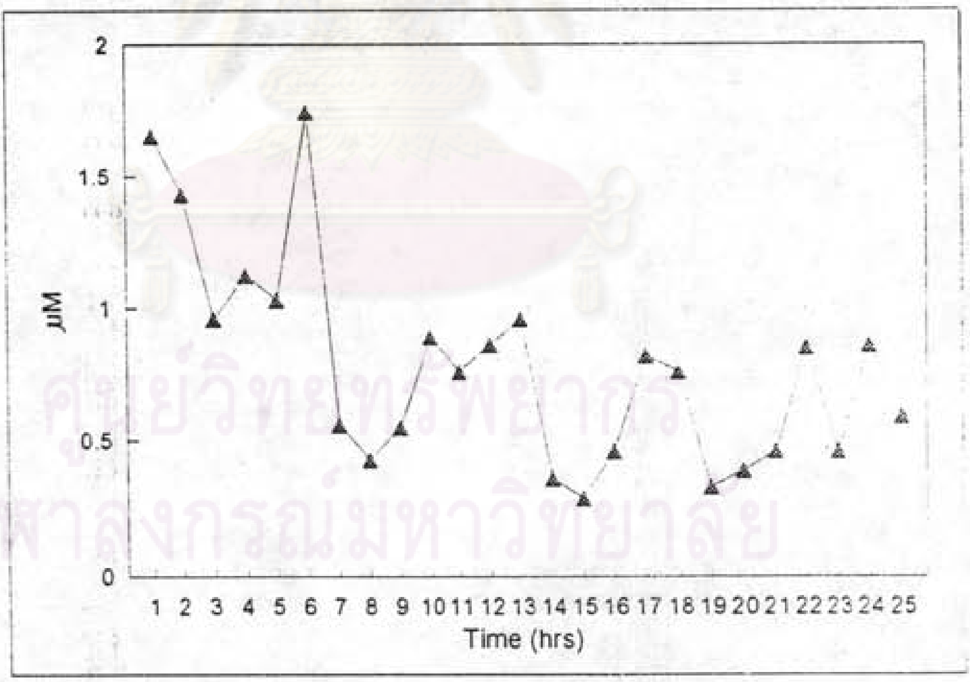


Figure 4.27 Concentration of dissolved organic phosphorus in water from unstirred and stirred sediment.

4.3.2 Amount of nitrate released in water from stirred and unstirred sediment

Results of the chemical analysis of nitrate concentrations in water are given in Table 4.8 and Figure 4.23. Amounts of nitrate released from unstirred and stirred sediment are given in Table 4.9.

In stirred sediment, measurements were taken hourly for 24 hours. Concentration of nitrate in stirred sediment ranged from 0.109 μg-at/l to 0.41 μg-at/l, and in unstirred sediment from 0.040 μg-at/l to 0.452 μg-at/l. Mean concentrations were 0.247 μg-at/l in stirred sediment and 0.235 μg-at/l in unstirred sediment. As Figure 4.23 suggests, nitrate profiles were similar in both stirred and unstirred seiment, with highest concentrations at the beginning then decreasing slightly over time to the 4th hour, then remaining constant.

In Table 4.9, released rate were 1.29 μmol m^{-2} h^{-1} in Container 1, 0.196 μmol m^{-2} h^{-1} in Container 2, -1.03 μmol m^{-2} h^{-1} in Container 3 and -0.907 μmol m^{-2} h^{-1} in Container 4. Net flux was -0.010 μmol m^{-2} h^{-1}. In unstirred sediment, releases rate were -0.629 μmol m^{-2} h^{-1} in Container 1 and 0.117 μmol m^{-2} h^{-1} in Container 2. Net flux was negative (-.256 μmol m^{-2} h^{-1}).

4.3.3 Amount of ammonia released in water from stirred and unstirred sediment

Results of the chemical analysis of ammonia concentrations in water are given in Table 4.8 and Figure 4.24. Amounts of ammonia released from stirred and unstirred sediment are given in Table 4.9.

In stirred sediment, concentrations ranged from 0.206 μg-at/l to 0.634 μg-at/l. In unstirred sediment, concentrations ranged from 0.206 μg-at/l to 0.634 μg-at/l. Mean concentrations were 0.458 μg-at/l in stirred sediment and 0.367 μg-at/l in unstirred sediment. The relationship between ammonia and stirred and unstirred sediment is shown in Figure 4.24. As can be seen, ammonia concentration in water was high in un stirred sediment in the first hour decreaseing at the mid point. In stirred sediment, ammonia concentrations were constant from the beginning through the 15th hour, dropped to about 0.3 μg-at/l at the 17th hour, then increased sharply to normal curve again.

In Table 4.9, released rates were -0.440 μmol m^{-2} h^{-1} in Container 1, -0.560 μmol m^{-2} h^{-1} in Container 2, -0.523 μmol m^{-2} h^{-1} in Container 3 and 0.290 μmol m^{-2} h^{-1} in Container 4. Net flux was -0.243 μmol m^{-2} h^{-1}. In unstirred seiment, released rates were -0.243 μmol m^{-2} h^{-1} in Container 1 and -0.989 μmol m^{-2} h^{-1}. Net release rate was -0.616 μmol m^{-2} h^{-1}.

4.3.4 Amount of dissolved organic nitrogen released in water from unstirred and stirred sediment

Amount of dissolved organic nitrogen in water from stirred and unstirred sediment are given in Table 4.8 and Figure 4.25. Fluxes of dissolved organic nitrogen released from stirred and unstirred sediment are given in Table 4.9.

In stirred sediment, concentrations ranged from 28.7 μg-at/l to 58.6 μg-at/l and in unstirred sediment ranged from 35.0 μg-at/l to 67.5 μg-at/l. Mean concentration was 46.2 μg-at/l in stirred sediment. In unstirred sedimen, it was 49.7 μg-at/l. As can be seen in Figure 4.25, concentrations of total nitrogen were high at the first hour and decreased slightly with time.

In Table 4.9, released rates were -124.2 μmol m^{-2} h^{-1} in Container 1, -77.9 μmol m^{-2} h^{-1} in Container 2, 16.6 μmol m^{-2} h^{-1} in Container 3 and -86.9 μmol m^{-2} h^{-1} in Container 4. Net released rate was -68.0 μmol m^{-2} h^{-1}. In unstirred sediment, released rates were 41.2 μmol m^{-2} h^{-1} in Container 1 and -23.7 μmol m^{-2} h^{-1} in Container 2. Net release rate was 8.73 μmol m^{-2} h^{-1}.

4.3.5 Amount of phosphate released in water from stirred and unstirred sediment

Results of chemical analysis of concentration of phosphate in water are given in Table 4.8 and Figure 4.26. The released rates are presented in Table 4.9.

In stirred sediment, concentrations of phosphate ranged from 0.001 μg-at/l to 0.076 μg-at/l. In unstirred sediment, from 0.003 μg-at/l to 0.025 μg-at/l. As can be seen in Figure 4.25 concentrations of phosphate in both system were similar trend with constantly concentration from the beginning through the end.

In Table 4.9, released rates were -0.218 μmol m^{-2} h^{-1} in Container 1, 0.397

μmol m^{-2} h^{-1} in Container 2, 0.116 μmol m^{-2} h^{-1} in Container 3 and 0.018 μmol m^{-2} h^{-1} in Container 4. Net released rate was 0.078 μmol m^{-2} h^{-1}. In unstirred sediment, released rates were -0.054 μmol m^{-2} h^{-1} in Container 1 and -0.099 μmol m^{-2} h^{-1} in Container 2. Net released rate was -0.076 μmol m^{-2} h^{-1}.

4.3.6 Amount o dissolved organic phosphorus released in water from stirred and unstirred sediment

Results of chemical analysis of dissolved organic phosphorus are presented in Table 4.8 and plotted in Figure 4.27. Fluxes of dissolved organic phosphorus released from stirred and unstirred sediment are presented in Table 4.9. Concentrations of DOP ranged from 0.086 μg-at/l to 0.772 μg-at/l in stirred sediment and from 0.098 μg-at/l to 0.536 μg-at/l in unstirred sediment. As can be seen in Figure 4.27, concentrations of DOP were similar in both systems, decreasing slightly with time.

Table 4.9 indicates released rates were 2.62 μmol m^{-2} h^{-1} in Container 1, -2.38 μmol m^{-2} h^{-1} in Container 2, -5.59 μmol m^{-2} h^{-1} in Container 3 and 1.33 μmol m^{-2} h^{-1} in Container 4. Net released rate was -1.00 μmol m^{-2} h^{-1}. In unstirred sediment, they were -0.643 μmol m^{-2} h^{-1} in Container 1 and -0.241 μmol m^{-2} h^{-1} in Container 2. Net released rate was -0.442 μmol m^{-2} h^{-1}.