Southeast Asian Fisheries Development Center

Analysis and Estimation of Trace Metals in Seawater and Sediment in the South China Sea, Area IV: Vietnamese Waters

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ABSTRACT

Water samples from off shore of Vietnam from latitude 6°N to 21°N and longitude 103°C to 112°E were collected on 30 April 1999 to 29 May 1999 and analyzed for copper (Cu), lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni), chromium (Cr), arsenic (As) and mercury (Hg). The concentration of metals Cu, Pb, Cd, Zn, Ni and Cr was measure using flameless atomic absorption spectroscopy. The total concentration of all eight metals was in concentration ranges of unpolluted coastal water. The results indicated that the concentration of metals in bottom layer higher than in surface layer. Also, trace metal contents in the surface sediment were studied in off shore of Vietnam during this cruise. Total metals content were measured. The range of concentration of metals were 10.3 - 71.0 $mg.g^{-1}$ for Cu, 12.9 - 33.7 $mg.g^{-1}$ for Pb, 1.29 - 18.72 $mg.g^{-1}$ for Cd, 45.8 - 164.8 $mg.g^{-1}$ for Zn, 21.2 - 93.6 $mg.g^{-1}$ for Cr, 5.7 - 45.8 $mg.g^{-1}$ for Ni, 1.64 - 3.80 $mg.g^{-1}$ for As, and 0.104 - 0.493 $mg.g^{-1}$ for Hg. The levels found in the present study are similar to data from other marine.

Key words: Trace metals, Seawater, Surface sediment, South China Sea, Off shore of Vietnam

Introduction

Aquatic systems such as the seawater, inland water etc. are important stages in the biogeochemical cycle. Although dissolved levels are usually in the trace range of 10^{-6}-10^{-9} Ml^{-1} they remain significant, because they entry into the food chain and interactions with suspended particulate and sediments largely occur via the dissolve state.

The various heavy metals as Cd, Ni, As, Hg, etc. in seawater become toxic if present in excessive quantities and pose a potential threat to the ecosystem. Therefore, there has been constant effort to measure the impact of these metals on fauna [De Silva].

In environmental research and protection toxic metal, particularly Cd, Pb, Hg, As, Ni, Cr, etc. are becoming increasingly signification owing their biological nondergradability and chromic toxicity resulting from their accumulation in vital organs of man. As part of the SEAFDEC Cooperative Program in the Study of Fisheries Oceanography of the South China Sea, a Research on trace heavy metals in seawater was made.

The first analyses of seawater were performed just prior the beginning to the 19th century in laboratories. However, problems arising from changes in chemical composition through evanosation, biological activity, or chemical interactions with the containing vessel, forced the marine chemist to transfer his laboratory from land to ships. Herman Walterberg, the chemist on the famous "Meteor Expedition" in 1925, pioneered this change. Today, there is a strong and necessary trend toward instrumental techniques, as opposed to the classical methods, especially when assaying very small amounts of materials.

General comparative considerations suggest atomic absorption spectroscopy and modern voltametric methods, particularly differential pulse stripping voltammetry with high sensitivity, precision, and accuracy also a simple sample preparation and treatment to be the most promising chose for the determination and characterization of toxic heavy metal traces in seawater.

Material and Methods

Analytical methods

The concentrations of metals: Cu, Pb, Cd, Zn, Ni, Cr, As and Hg in Vietnamese waters were studied in the SEAFDEC interdepartmental collaborative research survey. The samples were analyzed in laboratory of the Department for Analytical Science and Technique of the Institute of Chemistry, National Center for Natural Science and Technology of Vietnam, NCST.

All bottles, filter membranes and lab wares that would be contact with samples were carefully pre-washed by 10% suprapure HNO_3 acid and Mili-Q water. Merck standard solutions diluted by Mili-Q water was use as standard.

The concentrations of metals Cu, Pb, Cd, Zn, Cr, Ni were measured using graphite furnace atomic absorption spectrometer PE AAS 3300, USA and As by using hydride AAS technique with MHS-10, Hg by using coldvapour method with MHS-10, and 746 VA Trace Analyzer Metrohm, Switzerland. Polyethylene containers, which have been previously cleaned with nitric acid then rinse with water, shall be used for sampling.

Sampling

Fifty-eight stations from offshore of Vietnam from latitude 6°N to 21°N and longitude 103°E to 112°E were established in this study (Fig.1)

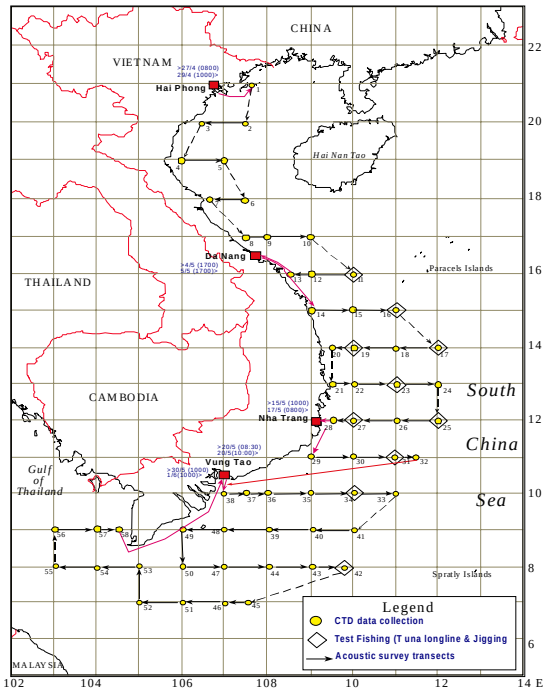

Fig. 1. Oceanographic Survey Station.

MV SEAFDEC collected the water samples on 30 April 1999 to 29 May 1999. The water was collected at each station during cruise at least two depth (surface and bottom) by water sampler attached to a rosette system. The water samples were transferred into acidic washed PE bottles and acidified to pH 1 with suprapure nitric acid for determination of Cu, Pb, Cd, Zn, Ni, Cr and As and with 1ml 10% $K_2Cr_2O_7$ solution to 1 liter for determination of Hg. Glass or other inert materials should be used if there is a risk of interaction of the sample with the container.

Determination of Cu, Pb, Cd, Zn, Ni and Cr

This method describes the determination of soluble copper, lead, cadmium, zinc, chromium and nickel in seawater and other saline waters by the simultaneous extraction of their complexes with ammonium pyrirolidine dithiocarbanate in to methyl isobutyl ketone and by the atomic absorption spectrophotometer with the graphite tube technique. Place 750ml aliquot of the sample, acidified seawater and each of the calibration solutions into series of 1 liter separating funnels fitted with polytetrafluoroethylene (PTFE) taps.

Add 35 ml of MIBK followed by 7ml of 1% APDC. Shake vigorously for 30 min. separate the organic layer in a polypropylene bottle and store for analysis. Allow the mixture to settle for at least 1h away from light or heat in the stoppered funnel. The settling time shall be strictly the same for all the solutions. Collect the organic layer taking care to avoid any trace of the aqueous phase (centrifuge if necessary) carry out a blank test in parallel with the determination by the same procedure, using the same quantities of all the reagents as in the sampling and chelation and extraction, but replacing the test portion by water.

Proceed as follows for each metal being determined. Before carrying out the spectrometric measurement, set up spectrometer according to the manufacturer's instructions by aspirating the organic extract of calibration solution of the metal being determined and using information in Table1.

Optimize the aspiration and conditions. Adjust the response of the instrument to zero absorbance with MIBK. For each metal being determined, aspirate the set of organic extracts of the calibration solutions. Plot a graph having the metal contents, in micrograms per liter, of the calibration solutions as abscissas and the corresponding values of absorbance as ordinates for example by measuring the absorbance of a calibration solution every five samples. Aspirate the organic extract of the test portion. Measure the absorbance of the metal being determined and after each measurement aspirate MIBK in order to rinse the nebulizer system.

Table 1. Wavelength (nm) used to determine metal element.

Element to be determined	Wavelength (nm)
Nickel	232.0
Copper	324.7
Zinc	213.8
Cadmium	228.8
Chromium	357.9
Lead	283.3 217.0

Determination of Mercury

Mercury ions are reduced to metallic mercury by $NaBH_4$, entrancement of the mercury in a current of inert gas at ambient temperature and determination of the mercury, by flameless atomic absorption spectrometry at a wavelength of 253.7nm

Take a test portion of 100 ml from the previously mixed sample containing not more than 0.5 mg of mercury. Prepare, just before use, using the standard mercury solutions at least five calibration solutions, covering the range of concentrations which can be measured with the apparatus to be used.

Treat each of these solutions immediately after their preparation in exactly the same way as the test portion on which the determination is to carry out. Also, proceed in exactly the same way on a solution in which the standard mercury solution is replaced with water.

Set up the instrument in accordance with the manufacturer's introductions. Transfer a volume of sample solution into aeration flask in accordance with the manufacturer's introductions with on the entrainment gas supply and let the developed mercury vapour flow through the absorption cell and measure the absorption of atoms in the beam of the PE - AAS - 3300 by using of MHS - 10 carry out a blank test with each batch of samples, but replacing the test portion with water and using the same volume of reagents as for the determination prefer.

Determination of Arsenic

The method is based on the atomic absorption measurement of arsenic generated by the thermal decomposition of arsenic (III) hydride. As (III) is reduced to gaseous arsenic (III) hydride (AsH_3) by reaction with sodium tetrahydroborate in a hydrochloric acid medium.

The absorbance is determined at a wavelength of 193.7nm. Set all instrumental parameters of the atomic absorption spectrometer in accordance with the manufacturer's operating manual and optimize the position of the absorption cell in order to obtain maximum transmission of the light beam.

Pass a stream of argon through the system and set the instrument to zero. Measure the absorption given by the solutions in the following order:

- Blank solution,
- Calibration solutions,
- Samples, prepared as follows,

Depending on the hydride system used, transfer an appropriate volume of the sample solution to the reaction vessel (MHS - 10). Connect the reaction vessel to the hydride system pass argon through the solution until the absorption signal of atomic absorption spectrometer returns to zero. For 20 ml of the sample solution add 5ml ± 0.1ml of sodium tetrahydroborate solution to the solution and record the signal. Repeat the procedure using separate portions of each solution. Use the mean of these results. Establish the calibration curve using means of values obtained with the blank and calibration solutions.

Results and Discussion

Certified Reference Seawater Probe CASS-3 of the Institute for Environmental Chemistry, Canada, were included in sample preparation and analysis as quality control samples to ensure the

accuracy of the results. The percentage recovery of copper was 102.5%, lead was 116.6%, cadmium was 116,6%, zinc was 108.9%, nickel was 104.1% and chromium was 109.8%. The result of analysis indicated good recoveries of all determined metals (Table 2).

Table 2. Analytical performance based on Reference Seawater. (µg/l).

	Cu	Pb	Cd	Zn	Ni	Cr
CASS-3	0.517	0.012	0.030	1.24	0.386	0.092
Our result	0.530	0.014	0.035	1.35	0.402	0.101

The concentration of the determined metals in seawater of survey cruise at surface and bottom layer of sampling are presented in the Tables 3, 4, 5, 6, 7, 8, 9, and 10 in nM and Tables11, 12, 13, 14, 15, 16, 17 and 18 in µg/l

Table 3. Cu-Concentration in seawater.

Station	Samples	Cu (nM)	Station	Samples	Cu (nM)	Station	Samples	Cu (nM)
1	1S	76.64	21	21S	65.16	41	41S	59.49
	1B	90.34		21B	80.11		41B	79.16
2	2S	73.81	22	22S	75.23	42	42S	58.07
	2B	87.19		22B	72.71		42B	78.06
3	3S	74.59	23	23S	72.71	43	43S	64.99
	3B	75.38		23B	67.83		43B	75.86
4	4S	79.00	24	24S	78.85	44	44S	60.12
	4B	76.48		24B	79.16		44B	83.57
5	5S	62.32	25	25S	75.07	45	45S	64.05
	5B	80.58		25B	76.48		45B	79.48
6	6S	67.99	26	26S	67.83	46	46S	58.07
	6B	67.20		26B	80.58		46B	78.22
7	7S	65.78	27	27S	76.01	47	47S	60.91
	7B	67.83		27B	78.06		47B	76.02
8	8S	58.86	28	28S	72.71	48	48S	64.99
	8B	74.59		28B	79.16		48B	58.54
9	9S	60.43	29	29S	75.07	49	49S	67.04
	9B	67.04		29B	92.22		49B	64.05
10	10S	60.75	30	30S	72.71	50	50S	61.85
	10B	72.23		30B	85.30		50B	81.52
11	11S	58.39	31	31S	62.01	51	51S	64.21
	11B	72.55		31B	77.75		51B	76.17
12	12S	51.93	32	32S	62.64	52	52S	78.85
	12B	61.85		32B	81.05		52B	79.16
13	13S	67.04	33	33S	67.99	53	53S	60.12
	13B	72.71		33B	75.86		53B	73.81
14	14S	61.85	34	34S	58.86	54	54S	58.07
	14B	75.70		34B	74.91		54B	60.90
15	15S	64.84	35	35S	64.84	55	55S	64.99
	15B	80.58		35B	66.26		55B	80.74
16	16S	60.43	36	36S	59.17	56	56B	63.74
	16B	62.48		36B	61.06		56B	80.89
17	17S	64.05	37	37S	67.83	57	57S	61.69
	17B	74.13		37B	77.43		57B	78.37
18	18S	59.17	38	38S	73.02	58	58S	70.50
	18B	75.86		38B	58.86		58B	74.28
19	19S	62.01	39	39S	69.09	*Note:*		
	19B	74.91		39B	76.64	• *S: Surface layer, 2m*		
20	20S	60.91	40	40S	59.96	• *B: Bottom layer, ≥ 100m*		
	20B	76.80		40B	80.58			

Table 4. Pb-Concentration in seawater.

Station	Samples	Pb (nM)	Station	Samples	Pb (nM)	Station	Samples	Pb (nM)
1	1S	**9.56**	**21**	21S	**8.73**	**41**	41S	**9.75**
	1B	**10.52**		21B	**9.85**		41B	**8.49**
2	2S	**9.79**	**22**	22S	**8.40**	**42**	42S	**8.11**
	2B	**13.18**		22B	**9.03**		42B	**8.59**
3	3S	**8.40**	**23**	23S	**8.16**	**43**	43S	**9.22**
	3B	**9.51**		23B	**9.27**		43B	**11.29**
4	4S	**10.23**	**24**	24S	**7.63**	**44**	44S	**8.59**
	4B	**11.15**		24B	**10.33**		44B	**9.75**
5	5S	**8.49**	**25**	25S	**9.80**	**45**	45S	**7.58**
	5B	**10.81**		25B	**9.07**		45B	**15.01**
6	6S	**9.07**	**26**	26S	**9.51**	**46**	46S	**7.82**
	6B	**8.97**		26B	**11.29**		46B	**11.87**
7	7S	**8.49**	**27**	27S	**10.23**	**47**	47S	**9.80**
	7B	**11.25**		27B	**13.61**		47B	**9.56**
8	8S	**8.30**	**28**	28S	**10.52**	**48**	48S	**8.78**
	8B	**8.83**		28B	**14.38**		48B	**11.25**
9	9S	**7.58**	**29**	29S	**9.75**	**49**	49S	**9.46**
	9B	**9.85**		29B	**10.62**		49B	**8.83**
10	10S	**8.83**	**30**	30S	**8.49**	**50**	50S	**8.25**
	10B	**10.96**		30B	**11.25**		50B	**9.70**
11	11S	**9.27**	**31**	31S	**7.14**	**51**	51S	**8.16**
	11B	**11.82**		31B	**11.63**		51B	**9.46**
12	12S	**9.70**	**32**	32S	**8.40**	**52**	52S	**8.69**
	12B	**9.60**		32B	**11.29**		52B	**11.92**
13	13S	**8.54**	**33**	33S	**7.82**	**53**	53S	**7.34**
	13B	**10.28**		33B	**11.97**		53B	**14.07**
14	14S	**8.11**	**34**	34S	**9.22**	**54**	54S	**7.14**
	14B	**7.78**		34B	**8.64**		54B	**9.27**
15	15S	**8.88**	**35**	35S	**8.78**	**55**	55S	**8.56**
	15B	**7.82**		35B	**11.48**		55B	**7.87**
16	16S	**7.58**	**36**	36S	**9.70**	**56**	56B	**7.53**
	16B	**6.95**		36B	**10.23**		56B	**9.60**
17	17S	**9.75**	**37**	37S	**8.40**	**57**	57S	**8.40**
	17B	**6.66**		37B	**6.47**		57B	**8.45**
18	18S	**6.37**	**38**	38S	**8.11**	**58**	58S	**10.52**
	18B	**7.53**		38B	**10.81**		58B	**10.52**
19	19S	**7.05**	**39**	39S	**8.74**			
	19B	**8.78**		39B	**9.51**			
20	20S	**9.70**	**40**	40S	**8.30**			
	20B	**8.54**		40B	**8.40**			

Note:

- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥ 100m***

Table 5. Cd-Concentration in seawater.

Station	Samples	Cd (nM)	Station	Samples	Cd (nM)	Station	Samples	Cd (nM)
1	1S	**1.86**	**21**	21S	**2.05**	**41**	41S	**1.25**
	1B	**2.14**		21B	**1.33**		41B	**2.31**
2	2S	**1.95**	**22**	22S	**1.60**	**42**	42S	**1.42**
	2B	**2.31**		22B	**2.05**		42B	**2.40**
3	3S	**1.69**	**23**	23S	**1.42**	**43**	43S	**1.07**
	3B	**2.05**		23B	**1.60**		43B	**2.58**
4	4S	**1.51**	**24**	24S	**1.33**	**44**	44S	**1.16**
	4B	**1.42**		24B	**1.42**		44B	**2.14**
5	5S	**1.78**	**25**	25S	**1.86**	**45**	45S	**0.98**
	5B	**1.51**		25B	**1.69**		45B	**2.22**
6	6S	**1.60**	**26**	26S	**1.69**	**46**	46S	**2.67**
	6B	**1.96**		26B	**1.95**		46B	**2.40**
7	7S	**1.51**	**27**	27S	**1.51**	**47**	47S	**2.49**
	7B	**1.16**		27B	**2.31**		47B	**2.58**
8	8S	**1.42**	**28**	28S	**1.60**	**48**	48S	**1.25**
	8B	**1.33**		28B	**2.76**		48B	**2.67**
9	9S	**1.60**	**29**	29S	**2.31**	**49**	49S	**1.86**
	9B	**1.33**		29B	**2.85**		49B	**1.60**
10	10S	**1.33**	**30**	30S	**1.51**	**50**	50S	**2.31**
	10B	**2.05**		30B	**2.76**		50B	**2.05**
11	11S	**1.07**	**31**	31S	**1.69**	**51**	51S	**1.78**
	11B	**2.14**		31B	**2.49**		51B	**2.31**
12	12S	**0.98**	**32**	32S	**1.95**	**52**	52S	**1.51**
	12B	**2.40**		32B	**2.14**		52B	**3.38**
13	13S	**1.16**	**33**	33S	**1.25**	**53**	53S	**1.42**
	13B	**2.76**		33B	**2.31**		53B	**3.91**
14	14S	**1.60**	**34**	34S	**1.16**	**54**	54S	**1.25**
	14B	**1.25**		34B	**1.07**		54B	**3.11**
15	15S	**1.07**	**35**	35S	**1.33**	**55**	55S	**1.07**
	15B	**1.42**		35B	**1.51**		55B	**2.14**
16	16S	**1.25**	**36**	36S	**1.51**	**56**	56B	**2.55**
	16B	**1.25**		36B	**2.14**		56B	**2.49**
17	17S	**1.69**	**37**	37S	**1.80**	**57**	57S	**0.98**
	17B	**1.86**		37B	**2.67**		57B	**2.85**
18	18S	**1.42**	**38**	38S	**1.95**	**58**	58S	**2.05**
	18B	**1.95**		38B	**1.69**		58B	**5.05**
19	19S	**1.86**	**39**	39S	**2.67**	***Note:***		
	19B	**1.16**		39B	**3.39**	• ***S: Surface layer, 2m***		
20	20S	**2.67**	**40**	40S	**1.51**	• ***B: Bottom layer, ≥ 100m***		
	20B	**1.07**		40B	**2.14**			

Table 6. Zn-Concentration in seawater.

Station	Samples	Zn (nM)	Station	Samples	Zn (nM)	Station	Samples	Zn (nM)
1	1S	**156.52**	**21**	21S	**156.68**	**41**	41S	**136.96**
	1B	**188.38**		21B	**118.45**		41B	**147.73**
2	2S	**149.36**	**22**	22S	**134.38**	**42**	42S	**146.97**
	2B	**180.65**		22B	**155.31**		42B	**133.17**
3	3S	**133.32**	**23**	23S	**120.43**	**43**	43S	**134.08**
	3B	**181.11**		23B	**134.38**		43B	**154.86**
4	4S	**145.91**	**24**	24S	**158.95**	**44**	44S	**133.17**
	4B	**162.90**		24B	**138.63**		44B	**168.06**
5	5S	**152.13**	**25**	25S	**132.56**	**45**	45S	**172.00**
	5B	**150.46**		25B	**135.59**		45B	**158.05**
6	6S	**150.46**	**26**	26S	**145.91**	**46**	46S	**161.83**
	6B	**147.27**		26B	**157.14**		46B	**147.73**
7	7S	**127.10**	**27**	27S	**152.73**	**47**	47S	**163.96**
	7B	**132.87**		27B	**170.02**		47B	**146.82**
8	8S	**127.71**	**28**	28S	**150.00**	**48**	48S	**132.56**
	8B	**137.57**		28B	**188.38**		48B	**150.76**
9	9S	**133.59**	**29**	29S	**151.22**	**49**	49S	**131.65**
	9B	**149.85**		29B	**174.27**		49B	**156.53**
10	10S	**162.75**	**30**	30S	**156.37**	**50**	50S	**136.96**
	10B	**156.38**		30B	**182.92**		50B	**167.91**
11	11S	**133.47**	**31**	31S	**146.06**	**51**	51S	**133.17**
	11B	**158.05**		31B	**198.99**		51B	**203.55**
12	12S	**141.36**	**32**	32S	**147.43**	**52**	52S	**140.45**
	12B	**135.59**		32B	**173.82**		52B	**161.99**
13	13S	**115.42**	**33**	33S	**134.53**	**53**	53S	**150.16**
	13B	**138.63**		33B	**164.11**		53B	**150.46**
14	14S	**133.47**	**34**	34S	**142.42**	**54**	54S	**126.04**
	14B	**131.50**		34B	**176.24**		54B	**134.08**
15	15S	**141.97**	**35**	35S	**140.15**	**55**	55S	**150.46**
	15B	**131.05**		35B	**148.49**		55B	**156.53**
16	16S	**133.32**	**36**	36S	**157.44**	**56**	56B	**150.64**
	16B	**139.81**		36B	**172.00**		56B	**167.75**
17	17S	**123.31**	**37**	37S	**134.54**	**57**	57S	**152.13**
	17B	**140.45**		37B	**148.95**		57B	**173.82**
18	18S	**154.86**	**38**	38S	**150.61**	**58**	58S	**102.53**
	18B	**163.50**		38B	**146.97**		58B	**187.17**
19	19S	**150.15**	**39**	39S	**139.08**	***Note:***		
	19B	**155.01**		39B	**156.53**	• ***S: Surface layer, 2m***		
20	20S	**167.14**	**40**	40S	**133.32**	• ***B: Bottom layer, ≥100m***		
	20B	**138.21**		40B	**161.98**			

Table 7. Ni-Concentration in seawater.

Station	Samples	Ni (nM)	Station	Samples	Ni (nM)	Station	Samples	Ni (nM)
1	1S	**20.61**	**21**	21S	**17.54**	**41**	41S	**13.29**
	1B	**36.62**		21B	**25.89**		41B	**29.47**
2	2S	**27.59**	**22**	22S	**28.62**	**42**	42S	**27.93**
	2B	**33.73**		22B	**24.87**		42B	**21.80**
3	3S	**25.21**	**23**	23S	**22.82**	**43**	43S	**29.64**
	3B	**39.35**		23B	**27.59**		43B	**24.19**
4	4S	**23.34**	**24**	24S	**21.63**	**44**	44S	**22.14**
	4B	**34.41**		24B	**28.96**		44B	**22.65**
5	5S	**19.08**	**25**	25S	**19.76**	**45**	45S	**21.46**
	5B	**29.47**		25B	**32.19**		45B	**36.45**
6	6S	**17.20**	**26**	26S	**25.21**	**46**	46S	**22.31**
	6B	**29.98**		26B	**27.59**		46B	**34.41**
7	7S	**33.73**	**27**	27S	**34.24**	**47**	47S	**20.09**
	7B	**24.53**		27B	**27.93**		47B	**33.38**
8	8S	**19.07**	**28**	28S	**24.18**	**48**	48S	**19.08**
	8B	**25.21**		28B	**25.89**		48B	**32.02**
9	9S	**14.82**	**29**	29S	**27.59**	**49**	49S	**17.20**
	9B	**27.59**		29B	**28.96**		49B	**29.64**
10	10S	**16.01**	**30**	30S	**25.04**	**50**	50S	**30.83**
	10B	**30.83**		30B	**41.05**		50B	**35.09**
11	11S	**21.46**	**31**	31S	**23.51**	**51**	51S	**29.13**
	11B	**30.49**		31B	**39.69**		51B	**36.28**
12	12S	**23.51**	**32**	32S	**21.97**	**52**	52S	**17.54**
	12B	**22.82**		32B	**42.24**		52B	**37.13**
13	13S	**22.82**	**33**	33S	**24.02**	**53**	53S	**16.86**
	13B	**21.46**		33B	**36.96**		53B	**39.86**
14	14S	**24.19**	**34**	34S	**29.47**	**54**	54S	**31.68**
	14B	**21.80**		34B	**39.86**		54B	**33.72**
15	15S	**15.33**	**35**	35S	**27.59**	**55**	55S	**22.31**
	15B	**34.58**		35B	**30.99**		55B	**32.70**
16	16S	**18.90**	**36**	36S	**22.82**	**56**	56B	**26.92**
	16B	**18.90**		36B	**29.98**		56B	**31.85**
17	17S	**18.39**	**37**	37S	**15.67**	**57**	57S	**21.12**
	17B	**19.42**		37B	**30.83**		57B	**34.41**
18	18S	**20.27**	**38**	38S	**16.52**	**58**	58S	**19.25**
	18B	**20.10**		38B	**34.58**		58B	**31.34**
19	19S	**20.44**	**39**	39S	**23.80**	***Note:***		
	19B	**23.34**		39B	**29.97**	• ***S: Surface layer, 2m***		
20	20S	**19.25**	**40**	40S	**16.86**	• ***B: Bottom layer, ≥ 100m***		
	20B	**24.87**		40B	**39.86**			

Table 8. Cr-Concentration in seawater.

Station	Samples	Cr (nM)	Station	Samples	Cr (nM)	Station	Samples	Cr (nM)
1	1S	**23.08**	**21**	21S	**16.54**	**41**	41S	**16.73**
	1B	**22.12**		21B	**13.08**		41B	**27.31**
2	2S	**19.80**	**22**	22S	**15.19**	**42**	42S	**17.69**
	2B	**24.23**		22B	**14.23**		42B	**16.73**
3	3S	**18.85**	**23**	23S	**14.23**	**43**	43S	**24.42**
	3B	**18.85**		23B	**15.19**		43B	**26.35**
4	4S	**18.46**	**24**	24S	**21.73**	**44**	44S	**16.54**
	4B	**16.15**		24B	**21.35**		44B	**27.30**
5	5S	**15.96**	**25**	25S	**20.00**	**45**	45S	**34.81**
	5B	**25.38**		25B	**19.04**		45B	**24.23**
6	6S	**18.65**	**26**	26S	**22.31**	**46**	46S	**25.00**
	6B	**27.12**		26B	**23.66**		46B	**22.69**
7	7S	**19.42**	**27**	27S	**18.85**	**47**	47S	**24.23**
	7B	**20.77**		27B	**20.77**		47B	**25.38**
8	8S	**16.35**	**28**	28S	**14.62**	**48**	48S	**21.15**
	8B	**30.77**		28B	**21.54**		48B	**23.65**
9	9S	**21.54**	**29**	29S	**25.39**	**49**	49S	**14.82**
	9B	**15.77**		29B	**24.23**		49B	**24.04**
10	10S	**14.62**	**30**	30S	**17.31**	**50**	50S	**15.19**
	10B	**23.46**		30B	**25.00**		50B	**35.00**
11	11S	**17.69**	**31**	31S	**16.54**	**51**	51S	**16.54**
	11B	**18.08**		31B	**21.35**		51B	**26.73**
12	12S	**16.73**	**32**	32S	**13.85**	**52**	52S	**15.38**
	12B	**26.16**		32B	**16.92**		52B	**23.37**
13	13S	**21.35**	**33**	33S	**16.15**	**53**	53S	**20.58**
	13B	**23.85**		33B	**19.04**		53B	**28.46**
14	14S	**18.46**	**34**	34S	**15.77**	**54**	54S	**21.54**
	14B	**25.19**		34B	**25.58**		54B	**25.00**
15	15S	**26.54**	**35**	35S	**15.19**	**55**	55S	**18.85**
	15B	**20.96**		35B	**23.85**		55B	**33.85**
16	16S	**14.23**	**36**	36S	**25.77**	**56**	56B	**15.92**
	16B	**22.18**		36B	**16.73**		56B	**30.39**
17	17S	**14.82**	**37**	37S	**22.31**	**57**	57S	**15.00**
	17B	**16.73**		37B	**17.69**		57B	**37.31**
18	18S	**23.27**	**38**	38S	**17.31**	**58**	58S	**20.38**
	18B	**15.19**		38B	**25.58**		58B	**25.38**
19	19S	**25.00**	**39**	39S	**25.19**	***Note:***		
	19B	**16.92**		39B	**24.23**	• ***S: Surface layer, 2m***		
20	20S	**17.69**	**40**	40S	**25.77**	• ***B: Bottom layer, ≥ 100m***		
	20B	**18.08**		40B	**25.19**			

Table 9. As-Concentration in seawater.

Station	Samples	As (nM)	Station	Samples	As (nM)	Station	Samples	As (nM)
1	1S	**21.22**	**21**	21S	**20.82**	**41**	41S	**23.62**
	1B	**17.22**		21B	**18.55**		41B	**21.49**
2	2S	**22.29**	**22**	22S	**19.22**	**42**	42S	**22.02**
	2B	**20.15**		22B	**16.68**		42B	**23.89**
3	3S	**17.48**	**23**	23S	**20.28**	**43**	43S	**21.76**
	3B	**21.49**		23B	**19.35**		43B	**23.62**
4	4S	**27.76**	**24**	24S	**24.56**	**44**	44S	**23.22**
	4B	**21.75**		24B	**22.82**		44B	**26.83**
5	5S	**23.89**	**25**	25S	**18.15**	**45**	45S	**21.36**
	5B	**17.61**		25B	**19.22**		45B	**21.36**
6	6S	**20.55**	**26**	26S	**22.56**	**46**	46S	**24.16**
	6B	**20.55**		26B	**20.02**		46B	**28.83**
7	7S	**32.70**	**27**	27S	**20.83**	**47**	47S	**27.76**
	7B	**21.88**		27B	**18.15**		47B	**19.09**
8	8S	**21.22**	**28**	28S	**19.75**	**48**	48S	**25.09**
	8B	**21.49**		28B	**18.01**		48B	**22.02**
9	9S	**30.96**	**29**	29S	**23.09**	**49**	49S	**23.49**
	9B	**21.62**		29B	**20.82**		49B	**29.09**
10	10S	**26.29**	**30**	30S	**21.22**	**50**	50S	**23.22**
	10B	**18.82**		30B	**20.42**		50B	**22.96**
11	11S	**33.37**	**31**	31S	**17.75**	**51**	51S	**26.96**
	11B	**19.09**		31B	**78.95**		51B	**20.28**
12	12S	**21.16**	**32**	32S	**21.22**	**52**	52S	**21.89**
	12B	**20.95**		32B	**24.16**		52B	**23.22**
13	13S	**21.22**	**33**	33S	**22.69**	**53**	53S	**20.42**
	13B	**20.15**		33B	**19.22**		53B	**24.69**
14	14S	**21.49**	**34**	34S	**23.09**	**54**	54S	**19.62**
	14B	**20.28**		34B	**19.75**		54B	**24.96**
15	15S	**19.62**	**35**	35S	**20.42**	**55**	55S	**21.89**
	15B	**21.36**		35B	**23.49**		55B	**24.16**
16	16S	**19.22**	**36**	36S	**26.03**	**56**	56B	**23.36**
	16B	**18.68**		36B	**38.03**		56B	**19.35**
17	17S	**23.89**	**37**	37S	**19.88**	**57**	57S	**19.89**
	17B	**16.82**		37B	**19.49**		57B	**26.43**
18	18S	**17.88**	**38**	38S	**16.42**	**58**	58S	**20.55**
	18B	**19.62**		38B	**19.49**		58B	**18.82**
19	19S	**23.49**	**39**	39S	**21.22**	***Note:***		
	19B	**19.62**		39B	**20.55**	• ***S: Surface layer, 2m***		
20	20S	**21.76**	**40**	40S	**19.62**	• ***B: Bottom layer, ≥ 100m***		
	20B	**20.82**		40B	**21.08**			

Table 10. Hg-Concentration in seawater.

Station	Samples	Hg (nM)	Station	Samples	Hg (nM)	Station	Samples	Hg (nM)
1	1S	**0.60**	**21**	21S	**0.85**	**41**	41S	**0.79**
	1B	**0.55**		21B	**0.35**		41B	**0.89**
2	2S	**0.55**	**22**	22S	**0.45**	**42**	42S	**0.85**
	2B	**0.69**		22B	**0.35**		42B	**0.89**
3	3S	**0.59**	**23**	23S	**0.45**	**43**	43S	**0.85**
	3B	**0.69**		23B	**1.24**		43B	**0.89**
4	4S	**0.40**	**24**	24S	**0.49**	**44**	44S	**0.85**
	4B	**0.40**		24B	**0.49**		44B	**0.80**
5	5S	**0.59**	**25**	25S	**0.45**	**45**	45S	**0.49**
	5B	**0.85**		25B	**0.41**		45B	**0.82**
6	6S	**0.75**	**26**	26S	**0.49**	**46**	46S	**0.60**
	6B	**0.55**		26B	**0.45**		46B	**0.45**
7	7S	**0.75**	**27**	27S	**0.45**	**47**	47S	**0.49**
	7B	**0.55**		27B	**0.35**		47B	**0.60**
8	8S	**6.48**	**28**	28S	**0.35**	**48**	48S	**0.60**
	8B	**0.49**		28B	**0.49**		48B	**3.60**
9	9S	**1.54**	**29**	29S	**0.99**	**49**	49S	**0.70**
	9B	**0.89**		29B	**0.89**		49B	**1.05**
10	10S	**0.59**	**30**	30S	**0.45**	**50**	50S	**2.09**
	10B	**0.60**		30B	**0.75**		50B	**1.45**
11	11S	**0.70**	**31**	31S	**0.65**	**51**	51S	**0.60**
	11B	**0.70**		31B	**0.65**		51B	**0.55**
12	12S	**0.75**	**32**	32S	**0.89**	**52**	52S	**0.55**
	12B	**0.45**		32B	**0.60**		52B	**0.55**
13	13S	**0.55**	**33**	33S	**0.80**	**53**	53S	**0.65**
	13B	**0.45**		33B	**3.09**		53B	**0.65**
14	14S	**0.40**	**34**	34S	**1.69**	**54**	54S	**0.60**
	14B	**0.80**		34B	**0.85**		54B	**0.49**
15	15S	**0.41**	**35**	35S	**0.60**	**55**	55S	**0.80**
	15B	**0.65**		35B	**0.70**		55B	**0.49**
16	16S	**0.35**	**36**	36S	**0.75**	**56**	56B	**0.60**
	16B	**0.49**		36B	**089**		56B	**7.13**
17	17S	**0.35**	**37**	37S	**0.45**	**57**	57S	**1.20**
	17B	**0.41**		37B	**0.75**		57B	**0.89**
18	18S	**0.55**	**38**	38S	**0.60**	**58**	58S	**0.60**
	18B	**0.89**		38B	**0.75**		58B	**2.46**
19	19S	**0.45**	**39**	39S	**0.70**	***Note:***		
	19B	**0.41**		39B	**0.95**	• ***S: Surface layer, 2m***		
20	20S	**0.55**	**40**	40S	**0.60**	• ***B: Bottom layer, ≥100m***		
	20B	**0.90**		40B	**2.59**			

Table 11. Cu-Concentration in seawater.

Station	Samples	Cu (µg/l)	Station	Samples	Cu (µg/l)	Station	Samples	Cu (µg/l)
1	1S	4.87	**21**	21S	4.14	**41**	41S	3.78
	1B	5.74		21B	5.09		41B	5.03
2	2S	4.69	**22**	22S	4.78	**42**	42S	3.69
	2B	5.54		22B	4.62		42B	4.96
3	3S	4.74	**23**	23S	4.62	**43**	43S	4.13
	3B	4.79		23B	4.31		43B	4.82
4	4S	5.02	**24**	24S	5.01	**44**	44S	3.82
	4B	4.86		24B	5.03		44B	5.31
5	5S	3.96	**25**	25S	4.77	**45**	45S	4.07
	5B	5.12		25B	4.86		45B	5.05
6	6S	4.32	**26**	26S	4.31	**46**	46S	3.69
	6B	4.27		26B	5.12		46B	4.97
7	7S	4.18	**27**	27S	4.83	**47**	47S	3.87
	7B	4.31		27B	4.96		47B	4.83
8	8S	3.74	**28**	28S	4.62	**48**	48S	4.13
	8B	4.74		28B	5.03		48B	3.72
9	9S	3.84	**29**	29S	4.77	**49**	49S	4.26
	9B	4.26		29B	5.86		49B	4.07
10	10S	3.86	**30**	30S	4.62	**50**	50S	3.93
	10B	4.59		30B	5.42		50B	5.18
11	11S	3.71	**31**	31S	3.94	**51**	51S	4.08
	11B	4.61		31B	4.94		51B	4.84
12	12S	3.30	**32**	32S	3.98	**52**	52S	5.01
	12B	3.93		32B	5.15		52B	5.03
13	13S	4.26	**33**	33S	4.32	**53**	53S	3.82
	13B	4.62		33B	4.82		53B	4.69
14	14S	3.93	**34**	34S	3.74	**54**	54S	3.69
	14B	4.81		34B	4.76		54B	3.87
15	15S	4.12	**35**	35S	4.12	**55**	55S	4.13
	15B	5.12		35B	4.21		55B	5.13
16	16S	3.84	**36**	36S	3.76	**56**	56B	4.05
	16B	3.97		36B	3.88		56B	5.14
17	17S	4.07	**37**	37S	4.31	**57**	57S	3.92
	17B	4.71		37B	4.92		57B	4.98
18	18S	3.76	**38**	38S	4.64	**58**	58S	4.48
	18B	4.82		38B	3.74		58B	4.72
19	19S	3.94	**39**	39S	4.39	***Note:***		
	19B	4.76		39B	4.87	• ***S: Surface layer, 2m***		
20	20S	3.87	**40**	40S	3.81	• ***B: Bottom layer, ≥ 100m***		
	20B	4.88		40B	5.12			

Table 12. Pb-Concentration in seawater.

Station	Samples	Pb (µg/l)	Station	Samples	Pb (µg/l)	Station	Samples	Pb (µg/l)
1	1S	**1.98**	**21**	21S	**1.81**	**41**	41S	**2.02**
	1B	**2.18**		21B	**2.04**		41B	**1.76**
2	2S	**2.03**	**22**	22S	**1.74**	**42**	42S	**1.68**
	2B	**2.73**		22B	**1.87**		42B	**1.78**
3	3S	**1.74**	**23**	23S	**1.69**	**43**	43S	**1.91**
	3B	**1.97**		23B	**1.92**		43B	**2.34**
4	4S	**2.12**	**24**	24S	**1.58**	**44**	44S	**1.78**
	4B	**2.31**		24B	**2.14**		44B	**2.02**
5	5S	**1.76**	**25**	25S	**2.03**	**45**	45S	**1.57**
	5B	**2.24**		25B	**1.88**		45B	**3.11**
6	6S	**1.88**	**26**	26S	**1.97**	**46**	46S	**1.62**
	6B	**1.86**		26B	**2.34**		46B	**2.46**
7	7S	**1.76**	**27**	27S	**2.12**	**47**	47S	**2.03**
	7B	**2.33**		27B	**2.82**		47B	**1.98**
8	8S	**1.72**	**28**	28S	**2.18**	**48**	48S	**1.82**
	8B	**1.83**		28B	**2.98**		48B	**2.33**
9	9S	**1.57**	**29**	29S	**2.02**	**49**	49S	**1.96**
	9B	**2.04**		29B	**2.20**		49B	**1.83**
10	10S	**1.83**	**30**	30S	**1.76**	**50**	50S	**1.71**
	10B	**2.27**		30B	**2.33**		50B	**2.01**
11	11S	**1.92**	**31**	31S	**1.48**	**51**	51S	**1.69**
	11B	**2.45**		31B	**2.41**		51B	**1.96**
12	12S	**2.01**	**32**	32S	**1.74**	**52**	52S	**1.80**
	12B	**1.99**		32B	**2.34**		52B	**2.47**
13	13S	**1.77**	**33**	33S	**1.62**	**53**	53S	**1.52**
	13B	**2.13**		33B	**2.48**		53B	**2.91**
14	14S	**1.68**	**34**	34S	**1.91**	**54**	54S	**1.48**
	14B	**1.61**		34B	**1.79**		54B	**1.92**
15	15S	**1.84**	**35**	35S	**1.82**	**55**	55S	**1.77**
	15B	**1.62**		35B	**2.38**		55B	**1.63**
16	16S	**1.57**	**36**	36S	**2.01**	**56**	56B	**1.56**
	16B	**1.44**		36B	**2.12**		56B	**1.99**
17	17S	**2.02**	**37**	37S	**1.74**	**57**	57S	**1.74**
	17B	**1.38**		37B	**1.34**		57B	**1.76**
18	18S	**1.32**	**38**	38S	**1.68**	**58**	58S	**2.18**
	18B	**1.56**		38B	**2.24**		58B	**2.18**
19	19S	**1.46**	**39**	39S	**1.81**	***Note:***		
	19B	**1.82**		39B	**1.97**	• ***S: Surface layer, 2m***		
20	20S	**2.01**	**40**	40S	**1.72**	• ***B: Bottom layer, ≥100m***		
	20B	**1.77**		40B	**1.74**			

Table 13. Cd-Concentration in seawater.

Station	Samples	Cd (µg/l)	Station	Samples	Cd (µg/l)	Station	Samples	Cd (µg/l)
1	1S	**0.21**	**21**	21S	**0.23**	**41**	41S	**0.14**
	1B	**0.24**		21B	**0.15**		41B	**0.26**
2	2S	**0.22**	**22**	22S	**0.18**	**42**	42S	**0.16**
	2B	**0.26**		22B	**0.23**		42B	**0.27**
3	3S	**0.19**	**23**	23S	**0.16**	**43**	43S	**0.12**
	3B	**0.23**		23B	**0.18**		43B	**0.29**
4	4S	**0.17**	**24**	24S	**0.15**	**44**	44S	**0.13**
	4B	**0.16**		24B	**0.16**		44B	**0.24**
5	5S	**0.20**	**25**	25S	**0.21**	**45**	45S	**0.11**
	5B	**0.17**		25B	**0.19**		45B	**0.25**
6	6S	**0.18**	**26**	26S	**0.19**	**46**	46S	**0.30**
	6B	**0.22**		26B	**0.22**		46B	**0.27**
7	7S	**0.17**	**27**	27S	**0.17**	**47**	47S	**0.28**
	7B	**0.13**		27B	**0.26**		47B	**0.29**
8	8S	**0.16**	**28**	28S	**0.18**	**48**	48S	**0.14**
	8B	**0.15**		28B	**0.31**		48B	**0.30**
9	9S	**0.18**	**29**	29S	**0.26**	**49**	49S	**0.21**
	9B	**0.15**		29B	**0.32**		49B	**0.18**
10	10S	**0.15**	**30**	30S	**0.17**	**50**	50S	**0.26**
	10B	**0.23**		30B	**0.31**		50B	**0.23**
11	11S	**0.12**	**31**	31S	**0.19**	**51**	51S	**0.20**
	11B	**0.24**		31B	**0.28**		51B	**0.26**
12	12S	**0.11**	**32**	32S	**0.22**	**52**	52S	**0.17**
	12B	**0.27**		32B	**0.24**		52B	**0.38**
13	13S	**0.13**	**33**	33S	**0.14**	**53**	53S	**0.16**
	13B	**0.31**		33B	**0.26**		53B	**0.44**
14	14S	**0.18**	**34**	34S	**0.13**	**54**	54S	**0.14**
	14B	**0.14**		34B	**0.12**		54B	**0.35**
15	15S	**0.12**	**35**	35S	**0.15**	**55**	55S	**0.12**
	15B	**0.16**		35B	**0.17**		55B	**0.24**
16	16S	**0.14**	**36**	36S	**0.17**	**56**	56B	**0.29**
	16B	**0.14**		36B	**0.24**		56B	**0.28**
17	17S	**0.19**	**37**	37S	**0.20**	**57**	57S	**0.11**
	17B	**0.21**		37B	**0.30**		57B	**0.32**
18	18S	**0.16**	**38**	38S	**0.22**	**58**	58S	**0.23**
	18B	**0.22**		38B	**0.19**		58B	**0.57**
19	19S	**0.21**	**39**	39S	**0.30**	***Note:***		
	19B	**0.13**		39B	**0.38**	• ***S: Surface layer, 2m***		
20	20S	**0.30**	**40**	40S	**0.17**	• ***B: Bottom layer, ≥ 100m***		
	20B	**0.12**		40B	**0.24**			

Table 14. Zn-Concentration in seawater.

Station	Samples	Zn (µg/l)	Station	Samples	Zn (µg/l)	Station	Samples	Zn (µg/l)
1	1S	**10.32**	**21**	21S	**10.33**	**41**	41S	**9.03**
	1B	**12.42**		21B	**7.81**		41B	**9.74**
2	2S	**9.85**	**22**	22S	**8.86**	**42**	42S	**9.69**
	2B	**11.91**		22B	**10.24**		42B	**8.78**
3	3S	**8.79**	**23**	23S	**7.94**	**43**	43S	**8.84**
	3B	**11.94**		23B	**8.86**		43B	**10.21**
4	4S	**9.62**	**24**	24S	**10.48**	**44**	44S	**8.78**
	4B	**10.74**		24B	**9.14**		44B	**11.08**
5	5S	**10.03**	**25**	25S	**8.74**	**45**	45S	**11.34**
	5B	**9.92**		25B	**8.94**		45B	**10.42**
6	6S	**9.92**	**26**	26S	**9.62**	**46**	46S	**10.67**
	6B	**9.71**		26B	**10.36**		46B	**9.74**
7	7S	**8.38**	**27**	27S	**10.07**	**47**	47S	**10.81**
	7B	**8.76**		27B	**11.21**		47B	**9.68**
8	8S	**8.42**	**28**	28S	**9.89**	**48**	48S	**8.74**
	8B	**9.07**		28B	**12.42**		48B	**9.94**
9	9S	**8.81**	**29**	29S	**9.97**	**49**	49S	**8.68**
	9B	**9.88**		29B	**11.49**		49B	**10.32**
10	10S	**10.73**	**30**	30S	**10.31**	**50**	50S	**9.03**
	10B	**10.31**		30B	**12.06**		50B	**11.07**
11	11S	**8.80**	**31**	31S	**9.63**	**51**	51S	**8.78**
	11B	**10.42**		31B	**13.12**		51B	**13.42**
12	12S	**9.32**	**32**	32S	**9.72**	**52**	52S	**9.26**
	12B	**8.94**		32B	**11.46**		52B	**10.68**
13	13S	**7.61**	**33**	33S	**8.87**	**53**	53S	**9.90**
	13B	**9.14**		33B	**10.82**		53B	**9.92**
14	14S	**8.80**	**34**	34S	**9.39**	**54**	54S	**8.31**
	14B	**8.67**		34B	**11.62**		54B	**8.84**
15	15S	**9.36**	**35**	35S	**9.24**	**55**	55S	**9.92**
	15B	**8.64**		35B	**9.79**		55B	**10.32**
16	16S	**8.79**	**36**	36S	**10.38**	**56**	56B	**9.93**
	16B	**9.22**		36B	**11.34**		56B	**11.06**
17	17S	**8.13**	**37**	37S	**8.87**	**57**	57S	**10.03**
	17B	**9.26**		37B	**9.82**		57B	**11.46**
18	18S	**10.21**	**38**	38S	**9.93**	**58**	58S	**6.76**
	18B	**10.78**		38B	**9.69**		58B	**12.34**
19	19S	**9.90**	**39**	39S	**9.17**	***Note:***		
	19B	**10.22**		39B	**10.32**	• ***S: Surface layer, 2m***		
20	20S	**11.02**	**40**	40S	**8.79**	• ***B: Bottom layer, ≥ 100m***		
	20B	**9.11**		40B	**10.68**			

Table 15. Ni-Concentration in seawater.

Station	Samples	Ni (µg/l)	Station	Samples	Ni (µg/l)	Station	Samples	Ni (µg/l)
1	1S	**1.21**	**21**	21S	**1.21**	**41**	41S	**0.78**
	1B	**2.15**		21B	**2.15**		41B	**1.73**
2	2S	**1.62**	**22**	22S	**1.62**	**42**	42S	**1.64**
	2B	**1.98**		22B	**1.98**		42B	**1.28**
3	3S	**1.48**	**23**	23S	**1.48**	**43**	43S	**1.74**
	3B	**2.31**		23B	**2.31**		43B	**1.42**
4	4S	**1.37**	**24**	24S	**1.37**	**44**	44S	**1.30**
	4B	**2.02**		24B	**2.02**		44B	**1.33**
5	5S	**1.12**	**25**	25S	**1.12**	**45**	45S	**1.26**
	5B	**1.73**		25B	**1.73**		45B	**2.14**
6	6S	**1.01**	**26**	26S	**1.01**	**46**	46S	**1.31**
	6B	**1.76**		26B	**1.76**		46B	**2.02**
7	7S	**1.98**	**27**	27S	**1.98**	**47**	47S	**1.18**
	7B	**1.44**		27B	**1.44**		47B	**1.96**
8	8S	**1.12**	**28**	28S	**1.12**	**48**	48S	**1.12**
	8B	**1.48**		28B	**1.48**		48B	**1.88**
9	9S	**0.87**	**29**	29S	**0.87**	**49**	49S	**1.01**
	9B	**1.62**		29B	**1.62**		49B	**1.74**
10	10S	**0.94**	**30**	30S	**0.94**	**50**	50S	**1.81**
	10B	**1.81**		30B	**1.81**		50B	**2.06**
11	11S	**1.26**	**31**	31S	**1.26**	**51**	51S	**1.71**
	11B	**1.79**		31B	**1.79**		51B	**2.13**
12	12S	**1.38**	**32**	32S	**1.38**	**52**	52S	**1.03**
	12B	**1.34**		32B	**1.34**		52B	**2.18**
13	13S	**1.34**	**33**	33S	**1.34**	**53**	53S	**0.99**
	13B	**1.26**		33B	**1.26**		53B	**2.34**
14	14S	**1.42**	**34**	34S	**1.42**	**54**	54S	**1.86**
	14B	**1.28**		34B	**1.28**		54B	**1.98**
15	15S	**0.90**	**35**	35S	**0.90**	**55**	55S	**1.31**
	15B	**2.03**		35B	**2.03**		55B	**1.92**
16	16S	**1.11**	**36**	36S	**1.11**	**56**	56B	**1.58**
	16B	**1.11**		36B	**1.11**		56B	**1.87**
17	17S	**1.08**	**37**	37S	**1.08**	**57**	57S	**1.24**
	17B	**1.14**		37B	**1.14**		57B	**2.02**
18	18S	**1.19**	**38**	38S	**1.19**	**58**	58S	**1.13**
	18B	**1.18**		38B	**1.18**		58B	**1.84**
19	19S	**1.20**	**39**	39S	**1.20**	***Note:***		
	19B	**1.37**		39B	**1.37**	• ***S: Surface layer, 2m***		
20	20S	**1.13**	**40**	40S	**1.13**	• ***B: Bottom layer, ≥ 100m***		
	20B	**1.46**		40B	**1.46**			

Table 16. Cr-Concentration in seawater.

Station	Samples	Cr (µg/l)	Station	Samples	Cr (µg/l)	Station	Samples	Cr (µg/l)
1	1S	**1.20**	**21**	21S	**0.86**	**41**	41S	**0.87**
	1B	**1.15**		21B	**0.68**		41B	**1.42**
2	2S	**1.03**	**22**	22S	**0.79**	**42**	42S	**0.92**
	2B	**1.26**		22B	**0.74**		42B	**0.87**
3	3S	**0.98**	**23**	23S	**0.74**	**43**	43S	**1.27**
	3B	**0.98**		23B	**0.79**		43B	**1.37**
4	4S	**0.96**	**24**	24S	**1.13**	**44**	44S	**0.86**
	4B	**0.84**		24B	**1.11**		44B	**1.42**
5	5S	**0.83**	**25**	25S	**1.04**	**45**	45S	**1.81**
	5B	**1.32**		25B	**0.99**		45B	**1.26**
6	6S	**0.97**	**26**	26S	**1.16**	**46**	46S	**1.30**
	6B	**1.41**		26B	**1.23**		46B	**1.18**
7	7S	**1.01**	**27**	27S	**0.98**	**47**	47S	**1.26**
	7B	**1.08**		27B	**1.08**		47B	**1.32**
8	8S	**0.85**	**28**	28S	**0.76**	**48**	48S	**1.10**
	8B	**1.60**		28B	**1.12**		48B	**1.23**
9	9S	**1.12**	**29**	29S	**1.32**	**49**	49S	**0.77**
	9B	**0.82**		29B	**1.26**		49B	**1.25**
10	10S	**0.76**	**30**	30S	**0.90**	**50**	50S	**0.79**
	10B	**1.22**		30B	**1.30**		50B	**1.82**
11	11S	**0.92**	**31**	31S	**0.86**	**51**	51S	**0.86**
	11B	**0.94**		31B	**1.11**		51B	**1.39**
12	12S	**0.87**	**32**	32S	**0.72**	**52**	52S	**0.80**
	12B	**1.36**		32B	**0.88**		52B	**1.22**
13	13S	**1.11**	**33**	33S	**0.84**	**53**	53S	**1.07**
	13B	**1.24**		33B	**0.99**		53B	**1.48**
14	14S	**0.96**	**34**	34S	**0.82**	**54**	54S	**1.12**
	14B	**1.31**		34B	**1.33**		54B	**1.30**
15	15S	**1.38**	**35**	35S	**0.79**	**55**	55S	**0.98**
	15B	**1.09**		35B	**1.24**		55B	**1.76**
16	16S	**0.74**	**36**	36S	**1.34**	**56**	56B	**0.83**
	16B	**1.15**		36B	**0.87**		56B	**1.58**
17	17S	**0.77**	**37**	37S	**1.16**	**57**	57S	**0.78**
	17B	**0.87**		37B	**0.92**		57B	**1.94**
18	18S	**1.21**	**38**	38S	**0.90**	**58**	58S	**1.06**
	18B	**0.79**		38B	**1.33**		58B	**1.32**
19	19S	**1.30**	**39**	39S	**1.31**	***Note:***		
	19B	**0.88**		39B	**1.26**	• ***S: Surface layer, 2m***		
20	20S	**0.92**	**40**	40S	**1.34**	• ***B: Bottom layer, ≥ 100m***		
	20B	**0.94**		40B	**1.31**			

Table 17. As-Concentration in seawater.

Station	Samples	As (µg/l)	Station	Samples	As (µg/l)	Station	Samples	As (µg/l)
1	1S	**1.59**	**21**	21S	**1.56**	**41**	41S	**1.77**
	1B	**1.29**		21B	**1.39**		41B	**1.61**
2	2S	**1.67**	**22**	22S	**1.44**	**42**	42S	**1.65**
	2B	**1.51**		22B	**1.25**		42B	**1.79**
3	3S	**1.31**	**23**	23S	**1.52**	**43**	43S	**1.63**
	3B	**1.61**		23B	**1.45**		43B	**1.77**
4	4S	**2.08**	**24**	24S	**1.84**	**44**	44S	**1.74**
	4B	**1.63**		24B	**1.71**		44B	**2.01**
5	5S	**1.79**	**25**	25S	**1.36**	**45**	45S	**1.60**
	5B	**1.32**		25B	**1.44**		45B	**1.60**
6	6S	**1.54**	**26**	26S	**1.69**	**46**	46S	**1.81**
	6B	**1.54**		26B	**1.50**		46B	**2.16**
7	7S	**2.45**	**27**	27S	**1.56**	**47**	47S	**2.08**
	7B	**1.64**		27B	**1.36**		47B	**1.43**
8	8S	**1.59**	**28**	28S	**1.48**	**48**	48S	**1.88**
	8B	**1.61**		28B	**1.35**		48B	**1.65**
9	9S	**2.32**	**29**	29S	**1.73**	**49**	49S	**1.76**
	9B	**1.62**		29B	**1.56**		49B	**2.18**
10	10S	**1.97**	**30**	30S	**1.59**	**50**	50S	**1.74**
	10B	**1.41**		30B	**1.53**		50B	**1.72**
11	11S	**2.50**	**31**	31S	**1.33**	**51**	51S	**2.02**
	11B	**1.43**		31B	**5.92**		51B	**1.52**
12	12S	**1.59**	**32**	32S	**1.59**	**52**	52S	**1.64**
	12B	**1.57**		32B	**1.81**		52B	**1.74**
13	13S	**1.59**	**33**	33S	**1.70**	**53**	53S	**1.53**
	13B	**1.51**		33B	**1.44**		53B	**1.85**
14	14S	**1.61**	**34**	34S	**1.73**	**54**	54S	**1.47**
	14B	**1.52**		34B	**1.48**		54B	**1.87**
15	15S	**1.47**	**35**	35S	**1.53**	**55**	55S	**1.64**
	15B	**1.60**		35B	**1.76**		55B	**1.81**
16	16S	**1.44**	**36**	36S	**1.95**	**56**	56B	**1.75**
	16B	**1.40**		36B	**2.85**		56B	**1.45**
17	17S	**1.79**	**37**	37S	**1.49**	**57**	57S	**1.49**
	17B	**1.26**		37B	**1.46**		57B	**1.98**
18	18S	**1.34**	**38**	38S	**1.23**	**58**	58S	**1.54**
	18B	**1.47**		38B	**1.46**		58B	**1.41**
19	19S	**1.76**	**39**	39S	**1.59**			
	19B	**1.47**		39B	**1.54**			
20	20S	**1.63**	**40**	40S	**1.47**			
	20B	**1.56**		40B	**1.58**			

Note:

- ***S: Surface layer, 2m***
- ***B: Bottom layer, ≥ 100m***

Table 18. Hg-Concentration in seawater.

Station	Samples	Hg (µg/l)	Station	Samples	Hg (µg/l)	Station	Samples	Hg (µg/l)
1	1S	**0.12**	**21**	21S	**0.17**	**41**	41S	**0.16**
	1B	**0.11**		21B	**0.07**		41B	**0.18**
2	2S	**0.11**	**22**	22S	**0.09**	**42**	42S	**0.17**
	2B	**0.14**		22B	**0.07**		42B	**0.18**
3	3S	**0.12**	**23**	23S	**0.09**	**43**	43S	**0.17**
	3B	**0.14**		23B	**0.25**		43B	**0.18**
4	4S	**0.08**	**24**	24S	**0.10**	**44**	44S	**0.17**
	4B	**0.08**		24B	**0.10**		44B	**0.16**
5	5S	**0.12**	**25**	25S	**0.09**	**45**	45S	**0.10**
	5B	**0.17**		25B	**0.08**		45B	**0.16**
6	6S	**0.15**	**26**	26S	**0.10**	**46**	46S	**0.12**
	6B	**0.11**		26B	**0.09**		46B	**0.09**
7	7S	**0.15**	**27**	27S	**0.09**	**47**	47S	**0.10**
	7B	**0.11**		27B	**0.07**		47B	**0.12**
8	8S	**1.30**	**28**	28S	**0.07**	**48**	48S	**0.12**
	8B	**0.10**		28B	**0.10**		48B	**0.72**
9	9S	**0.31**	**29**	29S	**0.20**	**49**	49S	**0.14**
	9B	**0.18**		29B	**0.18**		49B	**0.21**
10	10S	**0.12**	**30**	30S	**0.09**	**50**	50S	**0.42**
	10B	**0.12**		30B	**0.15**		50B	**0.29**
11	11S	**0.14**	**31**	31S	**0.13**	**51**	51S	**0.12**
	11B	**0.14**		31B	**0.13**		51B	**0.11**
12	12S	**0.15**	**32**	32S	**0.18**	**52**	52S	**0.11**
	12B	**0.09**		32B	**0.12**		52B	**0.11**
13	13S	**0.11**	**33**	33S	**0.16**	**53**	53S	**0.13**
	13B	**0.09**		33B	**0.62**		53B	**0.13**
14	14S	**0.08**	**34**	34S	**0.34**	**54**	54S	**0.12**
	14B	**0.16**		34B	**0.17**		54B	**0.10**
15	15S	**0.08**	**35**	35S	**0.12**	**55**	55S	**0.16**
	15B	**0.13**		35B	**0.14**		55B	**0.10**
16	16S	**0.07**	**36**	36S	**0.15**	**56**	56B	**0.12**
	16B	**0.10**		36B	**0.17**		56B	**1.43**
17	17S	**0.07**	**37**	37S	**0.09**	**57**	57S	**0.24**
	17B	**0.08**		37B	**0.15**		57B	**0.18**
18	18S	**0.11**	**38**	38S	**0.12**	**58**	58S	**0.12**
	18B	**0.18**		38B	**0.15**		58B	**0.49**
19	19S	**0.09**	**39**	39S	**0.14**	***Note:***		
	19B	**0.08**		39B	**0.19**	• ***S: Surface layer, 2m***		
20	20S	**0.11**	**40**	40S	**0.12**	• ***B: Bottom layer, ≥ 100m***		
	20B	**0.18**		40B	**0.52**			

The results are shown that concentrations of Cu, Pb, Cd, Zn, Ni, Cr and As in every samples were low and well within the range found in near shore as well as open ocean seawater elsewhere (Table 19). One attention point is that relatively Hg concentrations in the study area are found as compared with those in other marine areas. The highest concentration of Hg was observed at the station 8, which was located, offshore (Fig. 9). The average concentration of Hg appears to be considerably higher than open ocean value but same range obtained in semi-enclosed unpolluted seas.

Comparison of determined metals at different areas of world indicated that concentrations of Cu, Pb, Cd, Zn, Ni, Cr and As in Vietnamese Sea, South China Sea, Baltic Sea, Pacific Ocean and South African Coast were in the same concentration range.

The concentration values for all determined trace metals at the most stations were near placed average values. (Fig. 2, 3, 4, 5, 6, 7 and 8)

Table 19. Comparison of the concentration of Cu, Pb, Cd, Zn, Cr, Ni, As and Hg in Vietnamese waters with other areas of the World (nM) [Utoomprurkporn (1997), Utoomprurkporn (1998), Brugman (1977), Bruland (1983), Millins(1964), Brugman (1977), Gian (1987), Jacinto (1996)].

Trace Metals	Cu	Pb	Cd	Zn	Ni	Cr	As	Hg
South African Coast	4.7-23.6		0.3-1.4		10.2-66.4			
	468.18	20.67	2.58	424.9				
Sea of Japan	4.72		0.98		17.03			
China sea	6.3-36.2		0.4-1.1		11.9-85.2			
Gulf of Thailand	1.5-9.0	0.03-1.00	0.01-0.17		0.5-9.0			
Gulf of Thailand and East Coast of Peninsular Malaysia	1.6-14.2	0.05-0.87	0.001-0.10		1.7-8.5			
Off Sabah, Sarawak and Brunei Darussalam	2.9-20.5	0.02-1.50	0.01-1.37		1.3-14.1			
Ocean	47.24	14.49	0.89	152.9	8.82	0.96	40	0.15
Pacific Ocean	2.36	0.48	0.13	9.94	21.5		1.33	0.08
Atlantic Ocean		4.06	0.27	121.1				
Baltic Sea	111.8	3.86	2.58	125.38				
South China Sea	7.9-100	2.4-26	4.4-30	7.6-650.0				
This Study (Surface Layer)	65.67	10.04	1.61	142.6	22.69	19.26	22.35	0.775

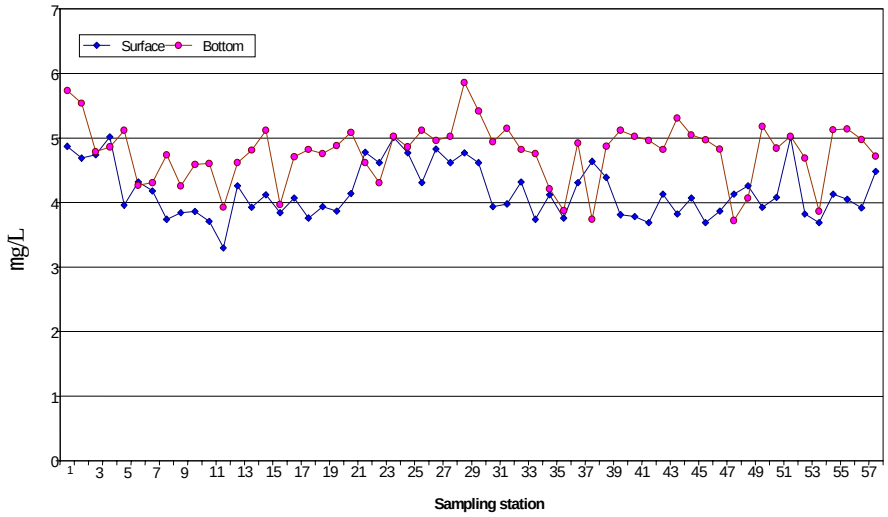

Fig. 2. Cu-Concentration in seawater.

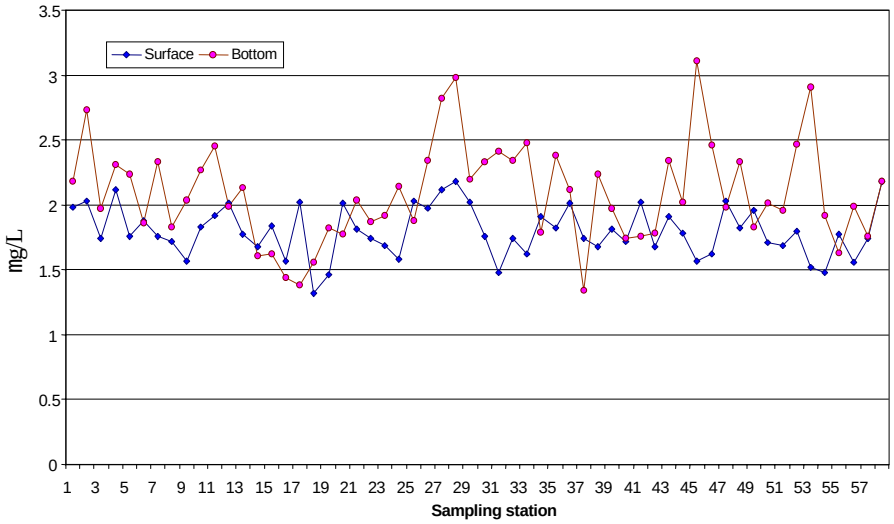

Fig. 3. Pb-Concentration in seawater.

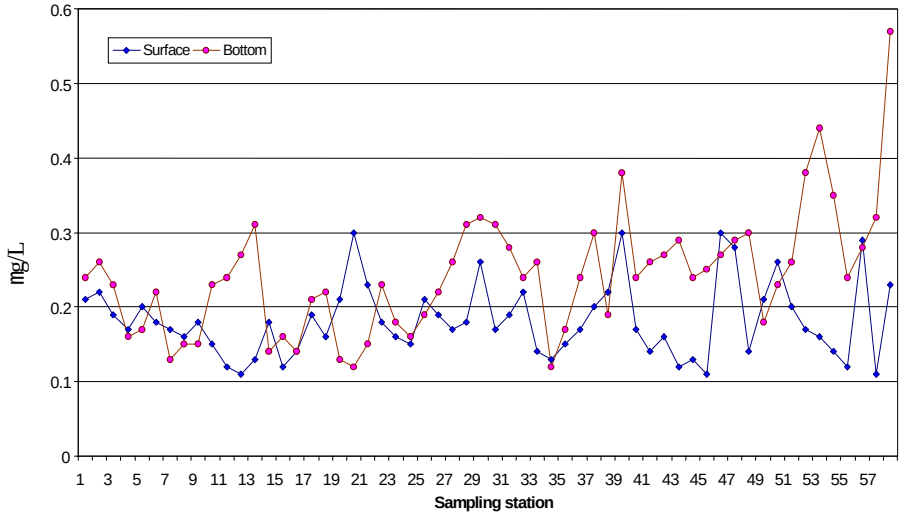

Fig. 4. Cd-Concentration in seawater.

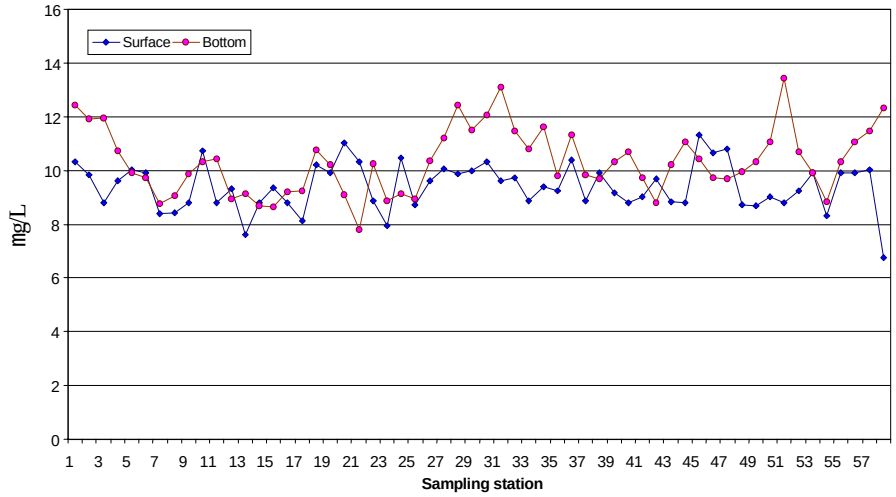

Fig. 5. Zn-Concentration in seawater.

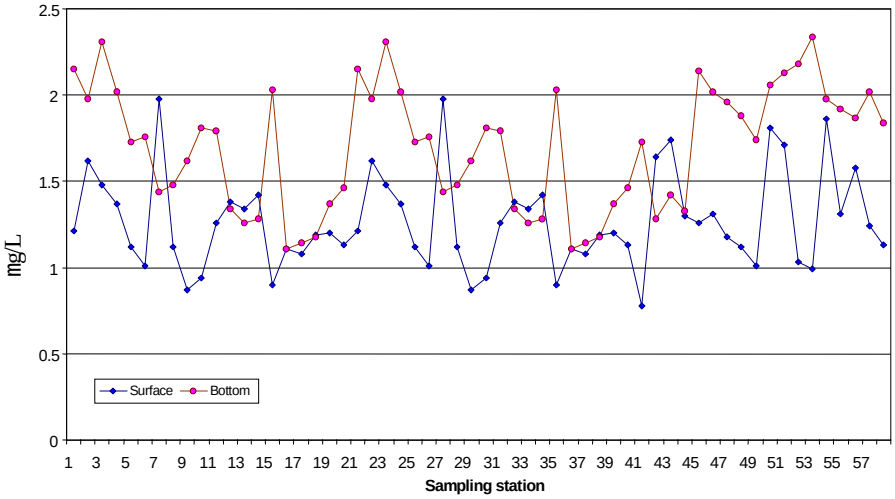

Fig. 6. Ni-Concentration in seawater.

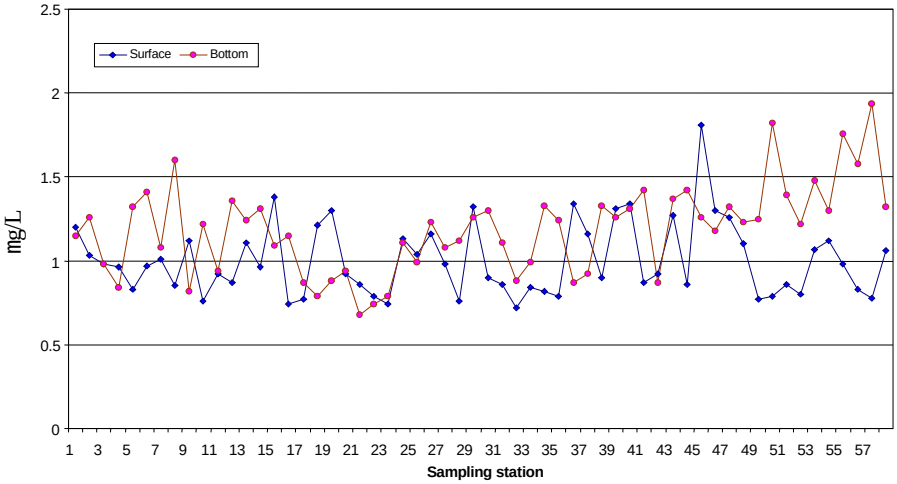

Fig. 7. Cr-Concentration in seawater.

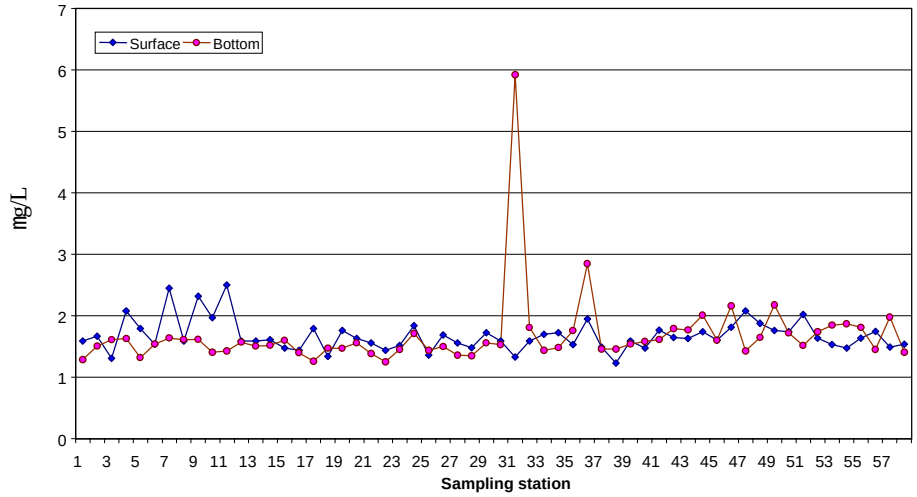

Fig. 8. As-Concentration in seawater.

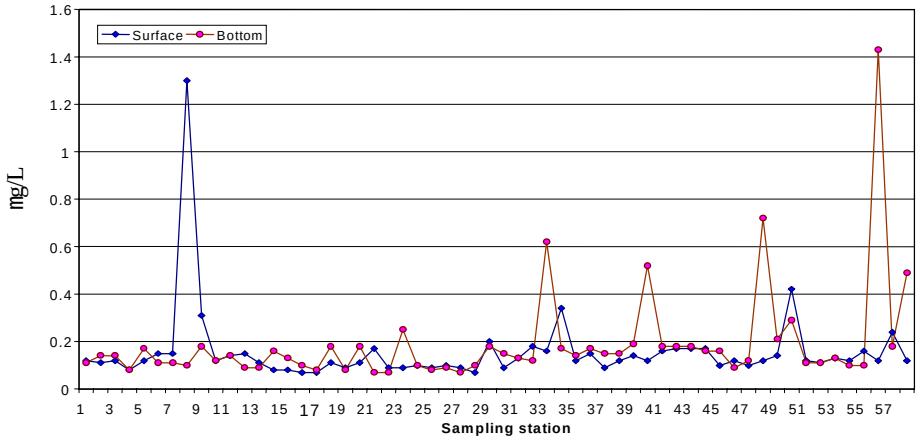

Fig. 9. Hg-Concentration in seawater.

ANALYSIS OF SEA-SEDIMENT

Sediment is known to be the key to ancient and historian environments. A sequence of sedimentary layers can tell us about environmental changes over time [Hallberg (1992)]. The geophysical properties of ocean sediments have been used as environmental indicators. Studies on ocean sediments have begun since the early 1900s. [Folk (1966), Krumbrein (1996)]

The recent sedimentary record can reveal cultural impacts on the environments during the industrial era. During formation and digenesis, the sediments also take an active part in the biogeochemical cycles of the elements, which affect the overlying water column.

Assessment of sediment contaminants has become increasingly import over the past several years. These assessments must be predictive of pollutant transport and of potential biological effects.

The bottom sediments logical properties not only play a major role in determining the richness of benthic life and productivity i.e. the diversity of benthic organisms but are also an important parameter that closely relates to pollution and mineral resources in the oceans.

It was carried as one subproject under the Collaborative Research Project. Objective of this research was to collect up - to -data sediment information concerning on the marine fishery resource and present oceanographic conditions in the sea area for suitable development of fishery resource scheme of the South China Sea.

Samples Collection and preparation

Surface sediment samples from offshore of Vietnam are collected using a Smith McIntyre grab on board of the M.V. SEAFDEC.

Out of the 58 stations, a total of 38 stations were sampled on 30 April 1999 to 29 May 1999 during the cruise (Fig. 1)

20 stations were not sampled due to technician problems (too deep).

A portion of sediment were carefully collected with a clean plastic spatula, kept in acid cleaned PE bottles, then stored at -20^{o}C until ready for analysis.

The sediment samples were dried at 85^{o}C then lightly ground to break up the particles. The sediment was achieved homogeneity and sieved through a 65 mm.

All equipment used for homogenization should be cleaned to minimize the potential of cross-contamination.

Analytical method

About 1 gram homogenized prepared sediment was totally digested in a Teflon decomposition vessel under pressure with a mixture of nitric, hydrochloric, perchloric and hydrofluoric acid. The Teflon bomb was placed inside a plastic pressure cooker, which was this. Then inside an ordinary household microwave over with the power turned on full for 1.5h at 150^{o}C.

After cooling, the digest was than made up to 50ml with Mili-Q water.

The sediment samples were analyzed in laboratory of the Department for Analytical Science and Technique of the Institute of Chemistry, NCST.

Results and Discussion

This report focuses only on the information gathered and data analyzed from the surface sediment samples collected during cruise.

The metal concentrations of Cu, Pb, Cd, Zn, Cr and Ni were determined with the same

The contents of trace heavy metals in sediments of the South China Sea, nevertheless, are not well documented.

For quality assurance standard reference materials (MESS-1 Gulf of sea Miramichi River) from National Research Council, Marine Analytical Chemistry Standards program, Ottawa, Canada were digested as above and analyzed for metals with same above described methods. (Table 20)

The total contents of determined metals in surface sediment are shown in Tables 21, 22, 23, 24, 25, 26, 27 and 28 respectively.

The average concentration of metals in surface layer were found 65.57 nM for Cu, 10.04 nM for Pb, 1.61 nM for Cd, 142.65 nM for Zn, 22.35 nM for As, 0.775 nM for Hg, 22.39 nM for Ni and 19.26 nM for Cr.

Comparison of concentration of determined metals reported by different papers are difficult to compare because of different method for samples sampling, preparation and determining used.

The range of concentration of metals were 10.3 - 71.0 $\mu g.g^{-1}$ for Cu, 12.9 - 33.7 $\mu g.g^{-1}$ for Pb, 1.29 - 18.72 $\mu g.g^{-1}$ for Cd, 45.8 - 164.8 $\mu g.g^{-1}$ for Zn, 21.2 - 93.6 $\mu g.g^{-1}$ for Cr, 5.7 - 45.8 $\mu g.g^{-1}$ for Ni, 1.64 - 3.80 $\mu g.g^{-1}$ for As, and 0.104 - 0.493 $\mu g.g^{-1}$ for Hg. The levels found in the present study are similar to data from other marine. [Shazili (1986), Shazili (1997), Shazili (1998), Brugman (1982)]

The highest contents of metals were 71.0 $\mu g.g^{-1}$ for Cu at station 2, 32.0 $\mu g.g^{-1}$ for Pb at station 3, 18.72 $\mu g.g^{-1}$ for Cd at station 40, 169.8 $\mu g.g^{-1}$ for Zn at station 2, 41.0 $\mu g.g^{-1}$ for Ni at station 3, 93.6 $\mu g.g^{-1}$ for Cr at station 58, 3.8 $\mu g.g^{-1}$ for As at station 5 and 0.493 $\mu g.g^{-1}$ for Hg at station 57. (Fig. 10, 11, 12, 13, 14, 15, 16 and 17)

Table 20. Analysis of certified reference materials.

MESS - 1	Certified Value (μg.g^{-1})	Measured Value (μg.g^{-1})	% Mean Recovery
Cu	25.1	26.15	104.2
Pb	34.0	36.18	92.8
Cd	0.59	0.63	106.4
Zn	191	203.99	106.8
Cr	71	66.39	93.5
Ni	29.5	28.62	97.0
Co	10.8	10.23	94.7
Hg	0.171	0.187	109.4

Table 21. Cu-Content in surface Sediment.

No.	Station	Cu (μg.g^{-1})	No.	Station	Cu (μg.g^{-1})
1	1	30.0	20	37	16.2
2	2	71.0	21	38	28.0
3	3	50.5	22	39	25.7
4	4	31.1	23	40	20.9
5	5	26.2	24	44	10.3
6	6	31.4	25	45	14.3
7	7	36.6	26	46	16.0
8	8	22.3	27	47	10.7
9	9	36.1	28	48	17.6
10	10	32.3	29	49	11.1
11	11	29.0	30	50	18.8
12	12	35.8	31	51	22.5
13	13	24.1	32	52	28.1
14	14	24.9	33	53	28.0
15	20	35.0	34	54	23.5
16	21	34.9	35	55	28.7
17	29	17.6	36	56	25.1
18	35	28.1	37	57	33.2
19	36	15.7	38	58	31.4

Table 22. Pb-Content in surface Sediment.

No.	Station	Pb (µg.g^{-1})	No.	Station	Pb (µg.g^{-1})
1.	1	19.3	20	37	16.1
2.	2	18.3	21	38	16.3
3.	3	32.2	22	39	15.6
4.	4	13.8	23	40	17.1
5.	5	17.4	24	44	14.0
6.	6	13.5	25	45	15.3
7.	7	17.8	26	46	17.5
8.	8	19.6	27	47	18.4
9.	9	14.4	28	48	18.6
10.	10	12.9	29	49	20.48
11.	11	13.9	30	50	16.8
12.	12	20.9	31	51	15.4
13.	13	17.8	32	52	12.9
14.	14	19.3	33	53	19.3
15.	20	18.3	34	54	14.4
16.	21	18.5	35	55	17.2
17.	29	19.4	36	56	14.2
18.	35	21.6	37	57	12.9
19.	36	33.7	38	58	21.0

Table 23. Cd-Content in surface Sediment.

No.	Station	Cd (µg.g^{-1})	No.	Station	Cd (µg.g^{-1})
1.	1	2.52	20	37	3.02
2.	2	1.29	21	38	5.56
3.	3	3.99	22	39	4.37
4.	4	1.52	23	40	18.72
5.	5	4.07	24	44	2.88
6.	6	4.26	25	45	3.67
7.	7	3.91	26	46	3.53
8.	8	3.26	27	47	3.70
9.	9	3.73	28	48	4.28
10.	10	3.13	29	49	3.69
11.	11	3.75	30	50	3.40
12.	12	3.44	31	51	4.23
13.	13	2.45	32	52	4.12
14.	14	3.46	33	53	6.63
15.	20	3.64	34	54	3.41
16.	21	4.36	35	55	4.27
17.	29	2.87	36	56	4.17
18.	35	4.42	37	57	4.53
19.	36	5.57	38	58	3.61

Table 24. Zn-Content in surface Sediment.

No.	Station	Zn (µg.g^{-1})	No.	Station	Zn (µg.g^{-1})
1.	1	102.7	20	37	56.7
2.	2	164.8	21	38	88.1
3.	3	163.7	22	39	74.3
4.	4	118.8	23	40	51.8
5.	5	86.6	24	44	75.4
6.	6	140.0	25	45	76.5
7.	7	132.2	26	46	71.3
8.	8	86.0	27	47	45.8
9.	9	139.3	28	48	51.4
10.	10	123.9	29	49	60.1
11.	11	102.5	30	50	51.0
12.	12	145.1	31	51	58.1
13.	13	115.6	32	52	107.7
14.	14	119.9	33	53	87.5
15.	20	141.1	34	54	106.2
16.	21	133.4	35	55	126.3
17.	29	79.8	36	56	71.3
18.	35	116.0	37	57	91.0
19.	36	74.9	38	58	115.2

Table 25. Ni-Content in surface Sediment

No.	Station	Ni (µg.g^{-1})	No.	Station	Ni (µg.g^{-1})
1.	1	11.9	20	37	23.9
2.	2	5.7	21	38	38.1
3.	3	41.0	22	39	29.6
4.	4	21.4	23	40	27.1
5.	5	19.3	24	44	27.8
6.	6	26.8	25	45	29.5
7.	7	35.0	26	46	29.5
8.	8	17.0	27	47	19.2
9.	9	40.8	28	48	27.3
10.	10	32.1	29	49	29.4
11.	11	28.7	30	50	27.9
12.	12	37.8	31	51	31.3
13.	13	22.8	32	52	41.5
14.	14	34.9	33	53	38.3
15.	20	45.8	34	54	29.5
16.	21	45.4	35	55	40.0
17.	29	26.4	36	56	29.4
18.	35	37.6	37	57	31.7
19.	36	30.9	38	58	33.8

Table 26. Cr-Content in Surface Sediment.

No.	Station	Cr (µg.g^{-1})	No.	Station	Cr (µg.g^{-1})
1.	1	43.1	20	37	50.1
2.	2	21.2	21	38	63.9
3.	3	74.8	22	39	54.0
4.	4	54.2	23	40	45.7
5.	5	45.4	24	44	53.5
6.	6	72.0	25	45	59.4
7.	7	56.6	26	46	58.3
8.	8	40.7	27	47	55.3
9.	9	71.0	28	48	58.5
10.	10	41.4	29	49	61.1
11.	11	56.5	30	50	58.5
12.	12	82.5	31	51	61.8
13.	13	70.5	32	52	82.1
14.	14	67.4	33	53	63.5
15.	20	81.5	34	54	89.7
16.	21	78.4	35	55	93.1
17.	29	42.1	36	56	75.1
18.	35	73.0	37	57	89.3
19.	36	47.2	38	58	93.6

Table 27. As-Content in surface Sediment.

No.	Station	As (µg.g^{-1})	No.	Station	As (µg.g^{-1})
1.	1	3.21	20	37	2.26
2.	2	3.21	21	38	2.62
3.	3	1.64	22	39	2.52
4.	4	2.86	23	40	3.62
5.	5	3.80	24	44	3.28
6.	6	2.78	25	45	2.00
7.	7	2.96	26	46	2.65
8.	8	1.76	27	47	2.16
9.	9	3.66	28	48	2.46
10.	10	2.98	29	49	3.26
11.	11	2.84	30	50	2.96
12.	12	2.64	31	51	3.44
13.	13	3.72	32	52	2.78
14.	14	2.92	33	53	3.12
15.	20	2.94	34	54	2.18
16.	21	2.40	35	55	2.46
17.	29	3.10	36	56	3.24
18.	35	2.86	37	57	2.78
19.	36	3.00	38	58	2.04

Table 28. Hg-Content in surface Sediment.

No.	Station	Hg (µg.g^{-1})	No.	Station	Hg (µg.g^{-1})
1.	1	0.160	20	37	0.159
2.	2	0.181	21	38	0.168
3.	3	0.338	22	39	0.158
4.	4	0.170	23	40	0.139
5.	5	0.155	24	44	0.141
6.	6	0.142	25	45	0.164
7.	7	0.152	26	46	0.132
8.	8	0.107	27	47	0.120
9.	9	0.155	28	48	0.151
10.	10	0.394	29	49	0.139
11.	11	0.161	30	50	0.268
12.	12	0.133	31	51	0.162
13.	13	0.127	32	52	0.480
14.	14	0.141	33	53	0.211
15.	20	0.188	34	54	0.266
16.	21	0.127	35	55	0.169
17.	29	0.130	36	56	0.158
18.	35	0.178	37	57	0.493
19.	36	0.107	38	58	0.104

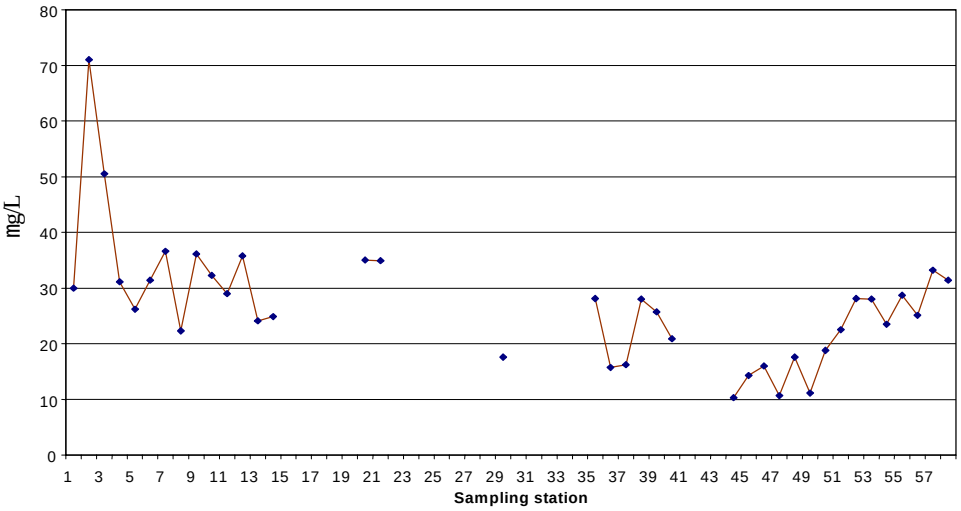

Fig. 10. Cu-Concentration in Sediment.

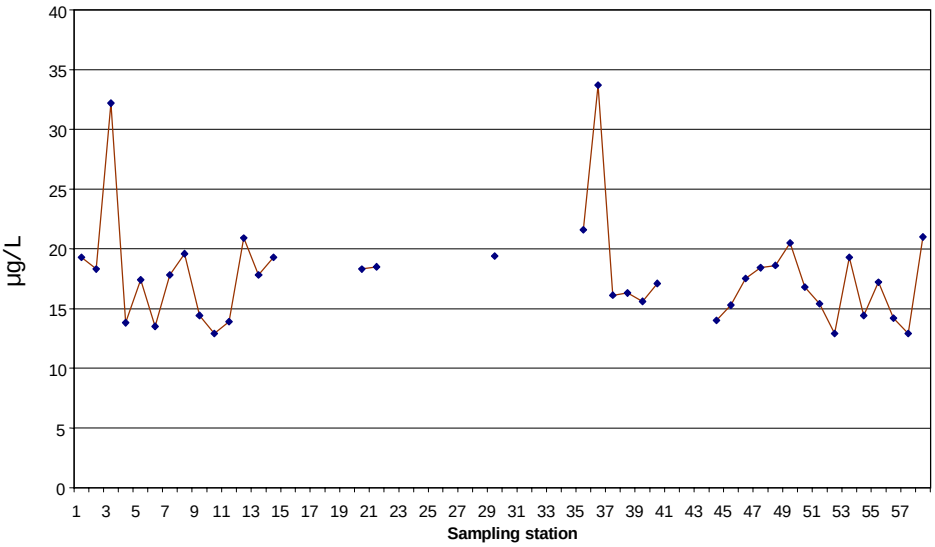

Fig. 11. Pb-Concentration in Sediment.

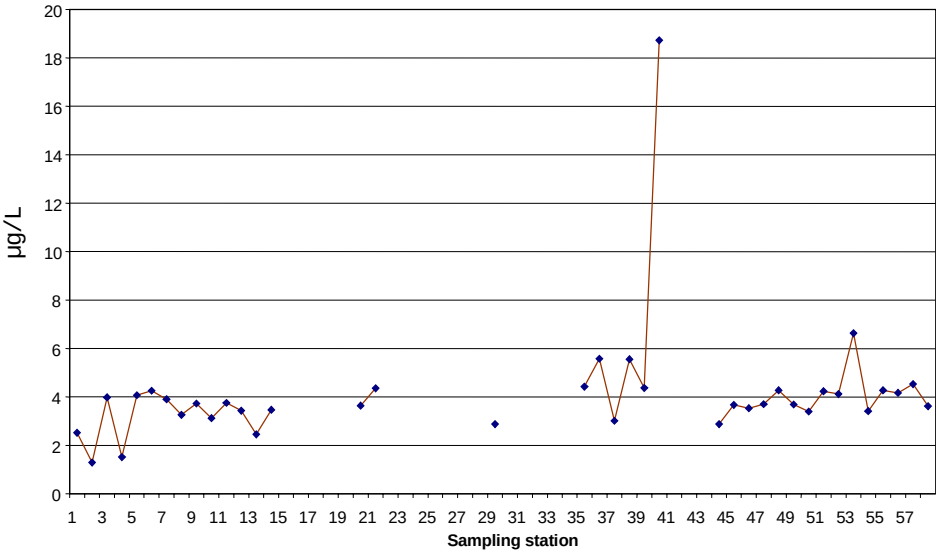

Fig. 12. Cd-Concentration in Sediment.

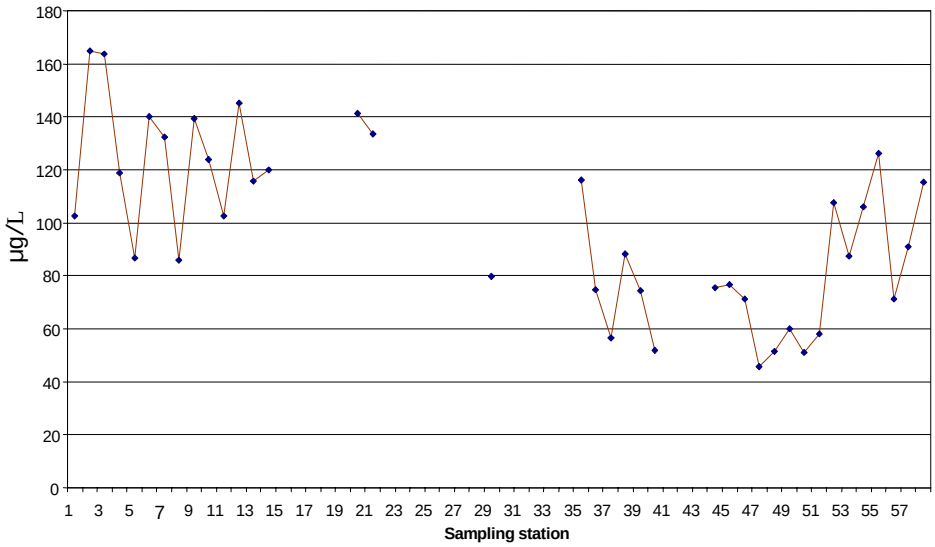

Fig. 13. Zn-Concentration in Sediment.

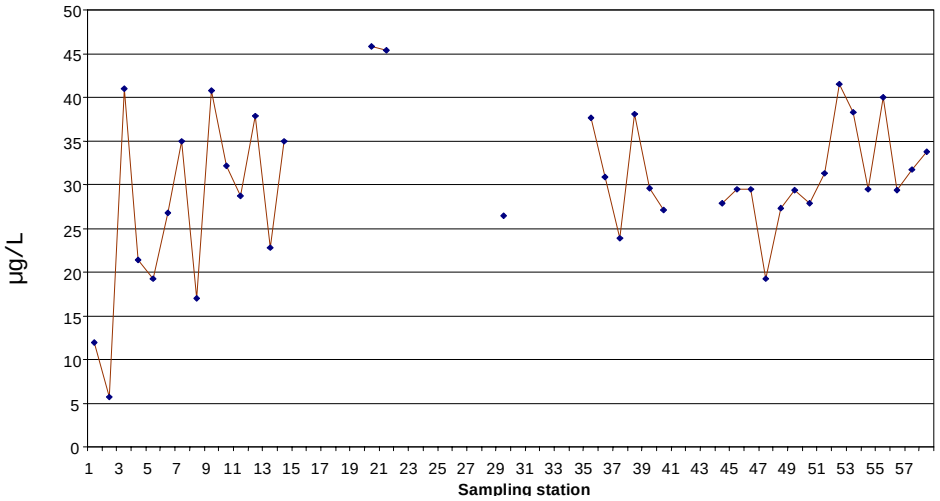

Fig. 14. Ni- Concentration in Sediment.

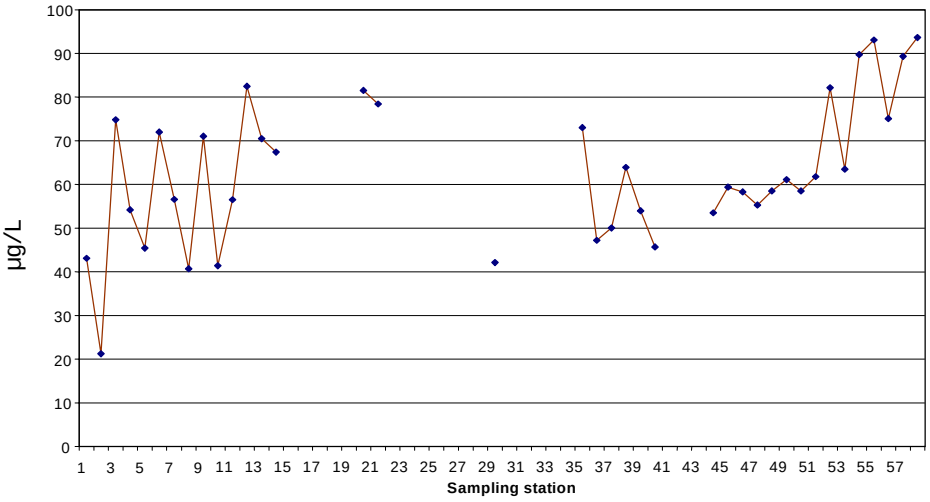

Fig. 15. Cr-Concentration in Sediment.

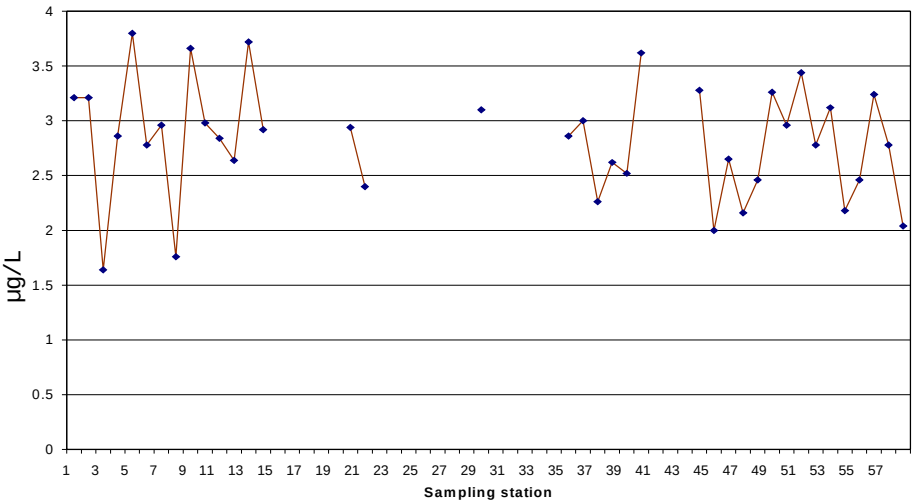

Fig. 16. As-Concentration in Sediment.

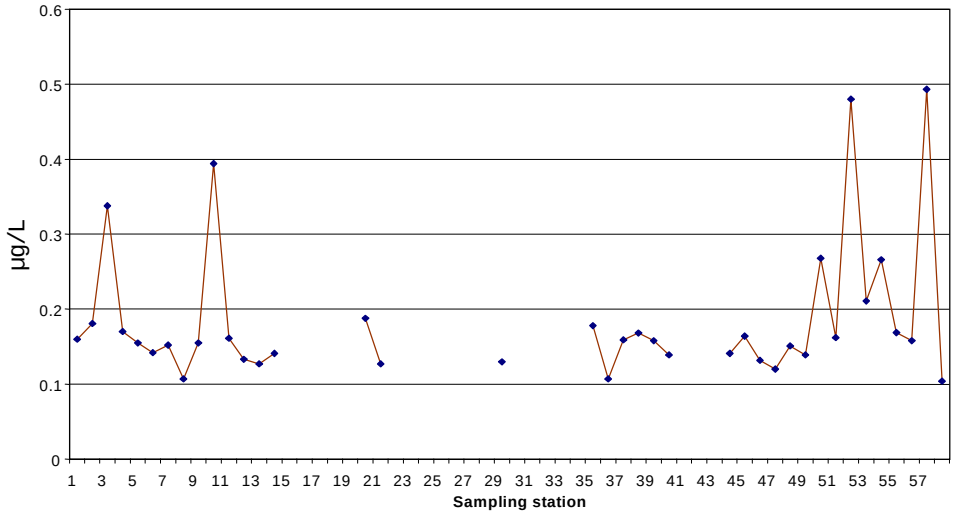

Fig. 17. Hg-Concentration in Sediment.

Conclusions

This research study was the first attempt, which covered largest surveyed areas of Vietnamese Sea.

The trace metal levels determined in this cruise is among the first reported values for trace heavy metals in seawater and sediments.

There is a meed to obtain other published data on trace metals at different areas of world.

It is now well know that trace metals are present in seawater and sediment in various chemical forms.

The determination and speciation of trace heavy metals in seawater and sediment for environmental research is of great significance for their interactions with suspended matter, sediment and their uptake by aquatic organimus and has become an area of key interest in present aquatic metal chemistry.

Data for distribution of trace metals between the water column, sediment and the suspended particulate material were important and necessary.

Studies on the relationship between metal concentration and other oceanography parameters and then fisheries resources in this study area are needed.

The coming sampling time is expected in the year of 2000 for further results to update the data in this report.

Acknowledgements

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