Trace Metals Concentrations and Distributions in Sea Water of the South China Sea, Area II :Sabah, Sarawak and Brunei Darussalam

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ABSTRACT

Water samples off Sabah, Sarawak and Brunei Darussalam were collected during July–August 1996 and May 1997 and analyzed for dissolved and particulate cadmium, copper, iron, lead and nickel. Dissolved metals were coprecipitated with cobalt-APDC while particulate metals were digested with aqua regia and hydrofluoric acid. The concentrations of metals were measured using graphite furnace atomic absorption spectrophotometer. Concentrations of cadmium, copper, lead and nickel were in the same concentration ranges of unpolluted coastal water elsewhere except for some high concentrations of cadmium at some stations offshore. Iron concentrations were much higher than other regions, and the concentrations were about twenty times those found in the Gulf of Thailand and east coast of Malay Peninsula. High concentrations of these five metals in the offshore area in the July-August sampling possibly came from the Indonesian water flowing northward due to the influence of the wind from the south.

Key words: trace metal, South China sea, Sabah, Sarawak, Brunei Darussalam

Introduction

As part of the SEAFDEC Cooperative Programme on the study of Fisheries Oceanography of the South China Sea, a study on trace metal contamination was made. Trace metals are the natural components in seawater. Prior to the period of human disturbance of the environment, trace metals in the water were derived from continental rocks by weathering and partly from sediment due to leaching, desorption, dissolution, cation exchange, and other processes. For some elements, such as lead, anthropogenic atmospheric input may also be important. As the natural system is at equilibrium, the input must be equal to the output where these dissolved trace metals in the water are removed back to solid phase, i.e. sediments, by a suite of geochemical reactions such as adsorption, precipitation and cation exchange. Some metals, mercury for example, can be volatile and removed from seawater via the atmosphere. These physical and chemical processes involving trace metals are strongly controlled by environmental factors, for instances, temperature, salinity (ionic strength), pH and redox potential [Drever (1982)]

In this report, the metals; cadmium, copper, nickel, lead and iron in water collected off Sabah, Sarawak and Brunei Darussalam were studied in the dissolved and particulate forms. Concentration and distribution of these trace metals can provide some details on sources, cycling and removal processes. It is also an indicator of human impact and imprint on the environment and on the quality of its living resources.

Methods

Dissolved trace metals in water samples were coprecipitated with cobalt-APDC [Boyle and Edmond (1977)] modified by [Huizenga (1981)]. Precipitates were collected by hand vacuum filtration on Nuclepore 0.4 µm membranes. The precipitates were further dissolved in HNO_3 and diluted with Milli-Q water. The final solutions were measured for cadmium, copper, iron, lead and nickel

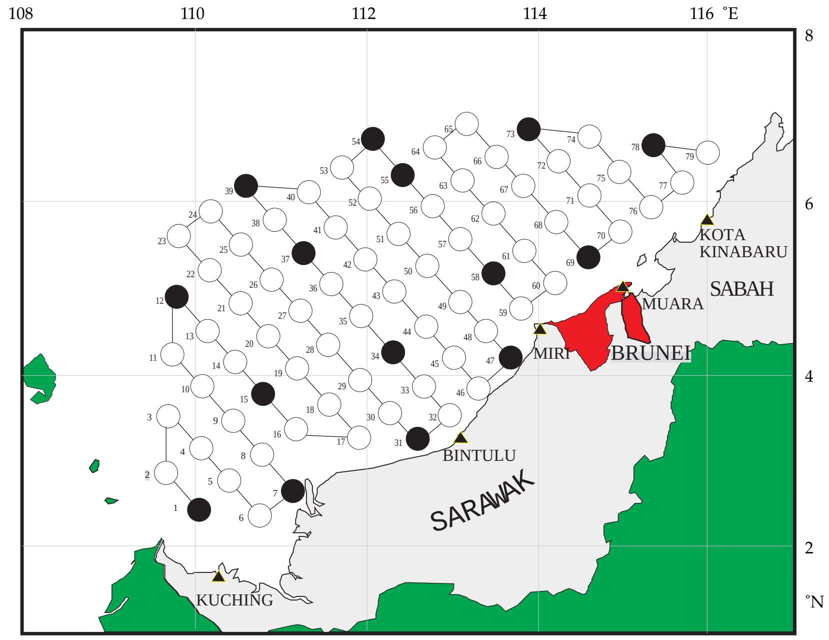


Fig. 1. Sampling stations (in dark circles)

using a Perkin Elmer Zeeman Graphite Furnace 4100ZL atomic absorption spectrophotometer. Merck standard solutions diluted by Milli-Q water was used as standards. Certified Reference Seawater CASS-2 of the Institute for Environmental Chemistry, Canada, was included in sample preparation and analysis as quality control samples to ensure the accuracy of the results. The percentage recovery of cadmium was 115.8%, copper was 94.5%, iron was 105.0%, nickel was 95.0% and lead was 110.5%. All bottles, filter membranes and labwares that would be in contact with samples were carefully pre-washed with nitric acid and Milli-Q water.

Particulates retained on the membrane filter were digested in a teflon decomposition vessel (Lorran, capacity 40 ml.) with aqua regia and HF. The teflon bomb was placed inside a plastic pressure cooker which was then placed inside an ordinary household microwave oven, with the power turned on full for 1 minute. Very pure boric acid was then added to the digested liquid and the liquid quantitatively transferred into a clean 10 ml. polyethylene tube with screw cap [Loring and Rantala (1990)]. Metal concentrations were determined with flameless graphite furnace atomic absorption spectrophotometry. Standard Reference Material used in quality control is MAG-1 by which the percentage recovery of cadmium was 93.2 %, copper was 101.0 %, iron 109.9%, nickel 85.2 % and lead 112.3 %.

Results and Discussion

The results showed that concentrations of dissolved cadmium, copper, nickel and lead in the samples were very low and well within the range found in unpolluted coastal water elsewhere (Table 1). Some high concentrations of cadmium (higher than 1 nM) were observed at station 39, 54, 73 and 78 which were located offshore (Fig 2 -5). Dissolved iron concentrations were 47- 1,672 nM in July-Aug 1996 and 92-2,020 nM in May 1997 which were higher than other regions. Further investigation on the sources of metals especially iron in this area should be carried out. Concentrations of dissolved and particulate metals at each station are shown in Appendix 1-4. Comparison of dissolved and particulate Cd, Cu, Fe, Pb and Ni at different areas in the South China Sea (Table 2) indicated that concentrations of copper, lead and nickel in the three areas i.e. off the Mekong Delta [Hungspreugs *et al*. (1998)], the Gulf of Thailand and east coast of Malay Peninsula [Utoomprurkporn *et al.* (1998)]

Table 1 Comparison of the concentrations of dissolved Cd, Cu, Fe, Ni and Pb off Sabah, Sarawak and Brunei Darussalam with others areas of the world (nM)

Trace metals	Cd	Cu	Fe	Ni	Pb
South African Coast[a]	0.3-1.4	4.7-23.6	12.5-39.4	10.2-66.4	-
Sea of Japan[a]	0.98	4.72	16.12	17.03	-
China Sea[a]	0.4-1.1	6.3-36.2	17.9-25.1	11.9-85.2	-
San Francisco Bay[b]	0.07-1.47	8.5-73.0	2.5-906	3.7-31.5	-
St. Lawrence Estuary[c]	0.53	17.15	537.18	13.8	-
Off the Mekong Delta[d]	0.05-0.17	3.2-9.7	-	2.92-12.40	0.06-0.85
Gulf of Thailand[e]	0.01-0.17	1.5-9.0	1.9-54.3	0.5-9.0	0.03-1.00
ocean margin[f]	0.18	6.3	7.2	10.2	0.12
This study	0.01-1.37	2.9-20.5	47-2020	1.3-14.1	0.02-1.50

a (Chester and Stoner, 1974) b (Flegal et al. 1991) C(Yeats and Loring, 1991)
d (Hungspreugs et al. 1998) e (Utoomprurkporn et al. 1998) f (Martin and Windom, 1991)

Table 2 Comparison of dissolved and particulate Cd, Cu, Fe, Pb and Ni in the South China Sea : off Sabah, Sarawak and Brunei Darussalam, the Gulf of Thailand and off the Mekong Delta (nM)

metal	off Sabah, Sarawak and Brunei		Gulf of Thailand[a]		off the Mekong Delta[b]	
	April-May 97	July-Aug 96	April-May 96	Sept-Oct 95	Mar-97	Oct-97
Cd_D	0.01-1.31	0.01-1.37	0.02-0.13	0.01-0.29	0.05-0.40	0.05-0.20
Cd_P	0.001-0.011	0.001-0.029	0.001-0.090	0.04-0.13	0.048-0.435	0.002-0.596
Cu_D	2.95-20.5	3.81-19.65	1.03-8.87	1.09-22.90	1.30-11.20	4.27-16.50
Cu_P	0.72-2.31	0.92-1.88	0.27-5.65	0.78-20.47	0.26-66.23	0.20-50.07
Fe_D	92-2020	47-1672	4.38-59.80	6.72-87.71	-	-
Fe_P	71-1911	255-1850	21.63-417.65	-	-	-
Ni_D	3.3-14.1	1.3-13.4	1.66-8.71	1.86-17.17	1.93-8.77	3.74-20.48
Ni_P	0.17-0.76	0.17-0.90	0.16-1.96	1.19-6.81	2.59-78.94	0.50-41.73
Pb_D	0.02-0.32	0.02-1.50	0.06-0.93	0.04-1.74	0.06-0.33	0.03-0.34
Pb_P	<0.02	<0.02	0.02-0.65	0.09-0.72	0.97-22.35	0.11-15.63

a (Hungspreugs and Utoomprurkporn, 1997)and (Rattanachongkiat, 1998)
b (Hungspreugs et al. 1998)
D = dissolved metal
P = particulate metal

Table 3. Percentage of dissolved Cd, Cu, Fe, Pb and Ni off Sabah, Sarawak and Brunei Darussalam

Sampling time	%Cd	%Cu	% Fe	% Pb	%Ni
July-Aug 96	58-100	75-94	Nov-95	> 99	67-97
April-May 97	65-100	60-95	18-88	> 99	84-98

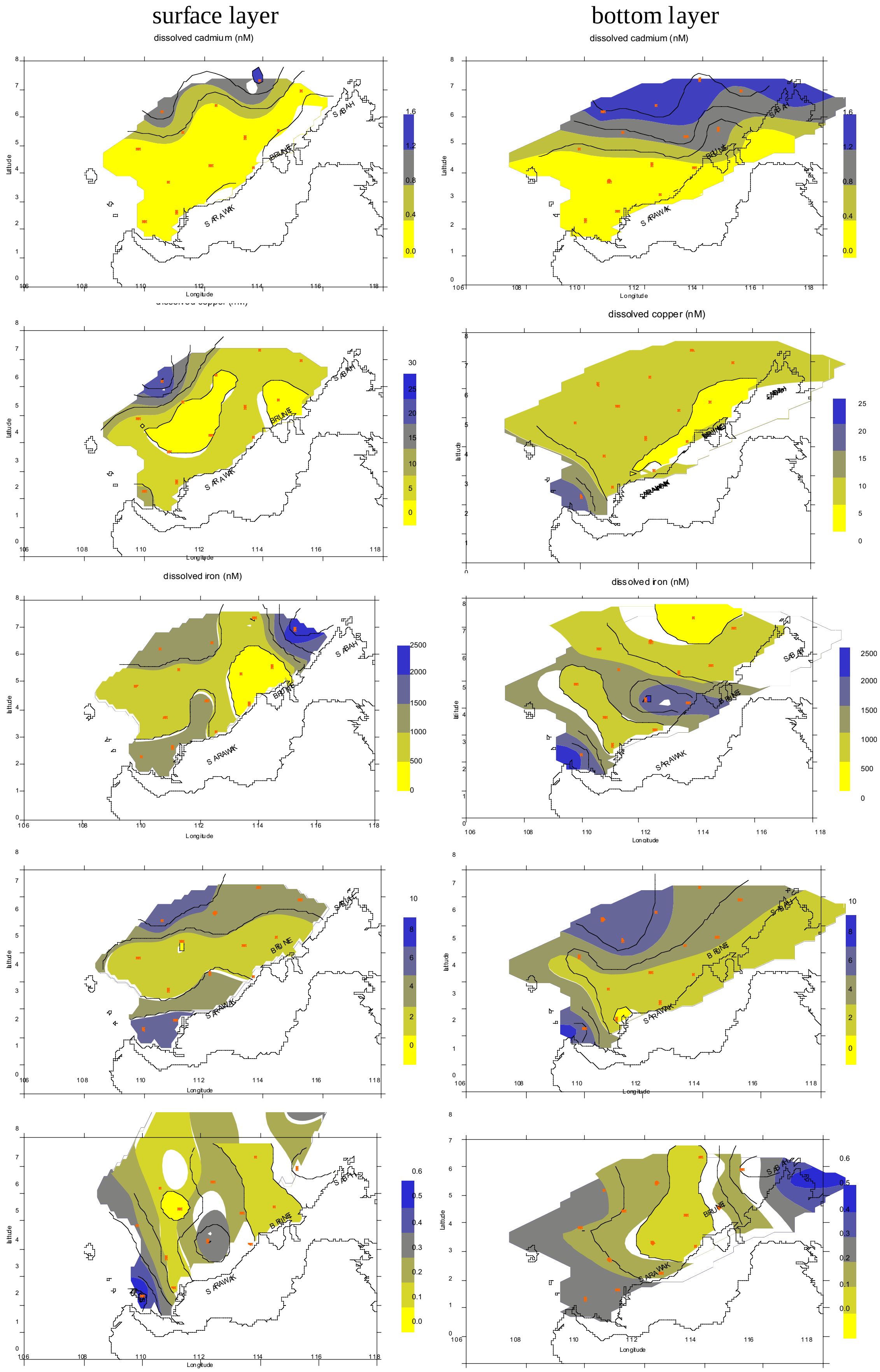


Fig. 2. Distribution of dissolved cadmium, copper, iron, nickel and lead (July-August 1996)

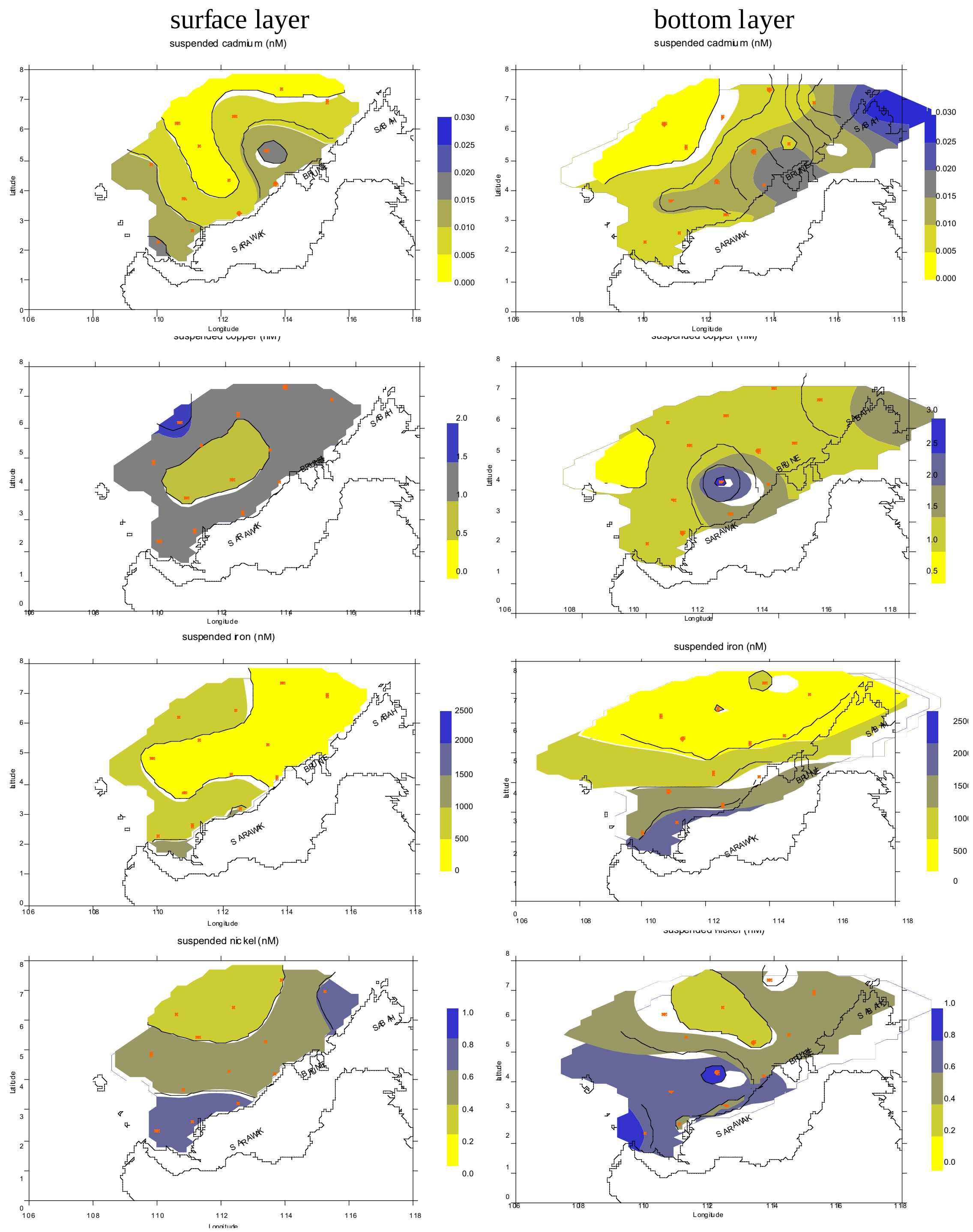


Fig.3. Distribution of suspended cadmium, copper, iron and nickel (July-August 1996)

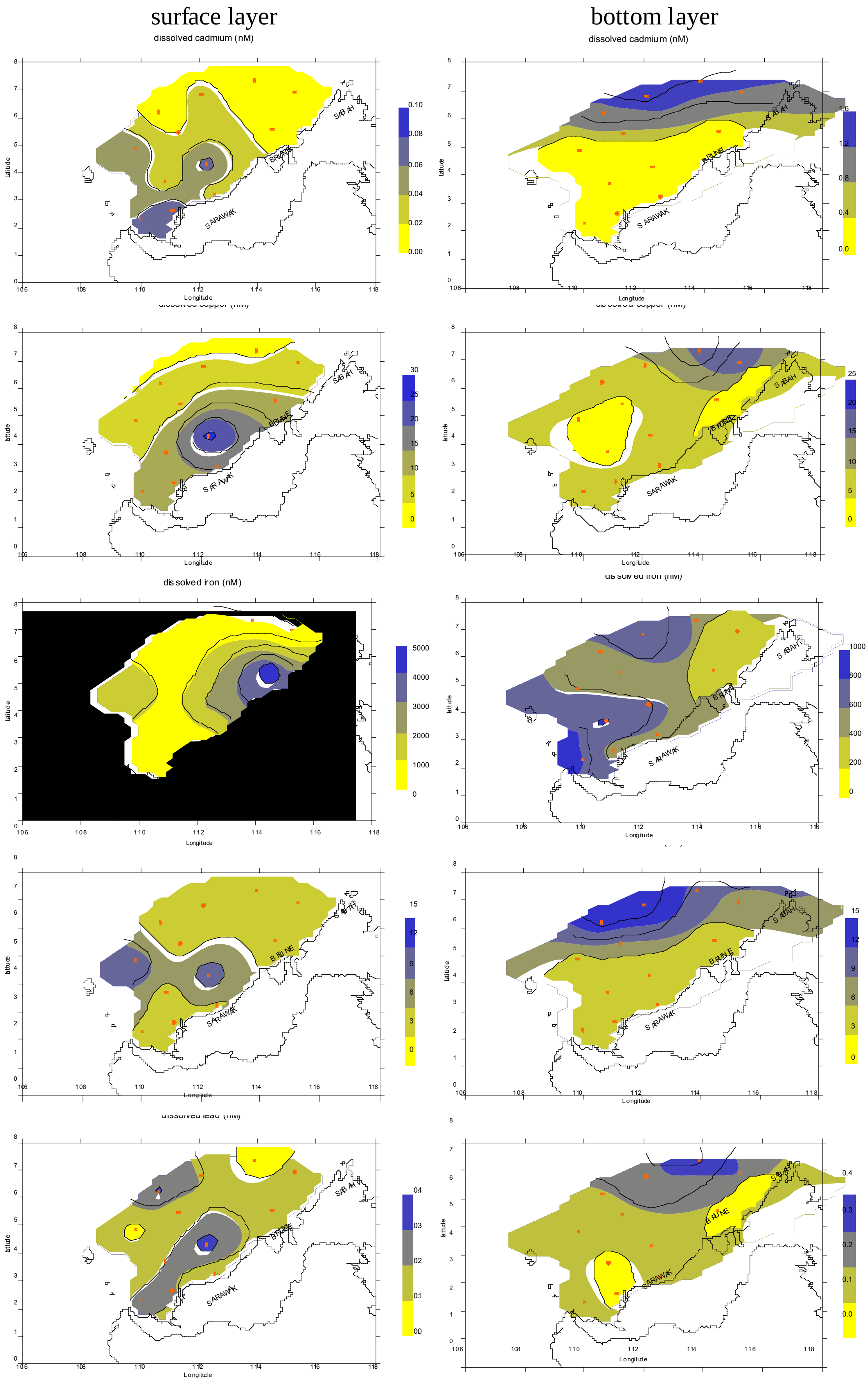


Fig. 4. Distribution of dissolved cadmium, copper, iron, nickel and lead (May 1997)

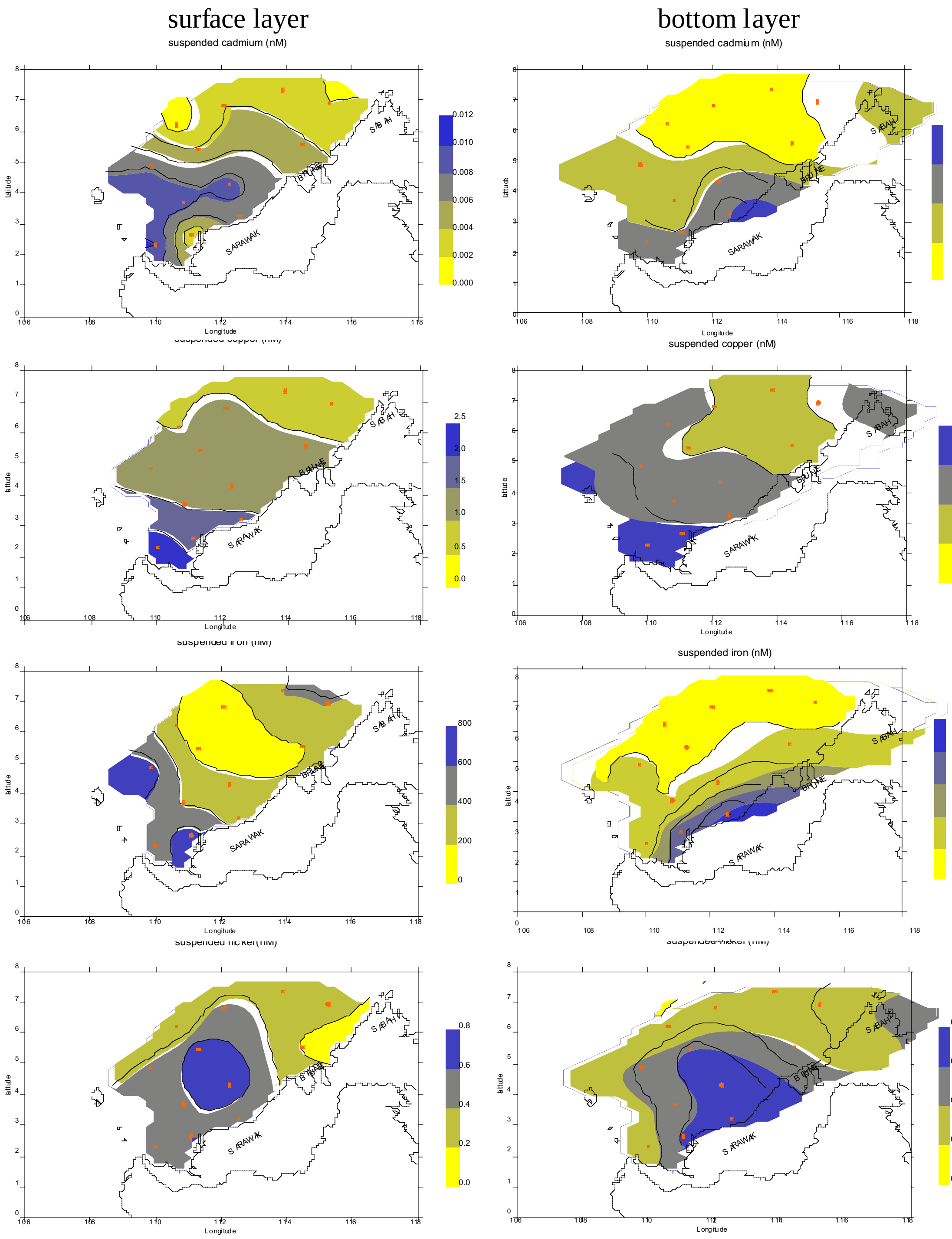


Fig. 5. Distribution of suspended cadmium, copper, iron, and nickel (May 1997)

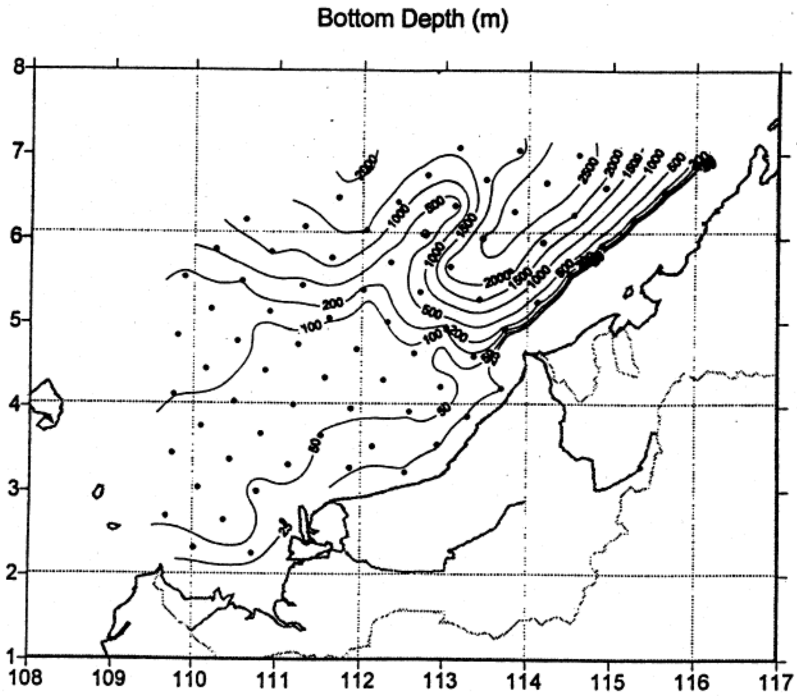


Fig.6. Botom topography off Sabah, Sarawak and Brunei Darussalam [from Snidvongs, *et al*, (1997)]

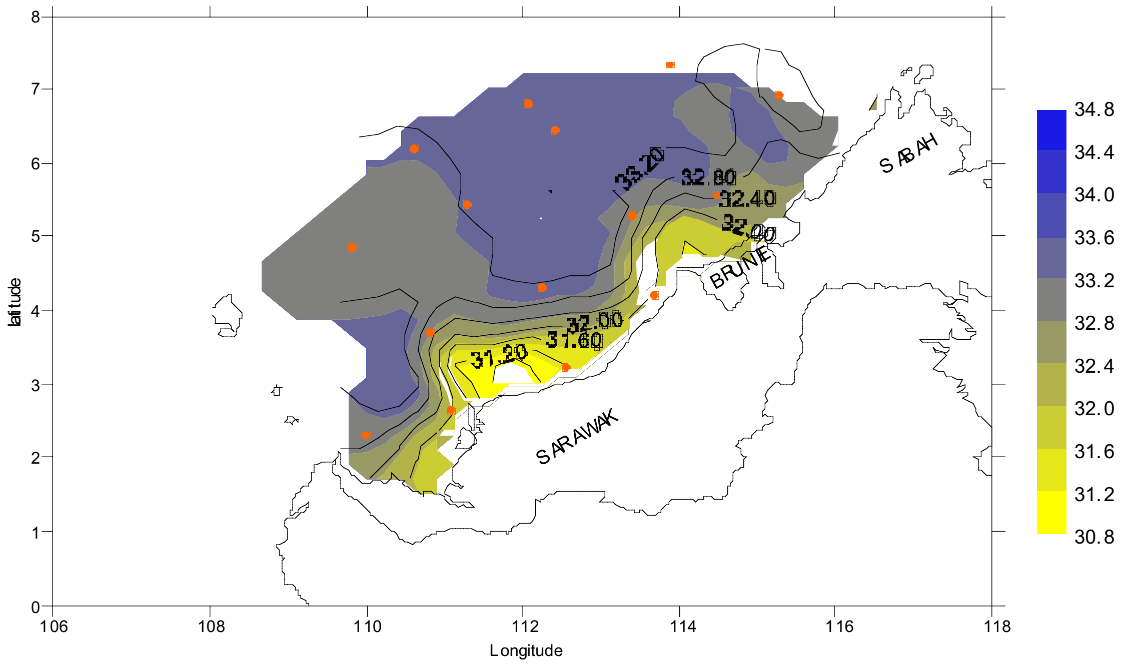
and the area in this study were in the same concentration range. However, cadmium concentrations at some stations offshore in this study area were higher than other two areas. Iron concentrations off Sabah, Sarawak and Brunei Darussalam were about twenty times higher than in the Gulf of Thailand and east coast of Malay Peninsula, but there were no data of iron in the Mekong Delta water.

Cadmium, copper, lead and nickel were mostly present in dissolved form (Table 3) while iron which is geochemically-controlled element [Martin and Windom (1991)] was in particulate form at most stations (low percentage of dissolved iron). However, high percentage of dissolved iron was found at some stations where high concentrations of iron were observed.

Bottom topography off Sarawak (Fig. 6) [Snidvongs, Siriraksophon and Rojana-anawat (1997)] was much shallower than off Brunei and Sabah. The surface mixed layer depths in this area were less than 50 meters. The extent of the influence of freshwater from the Rajang River and the Baram River is shown in Fig. 7. Higher freshwater input was observed in July – August 1996 than in May 1997. The contours of surface distribution of copper, iron lead and nickel reflected some effect of the river input especially in May 1997, but not for cadmium where higher concentrations were observed at stations offshore and extend down to the bottom layer (Fig. 2-5). High concentrations of copper, iron, lead and nickel were also found at stations offshore indicating other sources of these metals.

Surface circulation patterns during the two sampling periods indicated that the circulation appeared to be in the opposite direction (Fig. 8) [Soegiarto (1981)]. In August when the Southwest Monsoon prevails, the water flows from Java Sea up north to the Phillippines. The high concentration of these metals offshore in this season possibly came from the contamination in the Indonesian water. In May 1997, high concentration of metals in the surface layer were found near the coast but in the bottom layer high concentration of metals at stations offshore were still observed (Fig. 4). High metal/Al ratio in suspended particulate also showed the different sources of contamination in the two sampling periods (Fig. 9-10).

July-August 1996



April-May 1997

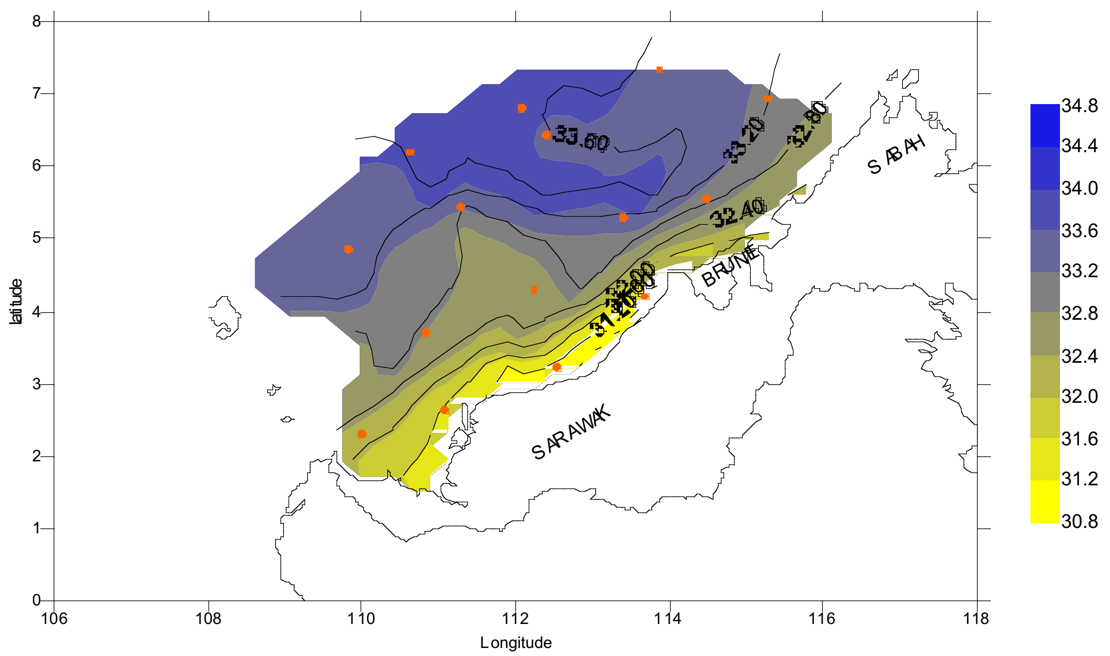


Fig. 7. Surface distribution of salinity

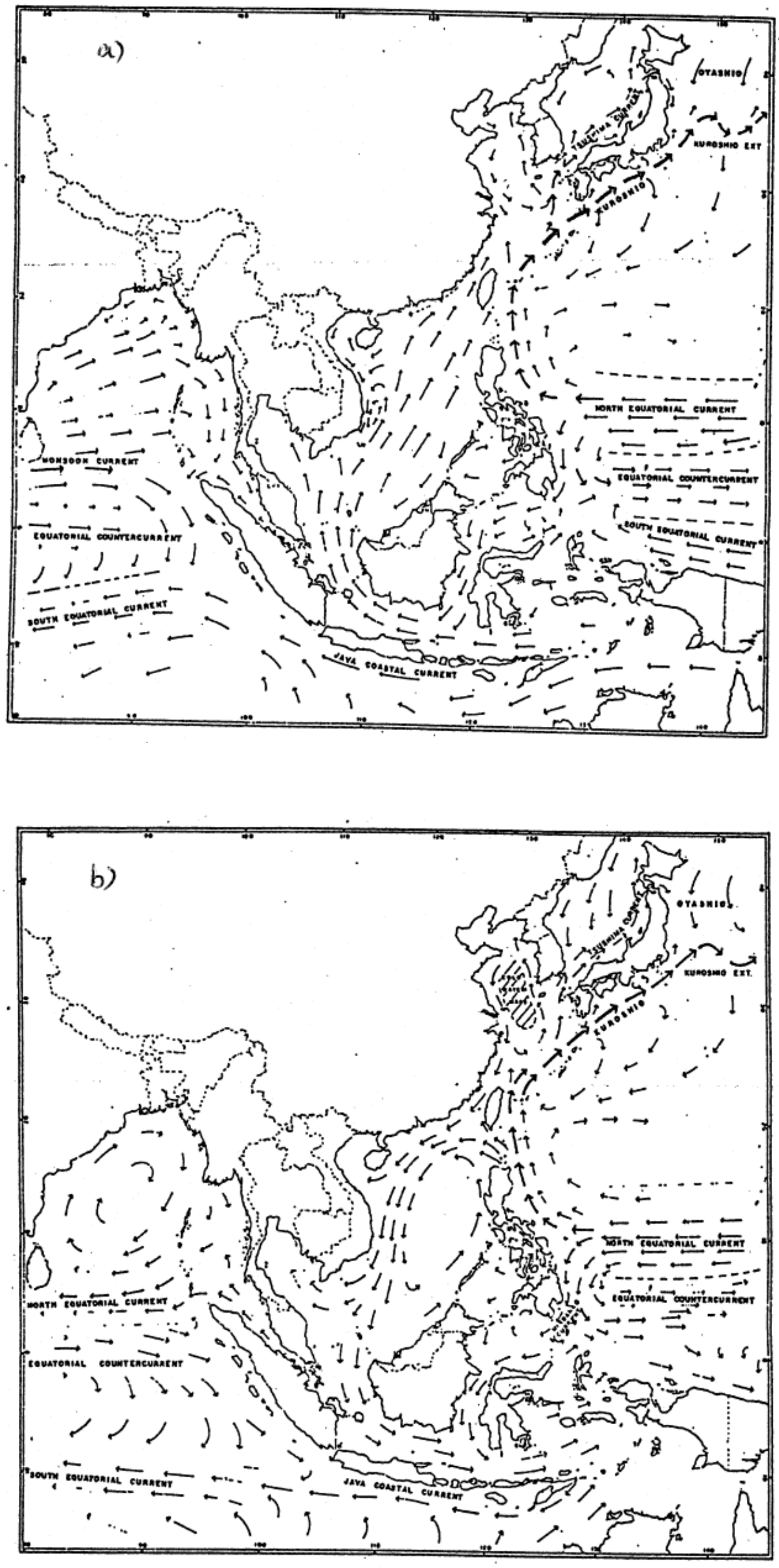


Fig. 8. Surface currents in East Asian Waters [from Soegiarto, (1981)] a. Southwest Monsoon season , b. Northeast Monsoon season

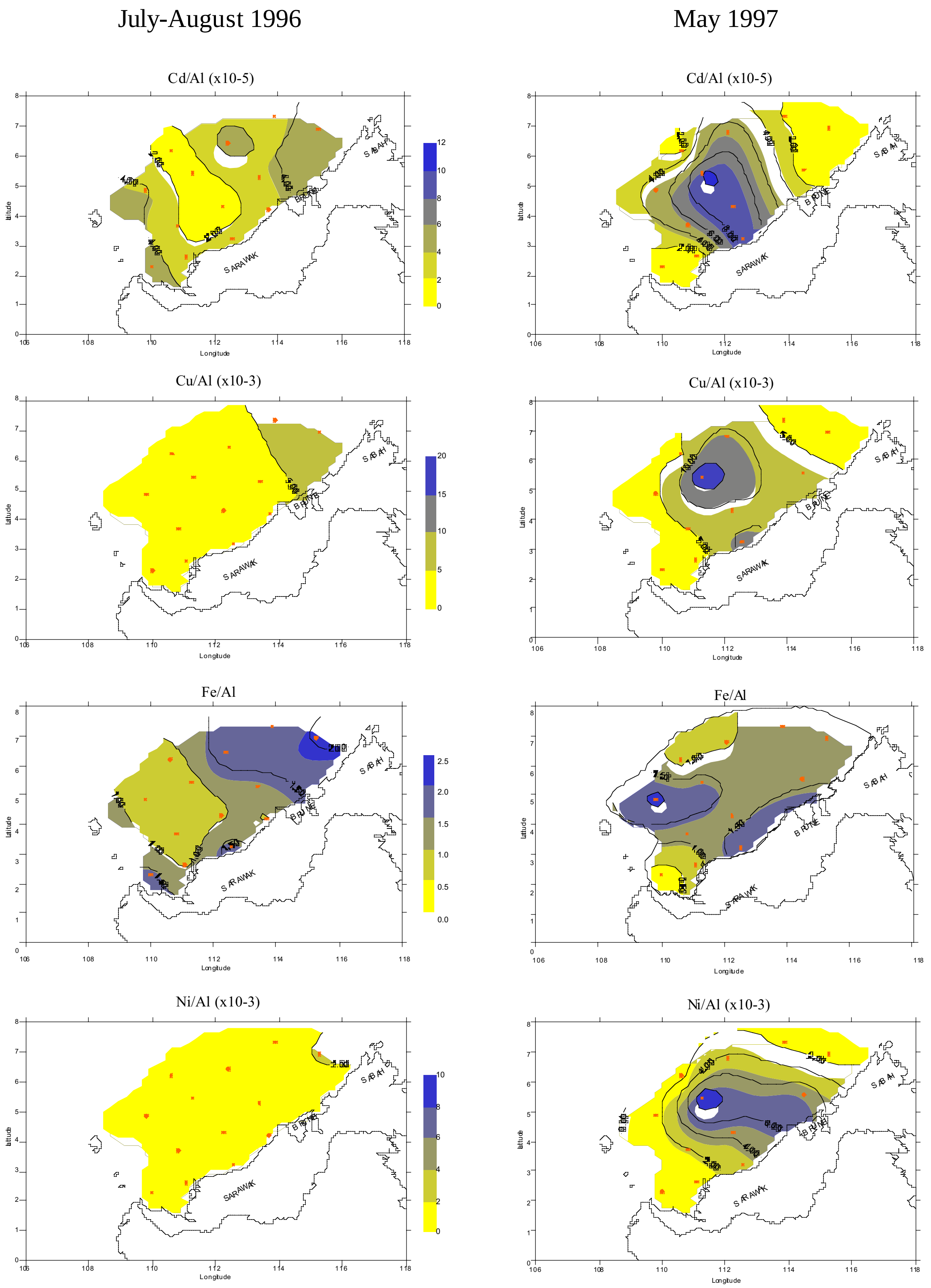


Fig. 9 Ratio of suspended Cd/Al, Cu/Al, Fe/Al and Ni/Al at surface layer

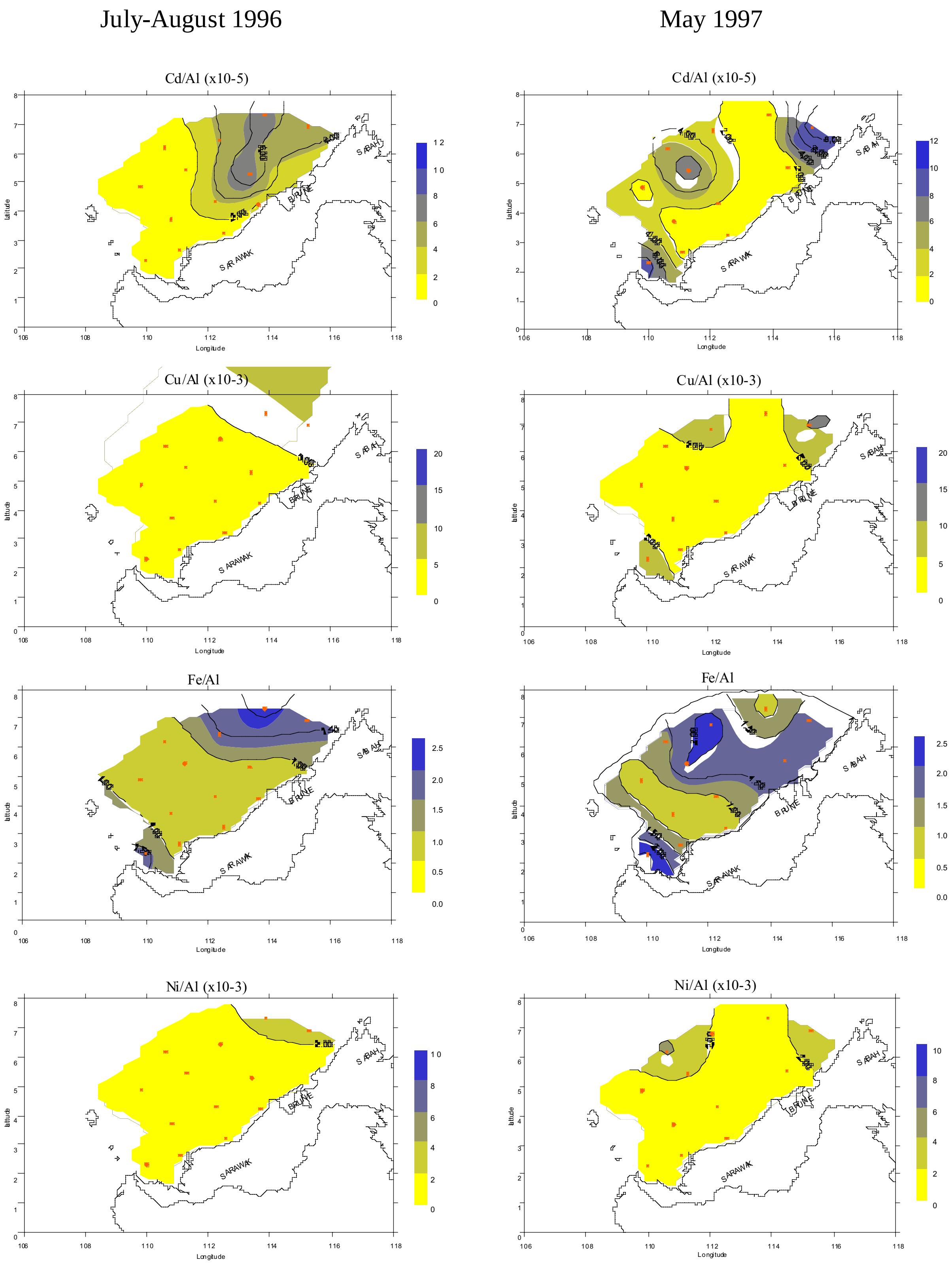


Fig. 10 Ratio of suspended Cd/Al, Cu/Al, Fe/Al and Ni/Al at bottom layer

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Reference

Boyle, E. A. and J. M. Edmond : Determination of Cu, Ni, and Cd in sea water by APDC chelate coprecipitation and flameless atomic absorption spectrophotometry. *Anal.Chim.Acta,* 91, 189-197 (1977).

Chester, R. and J.H. Stoner: The Distribution of Zinc, Nickel, Manganese, Cadmium, Copper and Iron in Some Surface Water from the World Ocean*., Marine Chemistry* 2, 17-32 (1974).

Drever, J.I.: The Geochemistry of Natural Waters. Prentice-Hall., Englewood Cliffs, N.J, 1982

Flegal, A.R., G.L. Smith, G.A. Gill, S. Sanudo-Wilhelmy and L.C.D. Anderson, 1991, Dissolved trace element cycles in the San Francisco Bay estuary, *Marine Chemistry* 36, 329.

Huizenga, D. L.: The cobalt-APDC coprecipitation technique for the preconcentration of trace metal samples. Graduate School of Oceanography, University of Rhode Island. Technical report 81-3, 1981, 93p.

Hungspreugs, M. and W. Utoomprurkporn: Distribution of some trace metals in the Gulf of Thailand. In House Seminar on SEAFDEC Interdepartment Collaborative Research Project. 18-19 February 1997.

Hungspreugs, M., W. Utoomprurkporn., A. Snidvongs, and S. Rattanachongkiat : A Comparative Study of Trace Metal Contamination in the Mekong Delta and the Chao Phraya Estuary . Proceedings of the International Workshop on the Mekong Delta, Feb 23-27, 1998, Chiang Rai, Thailand. pp.150-168.

Loring, D. H. and R.T.T.Rantala : Sediments and suspended particulate matter : Total and partial methods of digestion. International Council for the Exploration of the Sea. Techniques in Marine Environmental Sciences No.9. Copenhagen, Denmark, 1990, 14p.

Martin, J-M. and H. L. Windom : Present and future roles of ocean margins in regulating marine biogeochemical cycles of trace elements, in " Ocean Margin Processes in Global Change" (ed. By R.F.C. Mantoura, J.-M. Martin and R. Wollast) John Wiley, 1991, pp. 45-67.

Rattanachongkiat, S. : Distribution of trace metals in the Gulf of Thailand and east coast of Malay Peninsula. Master thesis, Department of Marine Science, Chulalongkorn University. 1998, 92p.

Snidvongs, A., S. Siriraksophon, and P. Rojana-anawat : Profiles of Oceanographic Data in the South China Sea Area 2: off Sabah, Sarawak and Brunei Darussalam during Post Monsoon Period. TD/RES/42, . Southeast Asian Fisheries Development Center., 1997, 179p.

Soegiarto, A.: The Oceanographic Features of the Southeast Asian Waters, in "Southeast Asian Seas, Frontiers for Development" (ed. by C. L. Sien and C. MacAndrews), McGraw-Hill, 1981, pp. 20 -47.

Utoomprurkporn, W., M. Hungspreugs, S. Rattanachongkiat, and A. Snidvongs : Biogeochemical Implications of Dissolved Trace Metal Concentration and Distribution in the South China Sea. Area I : the Gulf of Thailand and East Coast of Peninsular Malaysia. Seminar on Interdepartmental Collaborative Research Project, Bangkok, Thailand. 1998.

Yeats, P. A and D. H.Loring : Dissolved and Particulate Metal Distributions in the St.Lawrence Estaury. *Canadian Journal of Earth Sciences* 28, 729-742 (1991).

Appendix 1 Dissolved Cd, Cu, fe, Ni and Pd off Sabah, Sarawak and Brunei Darussalam in July-August, 1996

station	Cd (nM)	Cu(nM)	Fe(nM)	Ni(nM)	Pb(nM)
3-1-0 (9)	0.091	10.701	1188.391	7.109	0.545
3-1-35 (2)	0.107	19.652	2404.937	8.666	-2.43
3-7-0 (8)	0.039	7.254	1280.938	7.574	0.147
3-7-29 (2)	0.031	5.218	575.869	1.301	0.354
3-12-0 (11)	0.028	5.015	688.045	2.062	0.279
3-12-117 (1)	0.292	5.645	767.624	3.147	0.299
3-15-0 (9)	0.028	4.985	613.665	2.458	0.17
3-15-63 (2)	0.094	6.853	750.814	3.23	0.306
3-34-0 (10)	0.035	4.995	1254.694	4.259	0.418
3-34-59 (3)	0.074	5.196	2183.484	2.73	0.114
3-37-0 (10)	0.004	3.865	752.469	1.81	0.018
3-37-378 (2)	0.721	6.953	1041.81	7.201	0.305
3-39-0 (12)	1.001	26.032	1396.125	7.321	0.114
3-39-20 (11)	0.027	5.045	2600.907	3.563	0.29
3-39-55 (9)	0.033	4.26	1339.085	2.423	0.241
3-39-100 (7)	0.086	4.038	621.875	1.79	0.053
3-39-150 (6)	0.237	4.115	356.572	5.457	0.281
3-39-200 (5)	0.46	4.835	379.155	4.141	0.336
3-39-300 (4)	0.772	4.734	586.459	4.311	0.298
3-39-500 (3)	0.975	4.924	-4695.32	8.351	0.232
3-39-800 (2)	0.777	10.208	1649.295	5.936	0.139
3-39-1100 (1)	1.212	6.171	1287.949	7.427	0.337
3-47-0 (7)	0.033	5.5	121.423	3.877	0.209
3-47-27 (5)	0.054	4.593	1672.109	2.558	0.145
3-55-0 (10)	0.026	4.309	1260.586	5.73	0.304
3-55-1200 (1)	1.367	5.955	644.115	5.869	0.23
3-58-0 (11)	0.038	7.238	197.499	3.12	0.211
3-58-1500 (1)	1.088	5.968	895.172	3.882	-2.233
3-69-0 (11)	0.011	3.726	47.061	3.031	0.11
3-69-40 (8)	0.009	4.431	1674.015	3.846	0.379
3-69-60 (6)	0.028	5.134	335.452	3.28	0.236
3-69-70 (3)	0.061	3.813	668.46	3.4	0.227
3-73-0 (11)	1.324	6.425	458.23	4.859	0.124
3-73-60 (9)	0.022	5.912	598.235	3.02	0.317
3-73-200 (6)	0.5	5.257	1032.249	3.844	0.111
3-73-1000 (3)	1.209	5.563	265.302	3.961	0.206
3-73-1800 (1)	1.128	7.683	262.159	4.562	0.141
3-78-0 (11)	0.021	7.039	2263.187	4.29	0.338
3-78-1500 (1)	1.363	-95.391	565.048	13.433	0.534

Appendix 2 Susdended Cd, Cu, Fe, Ni and Pd off Sabah, Sarawak and Brunei Darussalam in July-August, 1996

Station	Cd (nM)	Cu(nM)	Fe(nM)	Ni(nM)
3-1-0 (9)	0.016	1.374	994.431	0.659
3-1-35 (2)	0.008	1.31	1453.512	0.873
3-7-0 (8)	0.011	1.436	927.083	0.769
3-7-29 (2)	0.006	1.372	1850.731	0.551
3-12-0 (11)	0.011	1.04	452.927	0.546
3-15-0 (9)	0.007	0.923	396.809	0.564
3-15-63 (2)	0.012	1.011	1082.486	0.784
3-31-0 (7)	0.009	1.285	1068.124	0.659
3-31-20 (1)	0.009	1.58	1511.703	0.561
3-34-10 (10)	0.002	0.916	468.756	0.505
3-34-59 (3)	0.013	-2.764	562.17	0.903
3-37-20 (10)	0.003	0.983	479.761	0.387
3-37-378 (2)	0.002	1.008	417.632	0.438
3-39-0 (12)	0.004	1.667	638.273	0.281
3-39-20 (11)	0.004	1.26	541.022	0.607
3-39-55 (9)	0.002	0.981	474.414	0.493
3-39-100 (7)	0.002	0.989	465.064	0.443
3-39-150 (6)	0.004	-2.478	449.122	0.172
3-39-200 (5)	0.001	1.031	376.542	0.329
3-39-300 (4)	0.009	1.045	269.617	0.442
3-39-500 (3)	0.002	0.956	329.748	0.387
3-39-800 (2)	0.007	1.199	279.776	0.39
3-39-1100 (1)	0	1.07	255.535	0.44
3-47-10 (7)	0	1.103	329.88	0.453
3-47-27 (5)	0.019	1.225	1533.086	0.564
3-55-20 (10)	0.008	0.999	553.294	0.284
3-55-1200 (1)	0.007	1.368	522.181	0.231
3-58-20 (11)	0.018	0.999	430.729	0.448
3-58-1500 (1)	0.02	1.076	397.652	0.344
3-69-40 (8)	0.004	1.068	1482.634	0.439
3-69-60 (6)	0.006	1.129	436.216	0.386
3-69-70 (3)	0.007	1.4	421.303	0.442
3-73-20 (11)	0.003	1.315	425.765	0.381
3-73-60 (9)	0.008	1.604	362.154	0.539
3-73-200 (6)	0.009	1.88	410.106	0.444
3-73-1000 (3)	0.001	1.783	397.4	0.7
3-73-1800 (1)	0.008	1.354	540.191	0.65
3-78-20 (11)	0.005	1.373	383.358	0.645
3-78-1500 (1)	-0.029	1.615	360.3	0.49

Appendix 3 Dissolved Cd, Cu, fe, Ni and Pd off Sabah, Sarawak and Brunei Darussalam in April-May 1997

station	Cd (nM)	Cu(nM)	Fe(nM)	Ni(nM)	Pb (nM)
4-1-0 (10)	0.061	12.007	491.457	5.494	0.209
4-1-33 (2)	0.288	6.389	898.387	4.767	0.17
4-7-0 (10)	0.083	9.841	200.246	5.345	0.214
4-7-33 (2)	0.036	5.794	497.647	3.133	0.049
4-12-0 (11)	0.058	6.176	1976.581	12.053	0.073
4-12-110 (1)	0.136	4.717	592.347	5.141	0.143
4-15-0 (12)	0.021	12.3	259.204	4.511	0.201
4-15-64 (1)	0.045	4.185	829.223	4.335	0.074
4-31-0 (10)	0.026	15.258	838.521	5.285	0.086
4-31-5 (8)	0.034	9.402	1462.957	4.715	0.083
4-31-10 (6)	0.027	14.996	468.835	3.573	0.329
4-31-15 (4)	0.042	6.976	498.913	4.966	0.185
4-31-19 (2)	0.042	6.235	557.978	3.975	0.175
4-34-0 (11)	0.069	27.138	2019.895	11.333	0.368
4-34-71 (1)	0.054	6.499	618.022	4.046	0.133
4-37-0 (12)	0.019	7.808	257.797	3.976	0.077
4-37-409 (1)	0.507	4.192	461.363	7.411	0.166
4-39-0 (12)	0.005	5.756	285.435	3.252	0.315
4-39-20 (11)	0.01	3.35	902.906	3.246	0.195
4-39-40 (10)	0.004	3.412	133.272	3.378	0.041
4-39-60 (9)	0.018	4.739	345.985	5.295	0.127
4-39-80 (8)	0.057	5.134	988.45	4.14	0.018
4-39-100 (7)	0.173	3.318	426.134	4.401	0.106
4-39-150 (6)	0.318	3.953	229.918	4.241	0.143
4-39-200 (5)	0.242	2.985	203.984	5.048	0.127
4-39-300 (4)	0.427	3.626	244.406	6.186	0.073
4-39-500 (3)	0.65	3.658	548.091	6.426	0.097
4-39-700 (2)	0.87	4.599	187.785	8.976	0.108
4-39-1100 (1)	1.034	6.854	530.092	13.029	0.166
4-54-10 (12)	0.028	6.128	445.514	4.209	0.205
4-54-1200 (1)	1.305	8.256	796.723	14.051	0.291
4-69-0 (10)	0.008	12.429	-4586.583	4.266	0.159
4-69-10 (9)	0.021	5.924	269.893	4.03	0.145
4-69-20 (8)	0.02	-138.782	280.78	5.025	0.184
4-69-30 (7)	0.02	12.833	237.068	11.57	0.049
4-69-40 (6)	0.07	6.918	335.902	8.851	0.128
4-69-50 (5)	0.017	5.009	596.171	6.758	0.239
4-69-60 (4)	0.011	4.161	223.567	6.685	0.139
4-69-70 (3)	0.036	5.132	1574.152	12.441	0.318
4-69-80 (2)	0.071	3.915	430.394	5.329	-1.51
4-69-90 (1)	0.095	3.859	233.129	3.826	0.07
4-73-0 (12)	0.001	3.755	124.703	4.664	0.049
4-73-30 (11)	0.011	4.67	185.572	3.058	0.137
4-73-50 (10)	0.005	3.959	162.546	3.711	0.148
4-73-100 (8)	0.235	8.853	725.797	3.963	0.607
4-73-200 (6)	0.319	2.951	329.657	4.297	0.209
4-73-1000 (3)	1.09	6.947	642.186	8.417	0.258
4-73-1750 (1)	1.187	20.546	423.275	8.222	0.315
4-78-0 (12)	0.02	6.874	92.482	3.802	0.123
4-78-1450 (1)	1.033	5.658	372.035	8.76	0.11

Appendix 4 Susdended Cd, Cu, Fe, Ni and Pd off Sabah, Sarawak and Brunei Darussalam in April - May 1997

station	Cd (nM)	Cu(nM)	Fe(nM)	Ni(nM)
4-1-0 (10)	0.01	2.314	529.441	0.496
4-1-33 (2)	0.011	1.839	636.189	0.28
4-7-0 (10)	0.002	1.785	711.886	0.605
4-7-33 (2)	0.008	1.691	1909.43	0.656
4-12-10 (11)	0.008	1.162	705.246	0.441
4-12-110 (1)	0.006	1.482	677.866	0.44
4-15-0 (12)	0.009	1.453	372.094	0.548
4-15-64 (1)	0.005	1.139	522.492	0.444
4-31-0 (10)	0.007	1.569	298.554	0.44
4-31-5 (8)	0.006	2.119	240.938	0.499
4-31-10 (6)	0.006	1.78	562.816	0.226
4-31-15 (4)	0.013	1.992	1911.354	0.551
4-31-19 (2)	0.014	-4.065	-2555.565	0.762
4-34-0 (11)	0.009	1.312	243.958	0.766
4-34-71 (1)	0.011	1.333	1084.62	0.761
4-37-0 (12)	0.004	1.278	131.065	0.71
4-37-409 (1)	0.003	0.927	157.105	0.71
4-39-0 (12)	0.001	0.981	199.391	0.225
4-39-20 (11)	0.001	1.101	1776.062	0.279
4-39-40 (10)	0.001	0.98	109.03	0.439
4-39-60 (9)	0	1.104	135.673	0.226
4-39-80 (8)	0.004	1.274	229.472	0.225
4-39-100 (7)	0	1.194	512.139	0.173
4-39-150 (6)	0.001	1.211	216.705	0.23
4-39-200 (5)	-	1.126	392.336	0.171
4-39-300 (4)	-	1.126	164.832	0.332
4-39-500 (3)	-	1.069	130.636	0.171
4-39-700 (2)	-	1.076	339.119	0.496
4-39-1100 (1)	-	1.133	70.784	0.226
4-54-10 (12)	0.004	1.097	98.791	0.451
4-54-1200 (1)	0.002	1.009	364.186	0.287
4-69-0 (10)	-	1.104	191.843	0.172
4-69-10 (9)	0.004	0.992	360.043	0.498
4-69-20 (8)	0.002	0.837	255.61	0.387
4-69-30 (7)	0.002	0.781	565.898	0.28
4-69-40 (6)	0.003	1.13	368.608	0.279
4-69-50 (5)	0.004	0.779	330.004	0.28
4-69-60 (4)	0.002	0.836	270.899	0.44
4-69-70 (3)	0.001	0.811	444.579	0.334
4-69-80 (2)	0.004	0.72	345.607	0.28
4-69-90 (1)	0.001	0.724	637.729	0.281
4-73-10 (12)	0.003	0.757	400.215	0.337
4-73-30 (11)	0.006	0.839	361.999	0.334
4-73-50 (10)	0.006	1.518	401.53	0.496
4-73-100 (8)	0.003	0.785	403.279	0.444
4-73-200 (6)	0.003	0.785	336.824	0.282
4-73-1000 (3)	0.004	0.812	320.041	0.227
4-73-1750 (1)	0.001	0.798	390.283	0.231
4-78-0 (12)	0.002	0.765	396.583	0.23
4-78-1450 (1)	0.006	1.094	221.148	0.449