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The contents and distribution of copper, zinc, cadmium and lead in sea water from Kagoshima Bay, in comparison with East China Sea

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Abstract

Sea water samples collected from Kagoshima Bay and the open ocean (the East China Sea) were analyzed for copper, zinc, cadmium and lead through dithizone-chloroform extraction followed by atomic absorption spectrometry.

Levels of copper, zinc, cadmium and lead contents including each class of depth were found to be in the range of 0.02~5.33 $\mu g/l$ (geometric mean 0.42), 0.2~69.9 $\mu g/l$ (geometric mean 2.18), 0.005~0.094 $\mu g/l$ (geometric mean 0.021) and 0.06~1.89 $\mu g/l$ (geometric mean 0.24) for 219 samples taken from Kagoshima Bay and 0.11~10.9 $\mu g/l$ (geometric mean 0.63), 0.17~26.9 $\mu g/l$ (geometric mean 3.99), 0.005~0.71 $\mu g/l$ (geometric mean 0.018) and 0.07~2.16 $\mu g/l$ (geometric mean 0.41) for 33 samples taken from the East China Sea, respectively.

In comparison of the mean levels for copper, zinc, cadmium and lead contents including each class of depth from Kagoshima Bay and the East China Sea, the cadmium level was the same. Mean levels of copper, zinc and lead contents for Kagoshima Bay were slightly lower than those for the East China Sea. This suggests that copper, zinc and lead have deposited in the sediments of Kagoshima Bay.

Key words: Heavy metals (Cu, Zn, Cd, Pb) contents, Sea water, Distribution

Introduction

Kagoshima Bay was said to be one of the few bays which was close to the natural condition, i.e. unpolluted or low pollution.

Mercury-polluted fish[1)] was found at the Northern Kagoshima Bay in November, 1973. Water quality[2)-4)], fish[5), 6)], shellfish[7)] fumarolic gases[8)] and sediments[9), 10)] from Kagoshima Bay were checked in detail by the university and research organization of Kagoshima Prefecture. A survey for submarine fumaroles in Kagoshima Bay by the Environmental Agency of the

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Government and Kagoshima Prefecture were carried out with a submarine boat in 1977 to investigate its contribution to the total mercury load in the area[5]. However, the mechanism for the concentration of mercury in fish has not yet been clear.

Copper, cadmium, lead and mercury are known as toxic metals. For many years, we have studied the trace heavy metals (Cu, Zn, Cd, Pb, Hg) in river waters[11), 12)], sea waters[13)–16)], marine sediments[17)–19)], biological samples[20), 21)] and hot spring waters[22)]. In general, the contents of those heavy metals are very small, on a ppb or sub ppb level and it is very difficult to get precise and reliable data based on them. It is, therefore, necessary to check the reliability of the analytical procedure employed using an interlaboratory comparison program. We have had a chance to participate in an interlaboratory comparison project using reference standard materials organized among twenty members[16, 17)].

This paper discusses the contents and distribution of acid soluble copper, zinc, cadmium and lead, their mutual relations and distributions based on the analytical results of sea waters from Kagoshima Bay and the East China Sea.

Experimental

Apparatus.

Atomic Absorption Spectrometer Equipment: The Shimadzu Atomic Absorption Spectrophoptometer was used.

Shaker Equipment: The Takabayashi Shaker was used.

Reagents.

All reagents used were of analytical-reagent grade.

Purified water was prepared using a water sealed hard glass distillation system.

Distilled chloroform was used.

Collection and Preservation of Samples.

Surface sea water were collected using a plastic vessel while deep sea water samples were collected by use of the Bandon Sampler (made from polypropylene) hanging on a stainless steel wire from Kagoshima Bay and East China Sea and from May, 1975 to October, 1982.

The sampling stations are shown in Figs. 1~3.

The collected sea water samples were preserved in a polyethylene bottles, which were excluded beforehand with approximately 2 mo*l*/*l* nitric acid for two weeks and then washed thoroughly with water. A 10 m*l* of concentrated nitric acid was added to 1 liter of sample after sampling. The samples were transported and analyzed in the laboratory.

All samples were analyzed without further filtration because based from a past experience, that filtered samples yielded lower results for copper. Regarding cadmium, however, we had no definite information as to any differences between filtered and unfiltered samples.

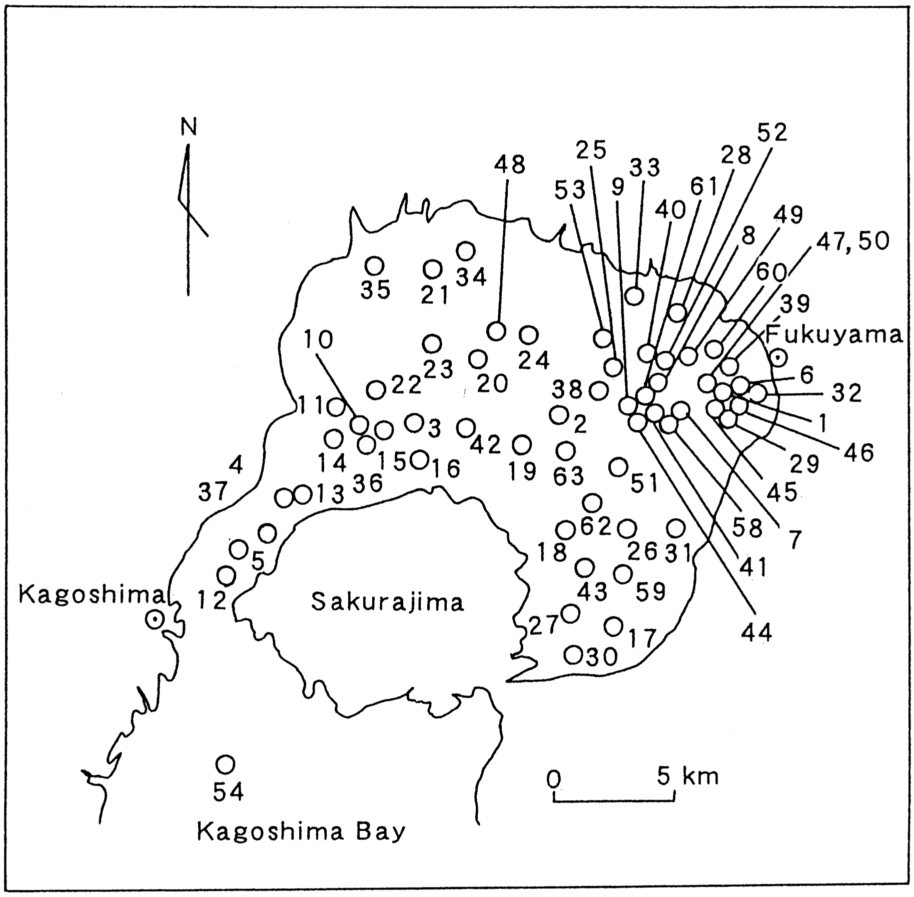

Fig. 1. Map of sampling stations for Kagoshima Bay sea water.

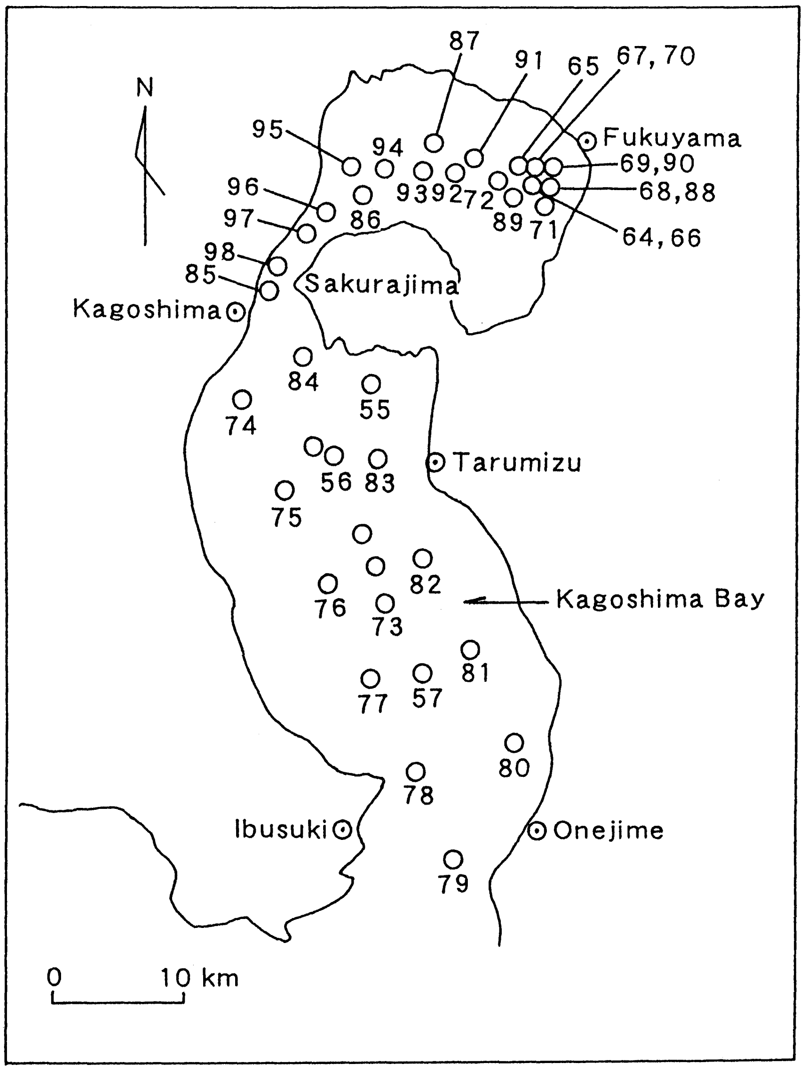

Fig. 2. Map of sampling stations for Kagoshima Bay sea water.

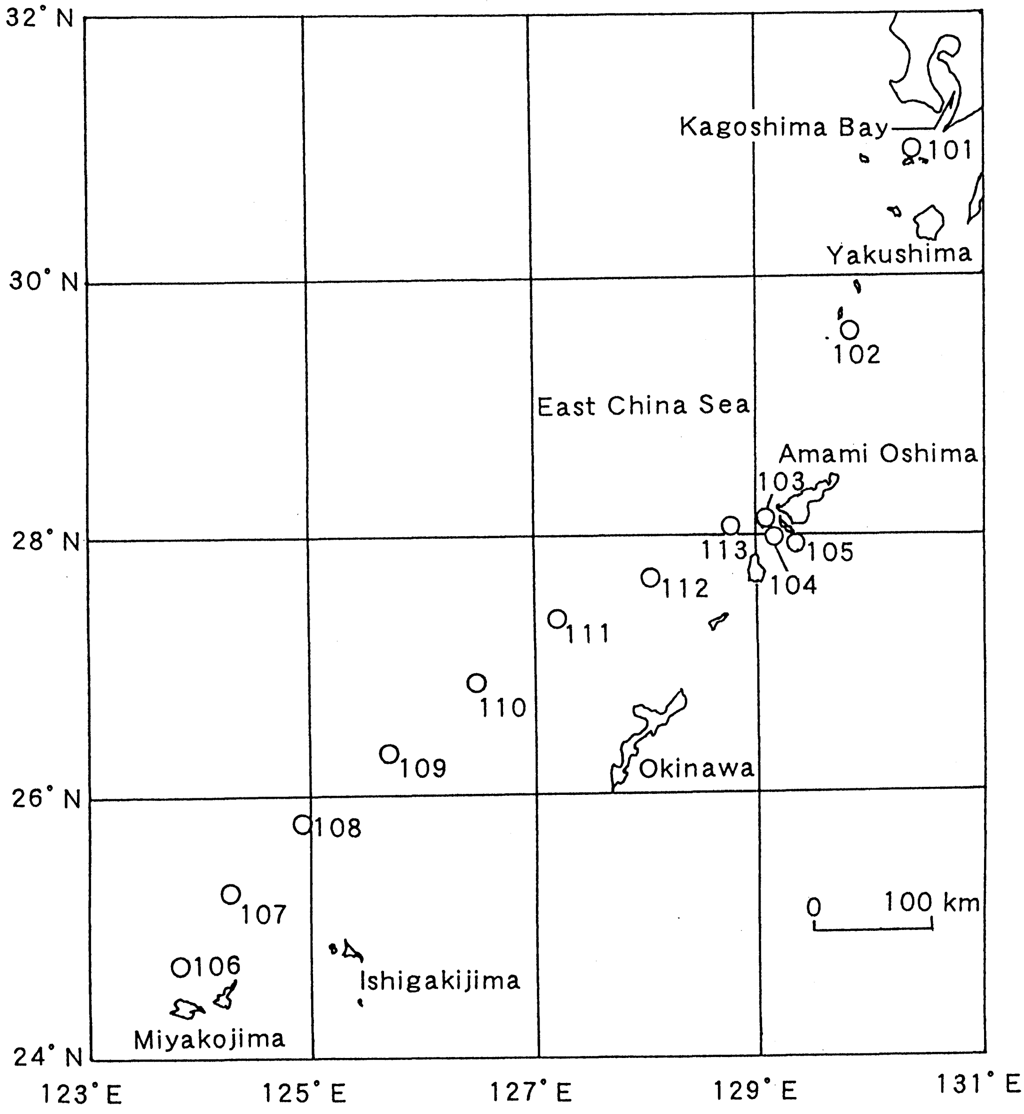

Fig. 3. Map of Sampling stations for East China Sea.

Analytical Procedure for Copper, Zinc, Cadmium and Lead in Sea Water.

The content of heavy metals in sea water are usually very low; as little as ppb levels. Thus, it is very difficult to obtain the precise and reliable results by direct method without preconcentration. Sea water samples were preconcentrated and analyzed by following the procedure previously published by the authors[18]. The schematic diagrams of the method are shown in Fig. 4 and Fig. 5. A 200 m*l* of sea water sample was used for copper and zinc analyses while a 1,500 m*l* was used for cadmium and lead determination.

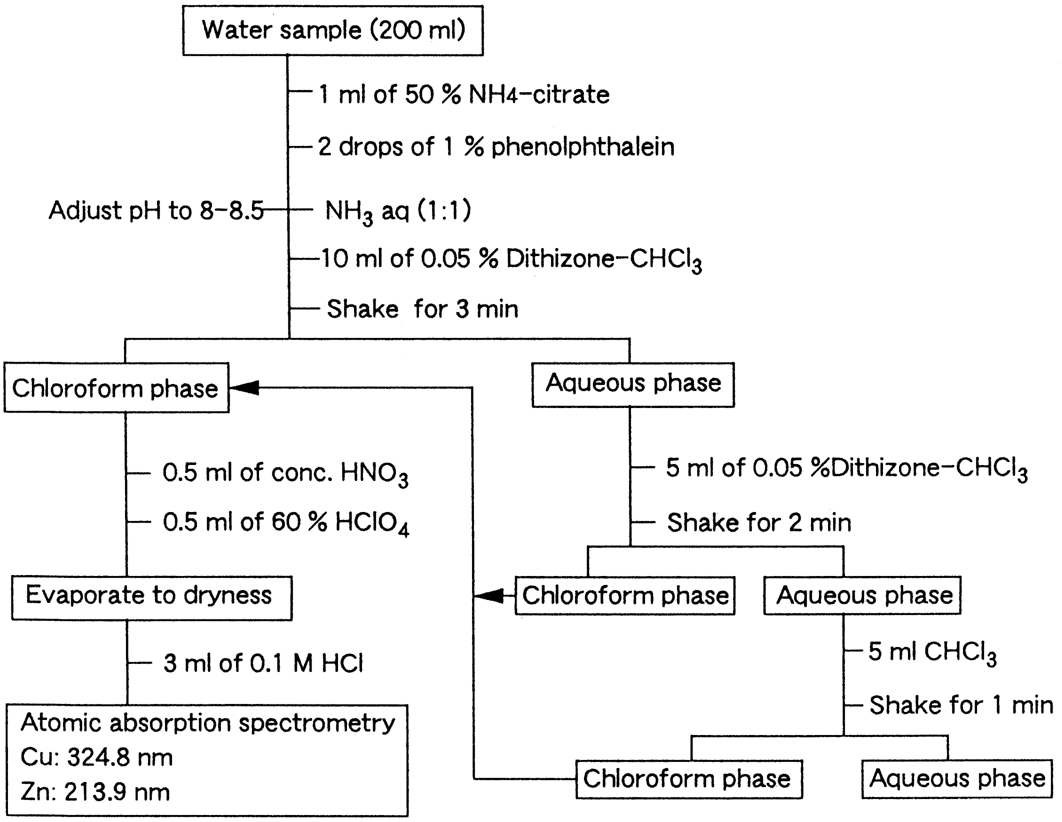

Fig. 4. Analytical procedures for copper and zinc determination in sea water samples.

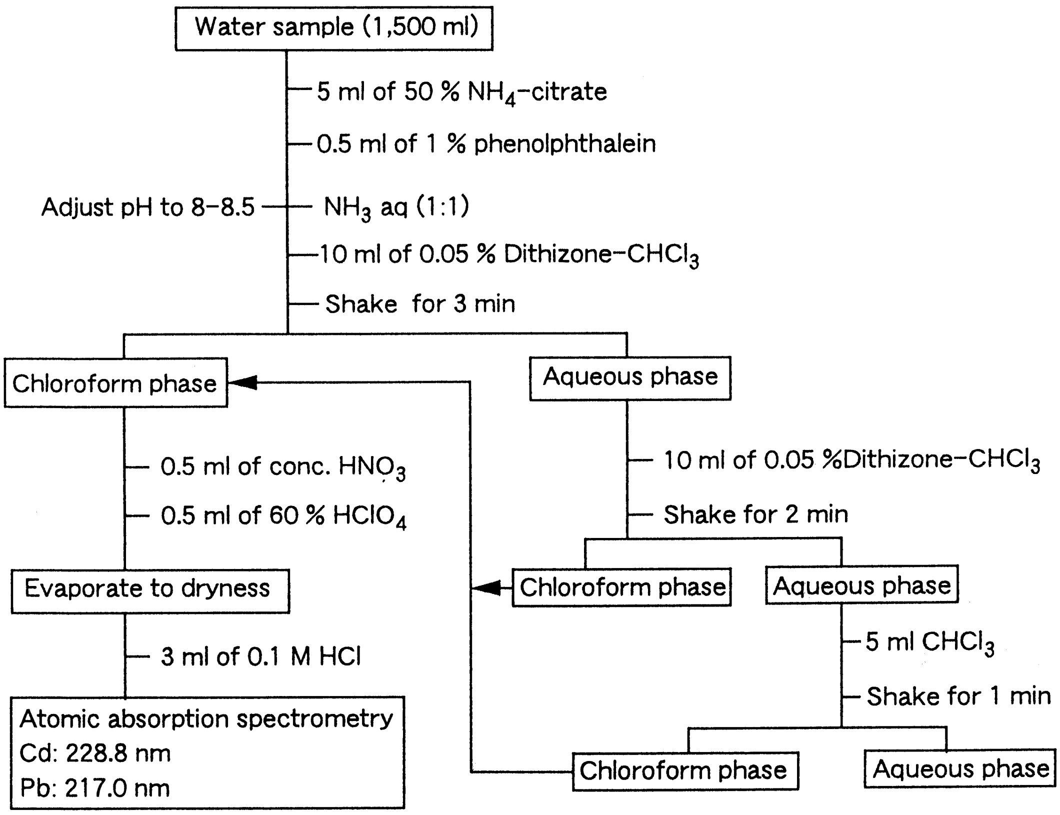

Fig. 5. Analytical procedures for cadmium and lead determination in sea water samples.

Results and Discussion

Contents of Copper, Zinc, Cadmium and Lead in Sea Water of Kagoshima Bay and the Open Sea Water (East China Sea).

The contents of copper, zinc, cadmium and lead in sea water samples taken from Kagoshima Bay and the East China Sea were analyzed. The samples were collected during the period 1975～1982. Sampling stations of Kagoshima Bay and the open sea (East China Sea) are shown in Figs. 1～3. The results for copper, zinc, cadmium and lead from the analytical procedures presented in Fig. 4 and Fig. 5) are shown in Tables 1～2.

The copper, zinc, cadmium and lead contents of Kagoshima Bay and the East China Sea are summarized in Table 3.

The ranges of copper, zinc, cadmium and lead contents for 97 surface water samples taken from Kagoshima Bay are 0.02～0.83 $\mu g/l$, 0.2～12.5 $\mu g/l$, 0.005～0.090 $\mu g/l$ and 0.06～0.86 $\mu g/l$, respectively. The arithmetic mean and geometric mean are 0.38, 1.08, 0.021, 0.26 $\mu g/l$ and 0.35, 0.77, 0.019, 0.23 $\mu g/l$, respectively.

The ranges of copper, zinc, cadmium and lead contents for 13 surface water samples taken from East China Sea are 0.11～10.9 $\mu g/l$, 0.17～2.3 $\mu g/l$, 0.005～0.027 $\mu g/l$ and 0.07～0.56 $\mu g/l$, respectively. The arithmetic mean and geometric mean are 1.16, 1.08, 0.011, 0.31 $\mu g/l$ and 0.38, 0.90, 0.010, 0.27 $\mu g/l$, respectively.

Levels of copper, zinc, cadmium and lead including each class of depth were found to be in the range of 0.02～5.33 $\mu g/l$ (geometric mean 0.42), 0.2～69.9 $\mu g/l$ (geometric mean 2.18), 0.005～0.094 $\mu g/l$ (geometric mean 0.021) and 0.06～1.89 $\mu g/l$ (geometric mean 0.24) for 219 samples taken from Kagoshima Bay and 0.11～10.9 $\mu g/l$ (geometric mean 0.63), 0.17～26.9 $\mu g/l$ (geometric mean 3.99), 0.005～0.71 $\mu g/l$ (geometric mean 0.018) and 0.07～2.16 $\mu g/l$ (geometric mean 0.41) for 33 samples taken from the East China Sea, respectively.

Vertical Distribution of Copper, Zinc, Cadmium and Lead in Sea Water of Kagoshima Bay.

Fig. 6 shows the vertical distribution of copper, Zinc, cadmium and lead contained in sea waters from Stn. 72, 73 and 89 of Kagoshima Bay. The vertical profiles of copper, Zinc, Cdmium and lead contents have increased appreciably in the depth and its contents are in similar trends.

Data from Tables 1 and 2 show that the copper, zinc, cadmium and lead content in all sea areas follow the same trend according to decreasing order of Zn > Cu > Pb > Cd. Although there are variations in some sampling sites within an area, majority of the sites have zinc content as the highest, and cadmium the least amount.

Table 1. Contents of copper, zinc, cadmium and lead in sea water of Kagoshima Bay

Sample	Stn. No.	Date	Depth (m)	W. T. (°C)	pH	Cu μg/l	Zn μg/l	Cd μg/l	Pb μg/l
K_1-1	1	May 7. '75	0	18.0	8.0	0.29	3.9	0.019	0.40
2	2	May 7. '75	0	18.0	8.0	0.19	0.7	0.017	0.32
3	3	May 7. '75	0	18.2	7.9	0.19	0.8	0.017	0.32
4	4	May 7. '75	0	18.2	8.0	0.22	0.8	0.013	0.28
5	5	May 7. '75	0	18.1	8.0	0.16	0.3	0.017	0.20
K_2-1	6	Jul. 31. '75	0	25.7	8.0	0.37	1.4	0.017	0.45
2	7	Jul. 31. '75	0	25.9	8.0	0.37	1.8	0.035	0.50
3	8	Jul. 31. '75	0	26.5	8.0	0.21	1.1	0.020	0.52
4	9	Jul. 31. '75	0	26.5	8.0	0.21	1.8	0.020	0.38
5	9	Jul. 31. '75	10	–	8.0	2.44	10.7	0.068	0.63
6	9	Jul. 31. '75	50	–	7.7	2.16	7.4	0.017	0.49
7	9	Jul. 31. '75	100	–	–	2.00	7.8	0.017	0.40
8	9	Jul. 31. '75	200	–	7.4	1.07	7.0	0.015	0.46
9	10	Jul. 31. '75	0	27.8	8.0	0.26	0.6	0.030	0.33
10	11	Jul. 31. '75	0	27.9	8.1	0.24	0.4	0.027	0.38
11	11	Jul. 31. '75	100	–	7.8	0.72	7.7	0.017	0.55
K_3-1	12	Nov. 10. '75	0	22.7	8.1	0.38	0.6	0.025	0.36
2	13	Nov. 10. '75	0	22.8	8.1	0.38	0.6	0.023	0.28
3	14	Nov. 10. '75	0	23.0	8.1	0.35	0.4	0.023	0.28
4	15	Nov. 10. '75	0	23.1	8.1	0.35	0.4	0.019	0.31
5	16	Nov. 10. '75	0	22.8	8.1	0.27	0.8	0.017	0.28
6	17	Nov. 10. '75	0	23.3	8.1	0.27	0.3	0.020	0.27
7	18	Nov. 10. '75	0	23.0	8.1	0.27	0.3	0.019	0.27
8	19	Nov. 10. '75	0	23.1	8.1	0.38	0.3	0.017	0.28
9	20	Nov. 10. '75	0	23.0	8.1	0.27	0.3	0.016	0.28
10	21	Nov. 10. '75	0	22.9	8.1	0.27	0.3	0.016	0.25
K_4-1	22	Nov. 25. '75	0	20.6	8.0	0.63	1.4	0.016	0.27
2	23	Nov. 25. '75	0	20.5	8.0	0.83	2.0	0.017	0.35
3	24	Nov. 25. '75	0	19.7	8.0	0.75	2.3	0.016	0.40
4	25	Nov. 25. '75	0	20.9	8.0	0.63	0.8	0.019	0.24
5	26	Nov. 25. '75	0	20.8	8.1	0.53	1.0	0.017	0.40
6	27	Nov. 25. '75	0	21.2	8.0	0.45	1.0	0.017	0.33
7	28	Nov. 25. '75	0	21.3	8.0	0.53	0.7	0.016	0.31
8	29	Nov. 25. '75	0	20.9	8.0	0.63	0.5	0.023	0.31
9	30	Nov. 26. '75	0	21.3	8.1	0.45	0.4	0.017	0.31
10	31	Nov. 26. '75	0	21.3	8.0	0.38	0.2	0.016	0.27
11	32	Nov. 26. '75	0	21.7	8.0	0.63	0.2	0.016	0.17
12	33	Nov. 26. '75	0	21.0	8.0	0.45	0.5	0.017	0.24
13	34	Nov. 26. '75	0	21.2	8.0	0.33	0.4	0.017	0.17
14	35	Nov. 26. '75	0	21.2	8.0	0.33	0.5	0.029	0.29
15	36	Nov. 26. '75	0	21.3	8.0	0.33	0.2	0.013	0.13
16	37	Nov. 26. '75	0	21.0	8.0	0.33	0.2	0.024	0.20
17	37	Nov. 26. '75	40	21.6	8.0	0.90	11.1	0.017	0.33
18	37	Nov. 26. '75	70	18.6	7.8	0.90	5.7	0.029	0.20

Table 1. (Continued)

Sample	Stn. No.	Date	Depth (m)	W. T. (°C)	pH	Cu μg/l	Zn μg/l	Cd μg/l	Pb μg/l
K_4-19	38	Nov. 26. '75	0	21.5	8.0	0.75	0.8	0.016	0.29
20	38	Nov. 26. '75	100	16.9	6.8	0.63	5.4	0.035	0.35
21	38	Nov. 26. '75	200	16.2	6.6	0.83	6.9	0.025	0.27
22	39	Nov. 27. '75	0	21.3	8.1	0.45	1.7	0.057	0.24
23	39	Nov. 27. '75	50	21.5	8.0	0.32	1.6	0.016	0.20
24	39	Nov. 27. '75	120	16.6	7.7	0.32	1.5	0.023	0.20
25	40	Nov. 27. '75	0	21.5	8.0	0.68	1.5	0.017	0.27
26	40	Nov. 27. '75	50	21.5	8.0	0.41	2.3	0.021	0.17
27	40	Nov. 27. '75	100	17.2	6.4	0.33	5.5	0.017	0.13
28	41	Nov. 27. '75	0	21.4	8.0	0.23	0.7	0.013	0.13
29	41	Nov. 27. '75	100	16.9	7.6	0.30	1.8	0.017	0.13
30	41	Nov. 27. '75	150	16.5	7.2	0.30	2.2	0.023	0.13
31	41	Nov. 27. '75	200	16.3	6.6	0.23	2.5	0.040	0.23
32	42	Nov. 28. '75	0	21.3	8.0	0.53	1.2	0.019	0.24
33	42	Nov. 28. '75	50	21.2	8.0	0.48	1.1	0.016	0.09
34	42	Nov. 28. '75	130	16.6	7.7	0.15	0.8	0.021	0.13
35	43	Nov. 28. '75	0	21.4	8.0	0.32	0.4	0.019	0.13
36	43	Nov. 28. '75	50	21.4	8.0	0.29	1.3	0.023	0.17
37	43	Nov. 28. '75	130	16.7	7.6	0.32	1.0	0.016	0.13
K_5-1	44	May 6. '76	0	19.0	8.3	0.45	0.58	0.050	0.46
-1	44	May 6. '76	50	16.9	8.0	0.38	0.88	0.016	0.20
-1	44	May 6. '76	100	16.6	7.9	0.33	1.75	0.016	0.30
-1	44	May 6. '76	200	16.5	7.3	0.38	4.00	0.016	0.20
-2	45	May 6. '76	0	20.0	8.3	0.38	0.88	0.090	0.86
-2	45	May 6. '76	10	19.0	8.3	0.38	1.08	0.094	0.86
-2	45	May 6. '76	50	16.4	8.0	0.33	0.75	0.022	0.46
-2	45	May 6. '76	70	16.4	7.9	0.38	1.50	0.016	0.24
K_6-1	46	Aug. 12. '76	0	28.8	8.0	0.42	1.95	0.037	0.27
-1	46	Aug. 12. '76	10	25.9	8.0	1.80	69.9	0.040	1.52
-1	46	Aug. 12. '76	50	20.1	7.8	0.90	32.6	0.024	1.09
-1	46	Aug. 12. '76	75	16.9	7.5	0.45	16.2	0.027	0.27
-2	47	Aug. 12. '76	0	28.5	8.1	0.42	1.20	0.017	0.20
-2	47	Aug. 12. '76	10	25.2	8.1	0.45	13.8	0.051	0.57
-2	47	Aug. 12. '76	50	20.3	7.9	0.35	9.23	0.017	0.20
-2	47	Aug. 12. '76	100	16.1	7.7	0.71	16.1	0.017	0.24
-2	47	Aug. 12. '76	195	15.7	7.0	2.19	69.8	0.073	1.89
-4	48	Aug. 12. '76	0	28.8	8.1	0.45	1.20	0.020	0.24
-4	48	Aug. 12. '76	10	24.8	8.0	0.60	6.30	0.053	0.67
-4	48	Aug. 12. '76	50	20.6	7.8	0.53	8.18	0.017	0.20
-4	48	Aug. 12. '76	100	16.5	7.7	0.45	13.2	0.032	0.27
-4	48	Aug. 12. '76	135	16.2	7.6	0.48	16.9	0.020	0.44
K_9-1	49	Sept. 29. '76	0	24.6	8.1	0.30	3.87	0.017	0.27
-1	49	Sept. 29. '76	50	21.3	7.9	0.30	2.75	0.027	0.24
-1	49	Sept. 29. '76	100	17.2	7.6	0.30	3.00	0.024	0.21

Table 1. (Continued)

Sample	Stn. No.	Date	Depth (m)	W. T. (°C)	pH	Cu μg/l	Zn μg/l	Cd μg/l	Pb μg/l
K_9-1	49	Sept. 29. '76	180	16.8	7.1	0.30	9.38	0.039	0.40
-2	50	Sept. 29. '76	0	24.0	8.2	0.42	1.88	0.032	0.21
-2	50	Sept. 29. '76	50	21.6	8.0	0.30	2.40	0.017	0.69
-2	50	Sept. 29. '76	100	16.9	7.6	0.30	2.33	0.017	0.85
-2	50	Sept. 29. '76	185	16.6	7.0	0.30	4.10	0.020	0.21
-3	51	Sept. 29. '76	0	25.0	8.2	0.30	1.20	0.036	0.35
-3	51	Sept. 29. '76	50	22.0	8.0	0.30	3.45	0.024	0.67
-3	51	Sept. 29. '76	70	18.4	7.8	0.45	3.00	0.027	0.37
-3	51	Sept. 29. '76	100	17.5	7.6	0.42	4.05	0.017	0.47
K_{11}-1	52	Oct. 12. '76	0	23.0	8.0	0.45	3.18	0.040	0.24
-1	52	Oct. 12. '76	70	19.9	7.8	0.45	4.73	0.013	0.20
-1	52	Oct. 12. '76	130	17.2	7.4	0.42	8.55	0.024	0.49
-2	53	Oct. 12. '76	0	23.0	8.0	0.42	2.58	0.027	0.56
-2	53	Oct. 12. '76	70	20.0	7.8	0.60	4.25	0.013	0.40
-2	53	Oct. 12. '76	100	17.2	7.5	0.53	4.88	0.017	0.72
-2	53	Oct. 12. '76	140	17.0	7.4	0.60	6.35	0.013	0.36
-3	54	Oct. 12. '76	0	25.0	8.1	0.30	2.55	0.013	0.16
-3	54	Oct. 12. '76	50	23.7	8.1	0.42	1.80	0.020	0.43
-3	54	Oct. 12. '76	100	17.8	7.9	0.42	2.10	0.024	0.29
-3	54	Oct. 12. '76	150	16.0	7.9	0.42	2.55	0.024	0.37
-3	54	Oct. 12. '76	215	16.0	7.9	0.53	4.47	0.017	0.40
K_{13}-D	55	Dec. 5. '76	0	19.0	8.3	0.38	0.78	0.017	0.17
-D	55	Dec. 5. '76	40	18.7	8.2	0.39	2.33	0.017	0.16
-D	55	Dec. 5. '76	80	17.9	8.1	0.42	3.75	0.027	0.17
-D	55	Dec. 5. '76	120	16.3	8.1	0.42	4.80	0.025	0.24
-D	55	Dec. 5. '76	160	15.5	8.0	0.45	7.35	0.040	0.27
-E	56	Dec. 5. '76	0	18.9	8.3	0.38	0.75	0.017	0.17
-E	56	Dec. 5. '76	120	16.5	8.1	0.30	3.23	0.017	0.17
-E	56	Dec. 5. '76	210	15.3	8.0	0.51	4.43	0.024	0.27
-G	57	Dec. 5. '76	0	18.8	8.2	0.27	1.08	0.013	0.16
-G	57	Dec. 5. '76	40	18.6	8.2	1.38	6.53	0.017	0.24
-G	57	Dec. 5. '76	100	17.6	8.1	0.48	2.55	0.013	0.24
-G	57	Dec. 5. '76	160	15.4	8.0	0.27	2.34	0.020	0.20
-G	57	Dec. 5. '76	180	15.4	8.0	0.69	5.10	0.051	0.24
-K	58	Dec. 6. '76	1	19.3	8.2	0.30	0.78	0.021	0.16
-K	58	Dec. 6. '76	148	16.3	7.2	1.47	12.9	0.017	0.16
-K	58	Dec. 6. '76	198	16.2	6.7	1.20	11.4	0.017	0.16
-X	59	Dec. 6. '76	1	19.2	8.1	0.54	1.35	0.013	0.16
-X	59	Dec. 6. '76	50	19.2	8.1	4.28	9.90	0.036	0.36
-X	59	Dec. 6. '76	80	18.6	8.0	2.82	9.98	0.020	0.47
-X	59	Dec. 6. '76	110	16.9	7.6	5.33	13.9	0.020	0.49
K_{17}-3	60	May 9. '77	0	19.8	8.3	0.45	0.63	0.019	0.23
-3	60	May 9. '77	50	15.6	8.0	0.54	4.25	0.020	0.21
-3	60	May 9. '77	165	14.7	7.5	0.42	8.63	0.019	0.21

Table 1. (Continued)

Sample	Stn. No.	Date		Depth (m)	W. T. (°C)	pH	Cu μg/l	Zn μg/l	Cd μg/l	Pb μg/l
K_{17}-4	61	May	9. '77	0	19.7	8.2	0.30	0.81	0.023	0.27
-4	61	May	9. '77	50	15.7	8.0	0.24	3.60	0.019	0.23
-4	61	May	9. '77	100	15.0	7.9	0.35	4.76	0.020	0.23
-4	61	May	9. '77	150	15.0	7.4	0.35	7.88	0.016	0.27
-4	61	May	9. '77	190	14.7	7.3	1.13	8.67	0.019	0.23
-5	62	May	9. '77	0	19.2	8.3	0.35	0.57	0.036	0.31
-5	62	May	9. '77	50	15.3	8.0	0.54	5.70	0.016	0.23
-5	62	May	9. '77	130	14.7	7.8	0.42	5.85	0.019	0.23
-6	63	May	9. '77	0	19.5	8.2	0.38	0.45	0.031	0.37
-6	63	May	9. '77	50	15.4	8.0	0.65	5.45	0.019	0.23
-6	63	May	9. '77	130	14.5	7.8	0.80	5.70	0.024	0.27
K_{18}-1	64	Aug.	17. '77	0	32.0	8.2	0.68	0.38	0.057	0.40
-1	64	Aug.	17. '77	50	22.0	8.0	0.27	5.55	0.031	0.43
-1	64	Aug.	17. '77	100	20.7	8.1	0.27	4.05	0.027	0.27
-1	64	Aug.	17. '77	150	16.7	7.4	0.26	4.88	0.015	0.13
-1	64	Aug.	17. '77	200	16.8	6.9	0.15	10.7	0.028	0.23
K_{19}-A-C	65	Nov.	18. '77	100	15.9	7.6	0.45	1.80	0.029	0.24
-A-C	65	Nov.	18. '77	200	15.1	6.8	2.10	4.53	0.047	1.44
K_{20}-1	66	Sept.	21. '78	0	28.0	8.3	0.48	0.48	0.031	0.24
-2	66	Sept.	21. '78	50	23.0	8.1	0.38	2.07	0.020	0.20
-3	66	Sept.	21. '78	100	17.6	7.8	0.38	2.55	0.020	0.15
-4	66	Sept.	21. '78	150	17.3	7.4	0.30	4.65	0.029	0.15
-5	66	Sept.	21. '78	195	16.5	7.1	0.30	7.50	0.029	0.20
K_{21}-1	67	Feb.	15. '79	0	15.5	7.9	0.30	0.80	0.016	0.13
-1	67	Feb.	15. '79	50	16.0	7.9	0.60	11.9	0.019	0.16
-1	67	Feb.	15. '79	100	16.3	7.9	0.54	6.86	0.029	0.16
-1	67	Feb.	15. '79	130	16.5	7.9	0.26	7.35	0.019	0.13
-2	68	Feb.	15. '79	0	15.3	7.9	0.60	3.41	0.016	0.20
-2	68	Feb.	15. '79	50	15.9	7.9	0.45	3.68	0.027	0.21
-2	68	Feb.	15. '79	100	15.9	7.9	0.30	3.38	0.016	0.24
-2	68	Feb.	15. '79	150	16.0	7.8	0.60	6.23	0.029	0.20
-2	68	Feb.	15. '79	200	15.9	7.8	0.26	4.01	0.029	0.16
-3	69	Feb.	15. '79	0	15.9	7.8	0.26	1.05	0.016	0.13
-3	69	Feb.	15. '79	50	15.9	7.8	0.45	3.83	0.016	0.13
-3	69	Feb.	15. '79	70	16.0	7.7	0.60	6.48	0.019	0.20
-4	70	Feb.	18. '79	0	16.0	8.2	0.26	0.90	0.018	0.16
-4	70	Feb.	18. '79	50	16.2	8.1	0.26	2.03	0.029	0.24
-4	70	Feb.	18. '79	100	16.2	8.1	0.26	2.85	0.019	0.16
-4	70	Feb.	18. '79	150	15.7	8.0	0.30	2.78	0.027	0.13
-4	70	Feb.	18. '79	200	15.4	8.0	0.60	6.15	0.077	0.13
-5	71	Feb.	18. '79	0	16.1	8.0	0.26	1.35	0.023	0.16
-5	71	Feb.	18. '79	50	16.1	8.0	0.26	3.33	0.016	0.13
-5	71	Feb.	18. '79	90	16.3	8.0	0.30	2.79	0.019	0.21
K_{24}-1	72	Sept.	19. '80	0	27.3	8.3	0.60	1.7	0.020	0.32

Table 1. (Continued)

Sample	Stn. No.	Date	Depth (m)	W. T. (°C)	pH	Cu μg/l	Zn μg/l	Cd μg/l	Pb μg/l
K_{24}-1	72	Sept. 19. '80	50	23.1	8.1	0.45	5.5	0.024	0.43
-1	72	Sept. 19. '80	100	20.1	8.0	0.35	5.4	0.016	0.29
-1	72	Sept. 19. '80	150	17.9	8.0	0.60	7.5	0.024	0.43
-1	72	Sept. 19. '80	200	17.3	8.0	0.75	10.0	0.024	0.44
-2	73	Sept. 20. '80	0	27.0	8.3	0.60	12.5	0.020	0.29
-2	73	Sept. 20. '80	50	21.6	8.0	0.41	4.5	0.013	0.29
-2	73	Sept. 20. '80	100	17.5	7.7	0.41	6.1	0.013	0.20
-2	73	Sept. 20. '80	150	17.2	7.4	0.45	7.8	0.020	0.16
-2	73	Sept. 20. '80	195	17.5	7.1	0.41	11.3	0.024	0.32
K_{26}-A	74	Oct. 15. '81	0	24.0	8.2	0.51	0.78	0.012	0.42
-B	75	Oct. 15. '81	0	24.1	8.2	0.47	0.50	0.014	0.30
-C	76	Oct. 15. '81	0	24.6	8.2	0.38	0.53	0.024	0.18
-C	76	Oct. 15. '81	50	23.3	8.1	0.32	5.07	0.024	0.19
-D	77	Oct. 15. '81	0	25.0	8.3	0.32	0.56	0.034	0.21
-E	78	Oct. 15. '81	0	24.3	8.2	0.33	0.36	0.034	0.26
-F	79	Oct. 15. '81	0	24.8	8.3	0.39	0.36	0.032	0.28
-G	80	Oct. 15. '81	0	24.8	8.2	0.24	0.41	0.008	0.06
-H	81	Oct. 15. '81	0	25.0	8.1	0.36	0.98	0.014	0.40
-I	82	Oct. 15. '81	0	25.6	8.1	0.29	0.48	0.018	0.08
-J	83	Oct. 15. '81	0	25.8	8.1	0.26	0.42	0.018	0.15
-K	84	Oct. 15. '81	0	24.5	8.1	0.38	0.35	0.026	0.08
-L	85	Oct. 16. '81	0	23.3	8.1	0.26	0.26	0.030	0.17
-M	86	Oct. 16. '81	0	23.2	8.2	0.23	0.24	0.028	0.22
-N	87	Oct. 16. '81	0	23.5	8.2	0.38	0.42	0.014	0.17
-O	88	Oct. 16. '81	0	24.4	8.1	0.32	1.02	0.010	0.20
-O	88	Oct. 16. '81	20	24.2	8.1	0.60	3.68	0.012	0.19
-O	88	Oct. 16. '81	50	23.1	8.1	0.38	4.10	0.016	0.09
-O	88	Oct. 16. '81	100	17.0	7.7	0.53	5.16	0.024	0.06
-O	88	Oct. 16. '81	190	16.0	6.8	0.72	11.3	0.034	0.30
K_{29}-1	89	Nov. 18. '82	0	22.0	8.2	0.50	1.53	0.011	0.11
-1	89	Nov. 18. '82	50	18.5	8.1	0.62	10.9	0.012	0.19
-1	89	Nov. 18. '82	100	17.5	7.6	0.38	11.4	0.016	0.10
-1	89	Nov. 18. '82	150	16.8	7.2	0.29	19.2	0.016	0.23
-1	89	Nov. 18. '82	200	16.8	6.7	0.32	36.8	0.019	0.28
-2	90	Nov. 18. '82	0	22.1	8.2	0.32	1.34	0.009	0.14
-3	91	Nov. 18. '82	0	21.5	8.3	0.14	0.81	0.011	0.08
K_{29}-4	92	Nov. 18. '82	0	21.4	8.3	0.26	1.44	0.007	0.17
-5	93	Nov. 18. '82	0	21.5	8.3	0.54	0.99	0.009	0.03
-6	94	Nov. 18. '82	0	21.8	8.2	0.33	0.74	0.007	0.09
-7	95	Nov. 18. '82	0	22.0	8.2	0.38	0.53	0.005	0.19
-8	96	Nov. 18. '82	0	22.0	8.2	0.21	0.90	0.016	0.10
-9	97	Nov. 18. '82	0	21.5	8.3	0.08	0.36	0.009	0.16
-10	98	Nov. 18. '82	0	21.4	8.3	0.02	0.87	0.005	0.14

Table 2. Contents of copper, zinc, cadmium and lead in sea water of the East China Sea

Sample	Stn. No.	Date	Depth (m)	W. T. (°C)	pH	Cu μg/l	Zn μg/l	Cd μg/l	Pb μg/l
K_{25}-1	101	Oct. 31. '80	0	22.5	8.3	0.15	2.3	0.013	0.44
-1	101	Oct. 31. '80	50	23.0	8.3	0.45	8.1	0.013	0.47
-1	101	Oct. 31. '80	100	21.0	8.3	0.87	11.6	0.020	0.64
-1	101	Oct. 31. '80	180	18.0	8.2	4.35	26.9	0.071	2.16
-2	102	Nov. 2. '80	0	25.3	8.3	0.15	1.5	0.013	0.56
-2	102	Nov. 2. '80	50	26.2	8.3	0.87	6.8	0.059	0.69
-2	102	Nov. 2. '80	100	25.0	8.2	1.05	10.7	0.057	0.60
-2	102	Nov. 2. '80	200	23.0	8.2	1.35	15.5	0.056	0.57
-2	102	Nov. 2. '80	500	15.0	8.0	0.60	3.9	0.043	0.56
-3	103	Nov. 3. '80	0	24.1	8.3	0.15	2.0	0.013	0.29
-3	103	Nov. 3. '80	50	24.3	8.3	2.18	18.5	0.024	1.16
-3	103	Nov. 3. '80	100	24.5	8.3	0.75	14.9	0.024	0.32
-3	103	Nov. 3. '80	150	23.7	8.3	0.75	10.7	0.024	0.51
-3	103	Nov. 3. '80	200	22.4	8.3	0.60	11.6	0.013	0.44
-3	103	Nov. 3. '80	500	16.5	8.0	1.17	13.9	0.033	0.67
-4	104	Nov. 6. '80	0	25.2	8.3	0.35	1.1	0.027	0.51
-4	104	Nov. 6. '80	10	25.4	8.3	0.41	6.2	0.020	0.29
-4	104	Nov. 6. '80	30	25.0	8.3	0.75	9.6	0.024	0.35
-4	104	Nov. 6. '80	50	25.0	8.3	0.78	9.6	0.027	0.69
-4	104	Nov. 6. '80	75	25.0	8.3	0.27	5.6	0.027	0.16
-5	105	Nov. 7. '80	0	25.8	8.3	0.35	1.3	0.013	0.28
-5	105	Nov. 7. '80	10	25.1	8.3	0.41	8.2	0.013	0.43
-5	105	Nov. 7. '80	30	25.3	8.3	0.75	8.7	0.013	0.29
-5	105	Nov. 7. '80	50	25.1	8.3	1.80	18.0	0.029	1.09
-5	105	Nov. 7. '80	70	25.4	8.3	1.61	12.8	0.037	0.69
K_{28}-1	106	Oct. 17. '82	0	27.0	8.2	0.60	0.32	0.007	0.25
2	107	Oct. 17. '82	0	27.5	8.3	0.26	0.65	0.007	0.23
3	108	Oct. 17. '82	0	26.5	8.3	0.11	1.08	0.011	0.20
4	109	Oct. 18. '82	0	26.8	8.3	0.93	0.90	0.004	0.34
5	110	Oct. 18. '82	0	26.0	8.3	0.36	0.17	0.009	0.07
6	111	Oct. 18. '82	0	26.5	8.3	10.9	0.84	0.009	0.43
7	112	Oct. 18. '82	0	25.9	8.3	0.23	0.96	0.015	0.33
8	113	Oct. 18. '82	0	26.0	8.3	0.51	0.92	0.005	0.12

Table 3. Average values of copper, zinc, cadmium and lead contents in sea water of Kagoshima Bay and the East China Sea

Locality		Content ($\mu g/l$) Cu	Zn	Cd	Pb
Kagoshima Bay	Range	0.02~0.83 (0.02~5.33)	0.2~12.5 (0.2~69.9)	0.005~0.090 (0.005~0.094)	0.06~0.86 (0.06~1.89)
	X_A	0.38 (0.53)	1.08 (4.57)	0.021 (0.023)	0.26 (0.28)
	X_G	0.35 (0.42)	0.77 (2.18)	0.019 (0.021)	0.23 (0.24)
	n	97 (219)	97 (219)	97 (219)	97 (219)
East China Sea	Range	0.11~10.9 (0.11~10.9)	0.17~2.3 (0.17~26.9)	0.005~0.027 (0.005~0.71)	0.07~0.56 (0.07~2.16)
	X_A	1.16 (1.12)	1.08 (7.45)	0.011 (0.023)	0.31 (0.51)
	X_G	0.38 (0.63)	0.90 (3.99)	0.010 (0.018)	0.27 (0.41)
	n	13 (33)	13 (33)	13 (33)	13 (33)

X_A: Arithmetic mean
X_G: Geometric mean
n : No. of samples
( ): Each class of depth included
Without ( ): Surface sea water

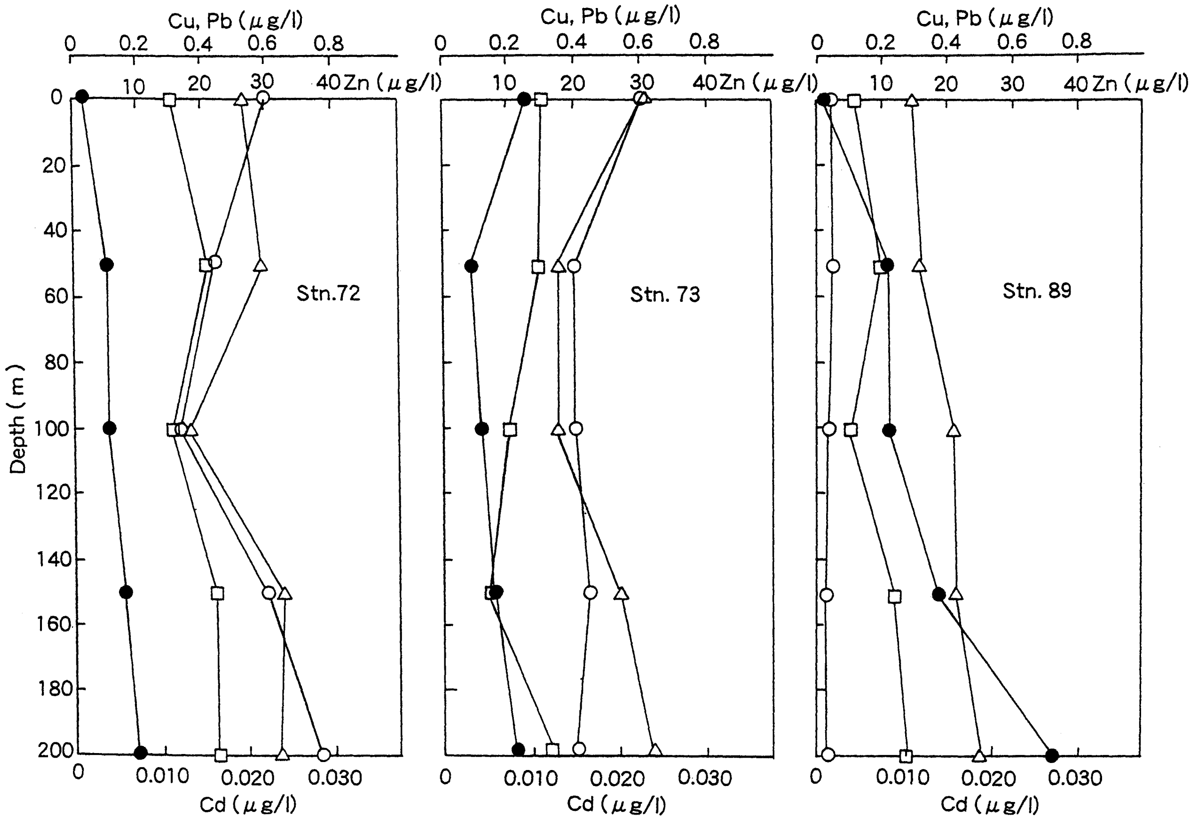

Fig. 6. Vertical profiles of copper, Zinc, cadmium and lead contents in sea water of Kagoshima Bay.
●: Copper
○: Zinc
△: Cadmium
□: Lead

Conclusion

We have determined the acid dissolved copper, zinc, cadmium and lead content in sea water samples from Northern Kagoshima Bay and East China Sea through dithizone-chloroform extraction followed by atomic absorption spectrometry.

Levels of copper, Zinc, cadmium and lead including each class of depth were found to be in the range of 0.02~5.33 $\mu g/l$ (geometric mean 0.42), 0.2~69.9 $\mu g/l$ (geometric mean 2.18), 0.005~0.094 $\mu g/l$ (geometric mean 0.021) and 0.06~1.89 $\mu g/l$ (geometric mean 0.24) for 219 samples taken from Kagoshima Bay and 0.11~10.9 $\mu g/l$ (geometric mean 0.63), 0.17~26.9 $\mu g/l$ (geometric mean 3.99), 0.005~0.71 $\mu g/l$ (geometric mean 0.018) and 0.07~2.16 $\mu g/l$ (geometric mean 0.41) for 33 samples taken from the East China Sea, respectively.

In comparison of mean levels of copper, zinc, cadmium and lead contents of Kagoshima Bay and East China Sea, cadmium was in the same level. Mean levels of copper, zinc and lead contents for Kagoshima Bay were slightly lower than those for the East China Sea. This suggests that copper, zinc and lead have deposited in the sediments of Kagoshima Bay.

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