The Contents and Distributions of Copper, Zinc, Cadmium and Lead in Sediments of Kagoshima Bay

Rep. Fac. Sci., Kagoshima Univ.,
No. 30, pp. 71~83 (1997)

The Contents and Distributions of Copper, Zinc, Cadmium and Lead in Sediments of Kagoshima Bay

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(Received September 10, 1997)

Keywords : Heavy metals (Cu, Zn, Cd, Pb) contents, Distribution, Marine sediment

Abstract

The acid decomposition sequential extraction procedure for determination of heavy metals has been applied to a marine sediments collected from Kagoshima Bay. This research was performed using flame atomic absorption spectrometry (FAAS). Copper, zinc, cadmium and lead in the sediments extracts were determined by FAAS, and we were investigated their distributions . The contents of copper, zinc, cadmium and lead in surface sediments were different in a small area. However, its vertical distributions showed higher concentrations excluding copper in the northern than in the southern area. A higher degree of positive correlation was found among the contents of copper, zinc, cadmium and lead in sediments of the southern area ; however, this type of closed correlation was not observed in the northern area. This was considered that factors such as urbanization activities around Kagoshima City, geological circumstances and submarine volcanic activity of northern Kagoshima Bay have produced significant changes in the sediments of Kagoshima Bay.

Introduction

The contents of heavy metals (Cu, Zn, Cd, Pb and Hg) are very small in low-polluted environmental samples, so that it is very difficult to get precise and reliable data on them. It was, therefore, necessary to check the reliability of the analytical procedure that we used with an inter laboratory comparison program[1]. Several years ago, the authors had the opportunity to participate in a inter laboratory comparison program for heavy metals[2),3)]. For many years, we have studied analytical and geochemical research about trace heavy metals (Cu, Zn, Cd, Pb and Hg) in river waters[3),4)], sea waters[5)-9)], marine sediments[10)-13)], hot springs[14),15)] and in biological materials[3),16)], especially around Sakurajima volcano, which is in southwestern Japan.

Research about the submarine fumaroles in Kagoshima Bay was performed by the Environmental Agency of the Government of Japan and Kagoshima Prefecture with a submarine boat in 1977 in order to investigate its contribution to amount of mercury load in the area[17)].

Submarine hydrothermal activity on and near the Galapágos Rift has been explored with the aid of the deep submersible, "Alvin". The sediments studied have an anomalously high concentration of metals such as iron, manganese, barium, copper , zinc and uranium[18),19)]. The authors have focused on heavy metal components (copper, zinc, cadmium, lead and mercury) which are derived from volcanic activity, based on the idea that volcanic activity must be related to the marine environment of Kagoshima Bay. The authors have analyzed copper, zinc, cadmium, lead and mercury concentration in sea water of Kagoshima Bay and their horizontal and vertical distributions had been already reported[7),9)]. This paper describes the contents of copper, zinc, cadmium and lead, their distributions, and their mutual relationship based on the analytical results of sedi-

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ments collected from Kagoshima Bay.

Experimental

General circumstances of Kagoshima Bay

Kagoshima Bay is a narrow inner bay (about 75 km long and 25km wide). It is an arm of the sea that penetrates deeply into the land from south to north.

Its bottom has unique topographic features, as may be seen from the vertical section shown in Fig.1. Sakurajima volcano, which is in the central area of the bay, separates the two sea areas, which communicate with each other only through Nishi Sakurajima Suidou, which is a shallow area about 40 m deep. Thus, the exchange of sea water between the northern areas(140 to 200 m deep) and the open ocean is not easy. The extent of pollution in the whole bay caused by human activities, both connected with daily living and industrial, is also dictated by water exchange because of the intricate topography of the bottom of the bay. There is significant fumarolic activity around Stations A1~22 and B1~6 in the northern area of the Kagoshima Bay (Fig.2). It influences the marine environment in a number of ways. Furthermore, the rate of sediment accumulation in Kagoshima Bay is high due to volcanic emissions from Minamidake of Sakurajima volcano, which has been active since October, 1955. The effects of volcanic emissions upon the sediments will be reported in another paper.

Collection Methods and Preservation of Sedimentary Samples

A Smith-McIntyre spring-loading grab was used to collect surface sediments, and a Fhleger bottom sampler, equipped with a plastic inner tube that was 3.3cm in inside diameter, was used to investigate the vertical distributions. The collected sediment samples were immediately cut into 10cm pieces in size ; each fragment was enclosed in a polystyrene bottle, refrigerated at the site, and then brought back to our laboratory. Each sample was then suction-filtered with a 0.45μm Millipore filter, air-dried, and grind with an agate mortar. The uniform sediment samples thus obtained were preserved for the subsequent determination of copper, zinc, cadmium and lead. All results of contents are shown in oven-dried basis

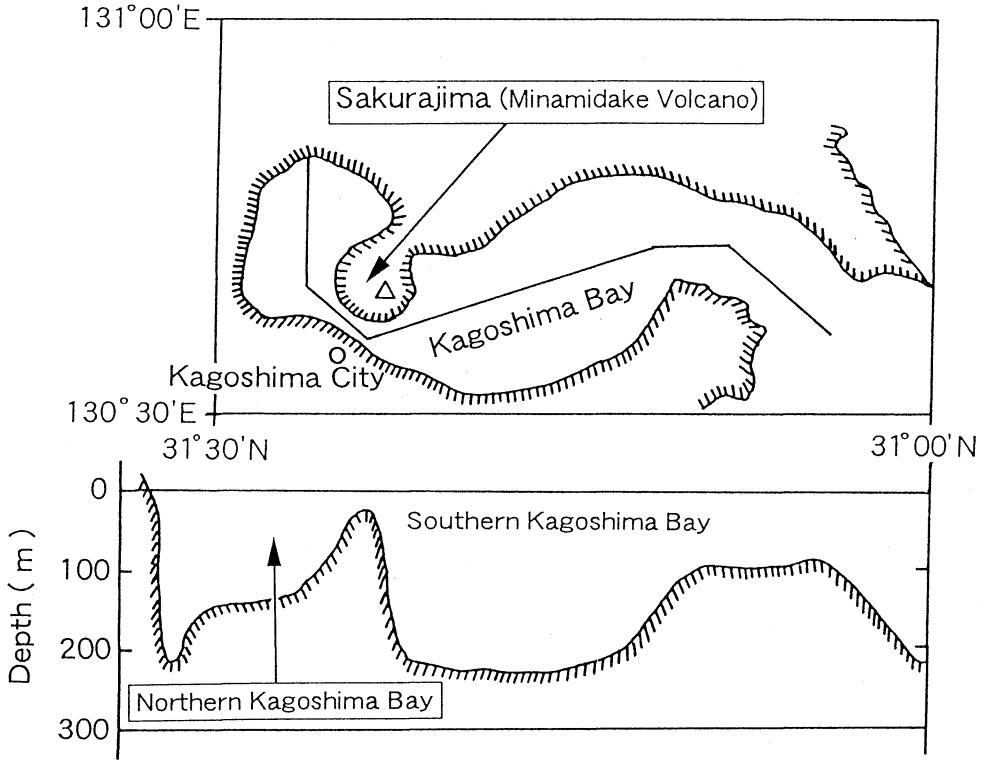

Fig. 1. Vertical section of Kagoshima Bay.

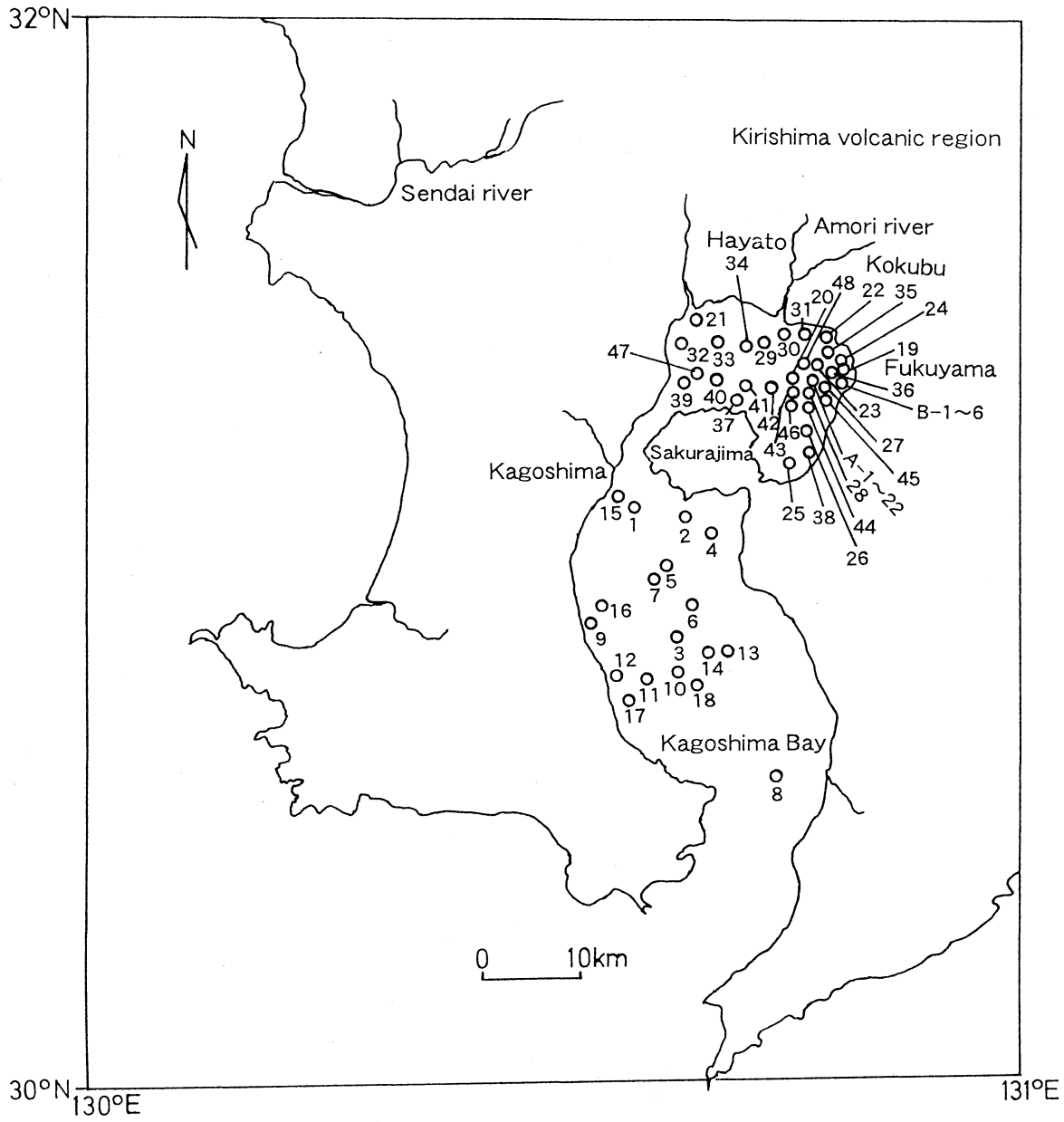

Fig. 2. Sampling stations of marine sediments in Kagoshima Bay.

(110℃, 6hr).

Sampling Stations

The sediment sampling stations in Kagoshima Bay are shown in Fig. 2 ; the station numbers are tabulated in Table 1.

Apparatus

We used a Shimadzu Model 646 atomic absorption spectrophotometer that was connected to an Ohkura recorder. We also used a Takabayashi Shaker.

Reagents

All of the reagents used were of analytical-reagent grade and were used without further purification.

The grades of acid (hydrochloric acid, hydrofluoric acid, nitric acid and perchloric acid) and the ammonium citrate used were all of analytical-special-reagent grade for the measurements of the toxic metals (Wako Chemicals). Purified water was used in all of the experiments using a Millipore Milli-Q SP water purification system after distilled water.

Each stock standard solutions (1,000 mg l^{-1}) were prepared by dissolving 1.000 g pure copper, zinc, cadmium and lead in nitric acid or hydrochloric acid,

and diluted to exactly 1 liter with water.

Analytical Procedures for the Determination of Copper, Zinc, Cadmium and Lead

We analyzed the prepared samples by following a procedure that we used previously[4]. A schematic diagram of this method is shown in Fig.3. A sediment sample is weighed in a platinum crucible, and is then decomposed with perchloric acid and hydrofluoric acid heated by sand bath. After evaporation to dryness, 7 M nitric acid is added, and the sample is allowed to stand at least 30min. in order to dissolve the remaining substance, and 500ml of water is added. Next, the pH is adjusted to 8~8.5 with (1 : 1) ammonia water, and the solution is put in a separating funnel and 5ml of 0.1% dithizone chloroform is added. The funnel is then shaken in order to extract the copper, zinc, cadmium and lead from aqueous phase to the chloroform phase as metal chelates. The chloroform phase is then decomposed with conc. nitric acid and 60% perchloric acid heated by sand bath, and after evaporation to dryness is dissolved in 5ml of 0.1M hydrochloric acid. The contents of copper, zinc, cadmium and lead of the solution are then determined by atomic absorption spectrometry (FAAS).

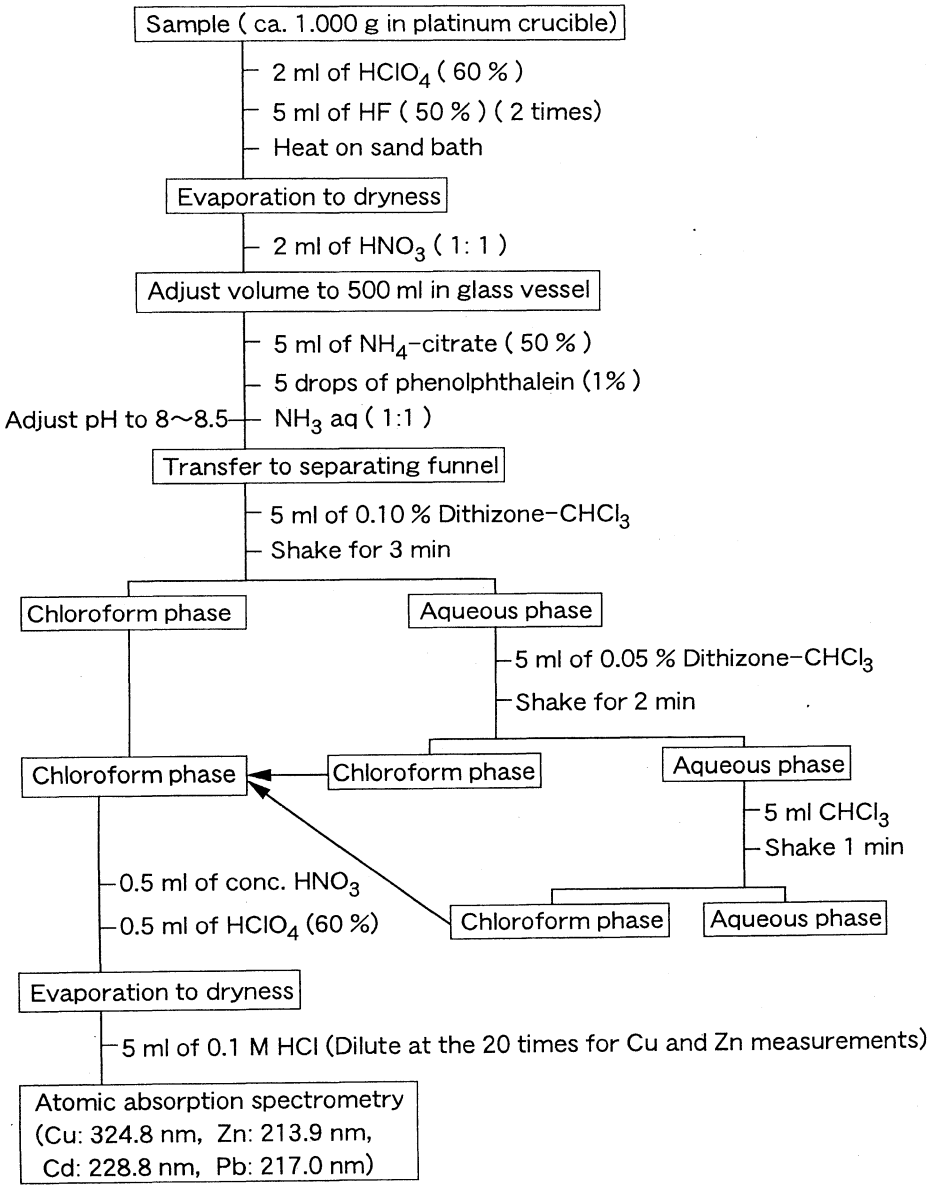

Fig. 3. Analytical procedures of copper, zinc, cadmium and lead determination for marine sediments.

Results and Discussion

Contents of copper, zinc, cadmium and lead in surface sediments (0 to 10cm deep)

The analytical results for copper, zinc, cadmium and lead in surface sediments of Kagoshima Bay are shown in Table 1. In the following section, Kagoshima Bay has been divided into two sections by a line that connects Kagoshima City and Sakurajima ; i.e. the southern (Stn.1 to 18) and the northern areas (Stn. 19 to 48, A1～22 and B1～6). The results for the southern and northern areas of Kagoshima Bay are summarized in Table 2, in which data from the northern area are shown separately for the station 200m in depth (A), the station 78m in depth (B), and the other stations (C). A is the area 200 m-deep within *ca.* 100m from the center of the fumarole group. B is the area 78m-deep within *ca.* 50 m from the center of the fumarole group. C is the area excluding A and B. The fumarolic gas at the station B was relatively low in temperature and had a composition of natural gas. While the fumarolic gas at station A was high in temperature (the max. was 215℃) and contains a great deal of volcanic gas like carbon dioxide, hydrogen sulfide, and hydrogen[17].

In Table 2, X_A, X_G, n represent the arithmetic mean, and geometric mean and the number of samples collected, respectively.

The data for the 200m (A) and 78m (B) stations are those of sediment samples collected in a past survey ; (an investigation by the Japan Environmental Agency, Kagoshima Prefecture, and the Japan Marine Science and Technology Center of northern Kagoshima Bay and was done with a submarine boat or an unmanned submersible Dolphin 3K). Samples near vicinity of a sea bottom fumarole were collected by means of a submarine boat or unmanned submersible Dolphin 3K according to visual observation.

Table 2 shows that the content of cadmium in area of the 200m station (A) was considerably higher than B and C station. But abnormal values like mercury[11] were not found as regarding in copper, zinc, cadmium and lead . The contents of copper and cadmium in northern area was considerably higher than southern area. The variation of zinc content was not found in both areas. The contents of lead in southern area was higher than northern A and B areas. As this reason, artificial load was considered. It was considered that size of particle of sediment was related to heavy metals (Cu, Zn, Cd and Pb) of station B. Particle size of sediment in B station was lagger than A and B stations.

Next, the authors have collected hydrothermal water from fumaroles at the station that was 200m in depth and the contents of cadmium and mercury were high 0.087$\mu g\ l^{-1}$ and 0.12$\mu g\ l^{-1}$, respectively[17]. The mention above shows that hydrothermal activity provides significant or dominant sources and sinks for several sea water components. Furthermore, fumarolic gases including constituents like As, Sb and Hg which exhibit volatility its exhibit as elements and in the form of compounds and hydrogen sulfide have been deposited directly in sediments under an anoxic conditions[6),11),13)]

Horizontal Distributions of Copper, Zinc, Cadmium and Lead in Surface Sediments

Figures 4～7 show the horizontal distributions of contents of copper, zinc, cadmium and lead in surface sediments collected at 76 stations over the entire area of Kagoshima Bay. The content of copper was high at a depth of 200m in the northern area and near the estuary of the Amori river, which flows down from the Kirishima volcanic region. The higher content of these compositions (especially cadmium and lead) were seen in the center of the southern and the northern areas, particularly in the vicinity of fumaroles that were 200m in depth. Sedimentary samples with high concentrations of cadmium and lead which were collected near these fumaroles, have never been found previously observed at sea level.

Vertical Distributions of Copper, Zinc, Cadmium and Lead in Surface Sediments

Figure 8 shows the vertical distributions of contents of copper, zinc, cadmium and lead in surface sediments of Kagoshima Bay. Here, contents of copper, zinc, cadmium and lead (abscissa) are plotted against the depth (ordinate) 10cm-interval vertical sections from the surface of the sediments to a depth of 100cm. We observed little change in the southern area (Stn.18), in regards to the contents of copper,

Table 1. Copper, zinc, cadmium and lead contents in surface sediments of Kagoshima Bay

Station No.	Depth (m)	Sampling Date	Content[a)]/mg kg^{-1} Cu	Zn	Cd	Pb	Remarks
1	144	Sept.21.'76	15.7	63.7	0.14	17.8	Southern Kagoshima Bay
2	170	Sept.22.'76	10.0	69.6	0.18	21.5	Southern Kagoshima Bay
3	226	Sept.21.'76	17.9	60.2	0.22	20.1	Southern Kagoshima Bay
4	160	Sept.21.'76	14.7	62.6	0.13	15.0	Southern Kagoshima Bay
5	217	Oct. 12.'76	12.8	70.6	0.22	20.4	Southern Kagoshima Bay
6	226	Oct. 30.'76	14.7	83.7	0.24	21.3	Southern Kagoshima Bay
7	218	Dec. 05.'76	12.4	67.3	0.23	23.2	Southern Kagoshima Bay
8	185	Dec. 05.'76	12.2	77.0	0.14	16.9	Southern Kagoshima Bay
9	13	Mar. 10.'77	2.6	49.9	0.10	11.5	Southern Kagoshima Bay
10	210	Mar. 10.'77	15.3	65.4	0.26	20.2	Southern Kagoshima Bay
11	110	Mar. 10.'77	11.6	62.9	0.14	16.0	Southern Kagoshima Bay
12	36	Mar. 10.'77	4.1	49.1	0.10	14.5	Southern Kagoshima Bay
13	100	Mar. 10.'77	10.6	66.1	0.15	16.5	Southern Kagoshima Bay
14	200	Mar. 10.'77	12.7	71.9	0.20	19.0	Southern Kagoshima Bay
15	80	Nov.06.'77	4.4	54.6	0.08	14.6	Southern Kagoshima Bay
16	40	Nov.06.'77	5.1	58.0	0.08	20.8	Southern Kagoshima Bay
17	150	Nov.06.'77	4.8	57.1	0.10	17.2	Southern Kagoshima Bay
18	215	Nov.06.'77	12.3	68.3	0.20	22.2	Southern Kagoshima Bay
19	78	Aug.12.'76	11.3	73.2	0.14	14.6	Northern Kagoshima Bay
20	140	Oct. 12.'76	13.0	69.4	0.15	14.9	Northern Kagoshima Bay
21	25	Oct. 29.'76	15.9	70.7	0.19	15.0	Northern Kagoshima Bay
22	38	Oct. 30.'76	16.3	56.6	0.15	15.3	Northern Kagoshima Bay
23	190	Oct. 30.'76	23.3	70.0	0.12	19.1	Northern Kagoshima Bay
24	180	Oct. 30.'76	14.6	79.8	0.16	16.8	Northern Kagoshima Bay
25	140	Oct. 30.'76	12.8	77.1	0.15	12.1	Northern Kagoshima Bay
26	118	Dec.06.'76	13.0	75.9	0.14	12.3	Northern Kagoshima Bay
27	202	Jan. 21.'77	18.3	71.0	0.09	18.0	Northern Kagoshima Bay
28	210	Apr.17.'77	17.1	53.1	0.12	16.6	Northern Kagoshima Bay
29	115	Oct. 29.'77	13.8	70.0	0.10	15.5	Northern Kagoshima Bay
30	104	Oct. 29.'77	21.5	55.6	0.11	16.9	Northern Kagoshima Bay

Table 1. (Continued)

Station No.	Depth (m)	Sampling Date	Content[a)] /mg kg^{-1} Cu	Zn	Cd	Pb	Remarks
31	40	Oct. 29.'77	23.0	65.1	0.11	17.0	Northern Kagoshima Bay
32	135	Oct. 29.'77	15.0	72.1	0.10	16.9	Northern Kagoshima Bay
33	145	Nov.06.'77	13.4	70.3	0.09	18.3	Northern Kagoshima Bay
34	140	Nov.06.'77	13.5	67.8	0.09	18.3	Northern Kagoshima Bay
35	140	Nov.06.'77	16.4	68.4	0.11	18.6	Northern Kagoshima Bay
36	195	Nov.06.'77	15.2	56.1	0.09	18.6	Northern Kagoshima Bay
37	30	Nov.06.'77	8.0	69.4	0.08	12.7	Northern Kagoshima Bay
38	100	Nov.06.'77	10.9	70.9	0.08	12.4	Northern Kagoshima Bay
39	150	Sept.20.'79	12.3	62.9	0.09	12.6	Northern Kagoshima Bay
40	155	Sept.20.'79	14.6	69.8	0.12	12.8	Northern Kagoshima Bay
41	140	Sept.20.'79	14.0	70.1	0.12	13.1	Northern Kagoshima Bay
42	140	Sept.20.'79	11.9	66.2	0.07	12.9	Northern Kagoshima Bay
43	190	Sept.20.'79	13.9	63.5	0.10	13.8	Northern Kagoshima Bay
44	195	Sept.20.'79	16.0	69.8	0.09	11.1	Northern Kagoshima Bay
45	200	Sept.20.'79	25.5	49.2	0.09	11.6	Northern Kagoshima Bay
46	192	Oct. 05.'79	20.5	59.8	0.15	18.1	Northern Kagoshima Bay
47	150	Sept.21.'77	13.3	67.8	0.13	17.7	Northern Kagoshima Bay
48	205	Nov.06.'77	17.2	77.0	0.14	16.9	Northern Kagoshima Bay
A-1	200	Sept.09.'77	15.6	45.9	0.13	9.4	Vicinity of a sea bottom fumarole
A-2	200	Sept.11.'77	18.4	155	0.20	13.0	Vicinity of a sea bottom fumarole
A-3	200	Sept.11.'77	16.9	67.7	0.57	19.5	Vicinity of a sea bottom fumarole
A-4	200	Sept.11.'77	19.3	54.5	0.13	12.2	Vicinity of a sea bottom fumarole
A-5	200	Sept.11.'77	10.0	76.7	0.79	27.7	Vicinity of a sea bottom fumarole
A-6	200	Sept.13.'77	32.5	51.0	0.48	17.4	Vicinity of a sea bottom fumarole
A-7	200	Sept.15.'77	17.2	46.6	0.14	11.7	Vicinity of a sea bottom fumarole
A-8	200	Sept.15.'77	13.1	45.0	0.14	12.9	Vicinity of a sea bottom fumarole
A-9	200	Sept.15.'77	13.4	50.4	0.11	13.3	Vicinity of a sea bottom fumarole
A-10	200	Aug.25.'78	15.7	51.9	0.15	11.0	Vicinity of a sea bottom fumarole
A-11	200	Aug.25.'78	18.2	51.9	0.16	11.9	Vicinity of a sea bottom fumarole
A-12	200	Aug.25.'78	18.3	54.0	0.17	12.6	Vicinity of a sea bottom fumarole

Table 1. (Continued)

Station No.	Depth (m)	Sampling Date	Content[a] /mg kg^{-1} Cu	Zn	Cd	Pb	Remarks
A-13	200	Aug.26.'78	15.6	54.5	0.16	13.9	Vicinity of a sea bottom fumarole
A-14	200	Aug.27.'78	12.4	61.4	0.22	20.7	Vicinity of a sea bottom fumarole
A-15	200	Aug.27.'78	23.7	59.0	0.33	22.2	Vicinity of a sea bottom fumarole
A-16	200	Jun. 28.'90	15.0	40.1	0.16	11.8	Vicinity of a sea bottom fumarole
A-17	200	Jun. 29.'90	9.8	46.4	0.17	9.2	Vicinity of a sea bottom fumarole
A-18	200	Jun. 30.'90	33.0	43.8	0.17	11.7	Vicinity of a sea bottom fumarole
A-19	200	Feb. 09.'91	15.2	105	0.17	12.9	Vicinity of a sea bottom fumarole
A-20	200	Feb. 10.'91	16.5	95.1	0.10	14.9	Vicinity of a sea bottom fumarole
A-21	200	Sept.13.'93	14.5	97.6	0.72	11.7	Vicinity of a sea bottom fumarole
A-22	200	Sept.15.'93	14.1	77.3	0.89	14.1	Vicinity of a sea bottom fumarole
B-1	100	Sept.12.'77	7.7	40.0	0.11	8.9	Vicinity of a sea bottom fumarole
B-2	100	Sept.12.'77	10.9	49.6	0.15	10.3	Vicinity of a sea bottom fumarole
B-3	100	Sept.14.'77	6.6	45.6	0.11	8.3	Vicinity of a sea bottom fumarole
B-4	100	Aug. 24.'78	9.6	60.8	0.14	10.7	Vicinity of a sea bottom fumarole
B-5	100	Sept.11.'93	8.4	59.9	0.17	9.6	Vicinity of a sea bottom fumarole
B-6	100	Sept.12.'93	6.7	64.7	0.17	9.0	Vicinity of a sea bottom fumarole

a) The contents of copper, zinc, cadmium and lead are converted to these values when samples are heated at 110 ℃ for 6 hr.

Table 2. Copper, zinc, cadmium and lead contents in surface sediments of Kagoshima Bay

		Content / mg kg^{-1} (110℃, 6 hr. dry basis)								
		Cu		Zn		Cd		Pb		
Sampling station		X_A[d]	X_G[e]	X_A[d]	X_G[e]	X_A[d]	X_G[e]	X_A[d]	X_G[e]	n[f]
Northern Kagoshima Bay	A[a]	17.2	16.4	65.0	61.0	0.28	0.22	14.4	13.8	22
	B[b]	8.3	8.2	53.4	52.7	0.14	0.14	9.5	9.4	6
	C[c]	15.5	15.1	67.3	66.9	0.12	0.11	15.4	15.1	30
Southern Kagoshima Bay		10.8	9.5	64.3	63.8	0.16	0.15	18.3	18.0	18

a) A is the area 200 m-deep within *ca.* 100 from the center of the fumarole group.

b) B is the area 78 m-deep within *ca.* 50 m from the center of the fumarole group.

c) C is the area excluding A and B.

d) X_A is the arithmetic mean.

e) X_G is the geometric mean.

f) n is the number of determined samples.

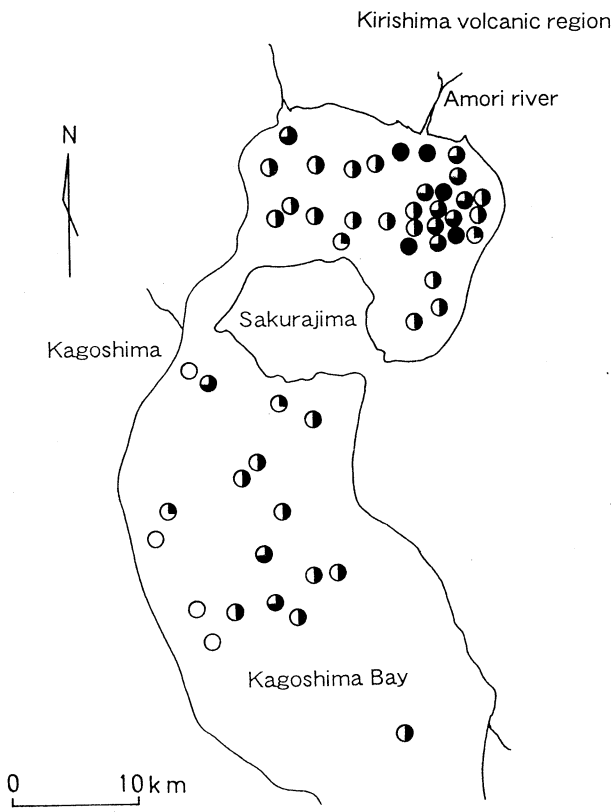

Fig. 4. Horizontal distribution of copper in surface sediments of Kagoshima Bay.

Cu mg kg^{-1} a)	No. of samples
○ ≦ 5.0	4
◔ 5.1 ~10.0	4
◑ 10.1 ~15.0	25
◕ 15.1 ~20.0	12
● 20.1 ≦	5

a) 110℃, 6 hr. dry basis.

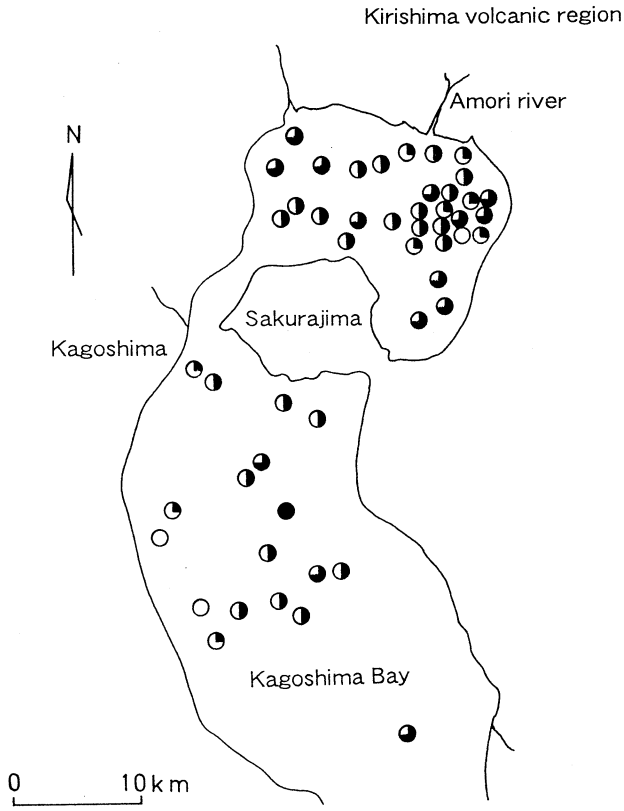

Fig. 5. Horizontal distribution of zinc in surface sediments of Kagoshima Bay.

Zn mg kg^{-1} a)	No. of samples
○ ≦50.0	3
◔ 50.1 ~60.0	9
◑ 60.1 ~70.0	23
◕ 70.1 ~80.0	14
● 80.1 ≦	1

a) 110℃, 6 hr. dry basis.

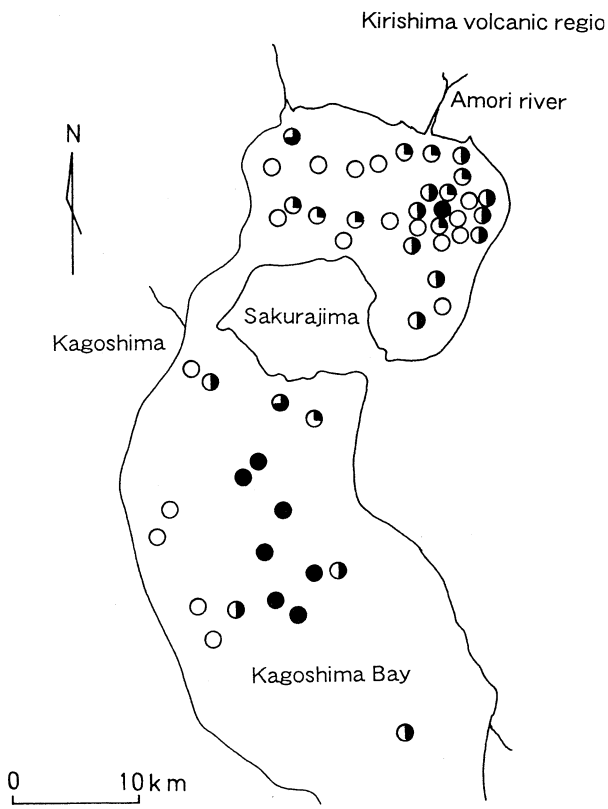

Fig. 6. Horizontal distribution of cadmium in surface sediments of Kagoshima Bay.

Cd mg kg^{-1} a)	No. of samples
○ ≦ 0.10	18
◔ 0.11 ~ 0.13	9
◑ 0.14 ~ 0.16	13
◕ 0.17 ~ 0.19	2
● 0.20 ≦	8

a) 110℃, 6 hr. dry basis.

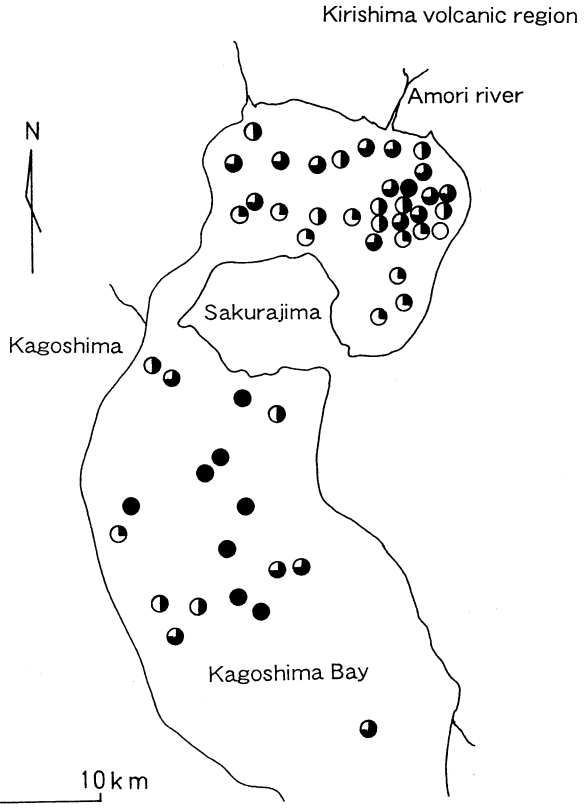

Fig. 7. Horizontal distribution of lead in surface sediments of Kagoshima Bay.

Pb mg kg^{-1} a)	No. of samples
○ ≦10.0	1
◔ 10.1 ~13.0	10
◑ 13.1 ~16.0	12
◕ 16.1 ~19.0	18
● 19.1 ≦	9

a) 110℃, 6 hr. dry basis.

zinc, cadmium and lead as regarding to the depth. In the northern area (Stn.48), however, the vertical distribution was uneven for cadmium and lead. Figure 8 also shows higher contents for all of the components excluding copper in the northern as opposed to the southern area. This tendency was also observed in the other stations. The rate of sedimentary accumulation in Kagoshima Bay is higher due to volcanic emissions from Minamidake of Sakurajima volcano. The amount of volcanic emissions is estimated *ca.* 2.0 x 10^8 tons up to the present[20].

Correlations among the Contents of Copper, Zinc, Cadmium and Lead in Surface Sediments

Table 3 shows the mutual correlation coefficients among the contents of copper, zinc, cadmium and lead in surface sediments in the southern and northern areas of Kagoshima Bay. As is clear from this table, a higher degree of positive correlation was found among the contents of copper, zinc, cadmium and lead in the southern as opposed to the northern areas. This is due to stronger volcanic activity in the latter as compared to the former.

We measured pH values during several years for southern Kagoshima Bay for every layer from the surface to a depth of 200 m. They ranged from 7.9 to 8.3. However, the pH values of the sea water in northern Kagoshima Bay decreased rapidly as the depth increased starting at a depth of 100 m, which resulted in a value that was less than 7.0 near the bottom of the stratification period. This suggests the presence of an acidic water mass below 100 m in this area; the origin of this acidic water mass can be explained as follows : the principal components of the gases that were collected directly from the fumaroles was carbon dioxide, which was 75～93%[17]. However, carbon dioxide has not been detected from the gases that were collected from the bubbles (at the surface sea water) that were above the marine fumaroles. This may imply the complete dissolving of carbon dioxide in sea water on the way from the

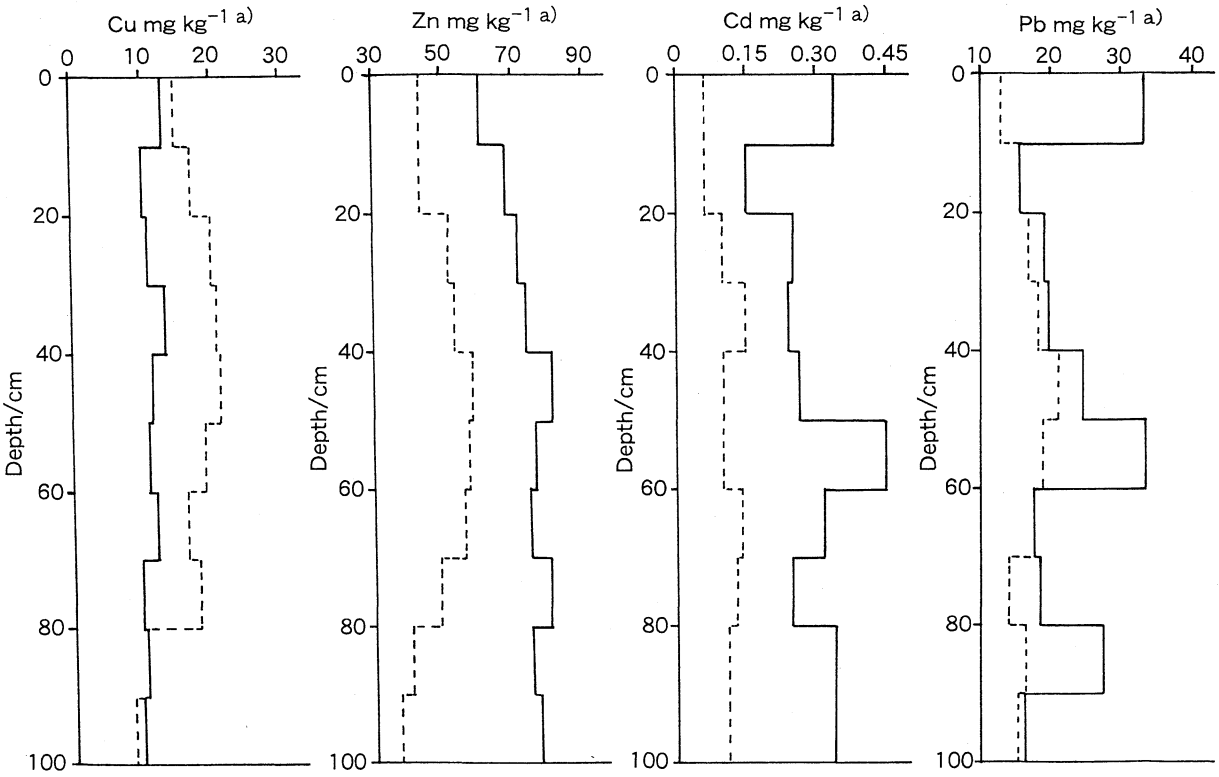

Fig. 8. Vertical distribution of copper, zinc, cadmium and lead in sediments of Kagoshima Bay.
--- : Stn. 18 (Southern Kagoshima Bay)
--- : Stn. 48 (Northern Kagoshima Bay)
a) 110℃, 6hr. dry basis.

the fumaroles at the sea bottom to the surface. Accordingly, the vertical sea water profiles of the contents of copper, zinc, cadmium and lead significantly increased in the depth of 200 m in the northern as opposed to the southern area[9].

Conclusion

The horizontal and vertical distributions of the contents of copper, zinc, cadmium and lead in sediments that were collected from Kagoshima Bay have been studied. The results may be summarized as follows : (1) The distribution of contents of copper, zinc, cadmium and lead in surface sediments of Kagoshima Bay showed considerably high concentrations of these components in a limited area. (2) Their vertical distributions (excluding copper) clearly showed higher concentrations in the northern as opposed to the southern area. We observed little change in the depth in the sediments of the southern area, but we did observe changes in sediments from the northern area. (3) A higher degree of correlation was found among the four components (copper, zinc, cadmium and lead) in surface sediments of the southern area, but no such correlations existed among those in the northern. This suggests that these components have been effected by volcanic activity which both took place in the past and under way at present. (4) Higher concentration of cadmium was found at a high temperature position that was 200 m in depth and that was close to the center of the volcanic activity in the northern area ; and anomalies for other components (Cu, Zn and Pb) were not observed.

From these results, it is considered that factors such as urbanization activities around Kagoshima City, geological circumstances, and the submarine volcanic activity of northern Kagoshima Bay have produced significant changes in the sediments of Kagoshima Bay. Volcanic activity exits disappearance. In order to completely understand this phenomenon, it is necessary to continue monitoring factors like the water quality, sediments, and the volcanic activity in the bay.

The authors are indebted to the Environmental Government of Japan and Environmental Pollution Control Section of Kagoshima Prefecture and the

Table 3. Mutual correlation coefficients of copper, zinc, cadminum and lead in sediments of Kagoshima Bay

(I)[a]

	Cu	Zn	Cd	Pb
Cu				
Zn	0.65			
Cd	0.77	0.67		
Pb	0.51	0.60	0.71	

(n^{c})=18)

(II)[b]

	Cu	Zn	Cd	Pb
Cu				
Zn	−0.06			
Cd	0.07	0.20		
Pb	0.28	0.19	0.31	

(n^{c})=58)

a) (I) is southern Kagoshima Bay. b) (II) is northern Kagoshima Bay. c) (n) is the number of determined samples.

Institute of Environmental Pollution and Public Health of Kagoshima Prefecture and the Japan Marine Science and Technology Center for their practical assistance, such as in the collection of samples and as well as for their very helpful comments and advice.

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