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The contents and distribution of arsenic and antimony 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 arsenic and antimony by hydride generation-atomic absorption spectrometry with hydrogen-nitrogen flame using sodium borohydride solution as reductant.

Levels of arsenic and antimony contents including each class of depth were found to be in the range of 0.5 ~ 8.8 $\mu g/\ell$ (geometric mean 1.5_8), 0.10~2.16 $\mu g/\ell$ (geometric mean 0.27_5) for 54~91 samples taken from Kagoshima Bay and 1.0~2.2 $\mu g/\ell$ (geometric mean 1.4_0), 0.15~0.61 $\mu g/\ell$ (geometric mean 0.23_7) for 59~67 samples taken from the East China Sea, respectively.

In comparison of the mean levels for arsenic and antimony contents including each class of depth from Kagoshima Bay and the East China Sea, the arsenic and antimony level were slightly higher than those for the East China Sea. Arsenic and antimony contents in sea water at the hot position 200 m deep near the fumarole of northern Kagoshima Bay were higher than those for southern Kagoshima Bay. This suggests that arsenic and antimony have supplied as result of volcanic activity which both took place in the past and are under way at present.

Key words: Arsenic, antimony, Sea water, Distribution

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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 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.

Arsenic and antimony are known as toxic elements same as mercury. For many years, we have studied the trace elements (Cu, Zn, Cd, Pb, As, Sb, Hg) in river waters[11),12)], sea waters [13)-16)], marine sediments[17)-20)], biological samples[21),22)] and hot spring waters[23),24)]. In general, the contents of those elements are very small, on a ppb or ppt 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[14),21)].

This paper discusses the contents and distribution of acid soluble arsenic and antimony, 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 Spectrophotometer was used.

Hydride generation equipment: The Shimadzu Arsenic Analyzer ASA-1 was used.

Reagents.

Reagents used were of analytical-reagent grade. The hydrochloric acid and sodium borohydride were analytical- special-reagent-grade for the measurements of the toxic metals.

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

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 Oct., 1981 to June, 1990.

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

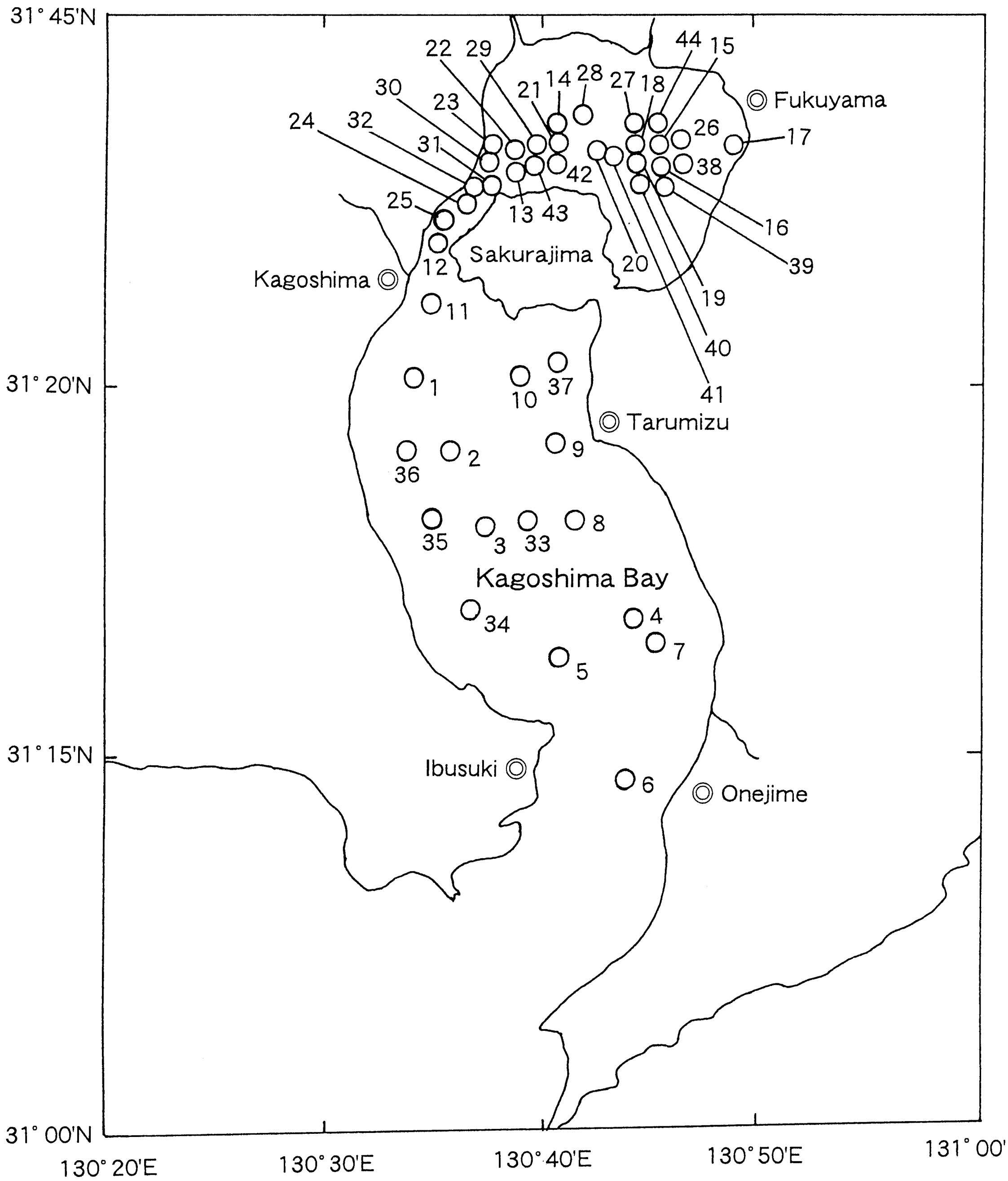


Fig. 1. Map of sampling stations for Kagoshima Bay sea waters.

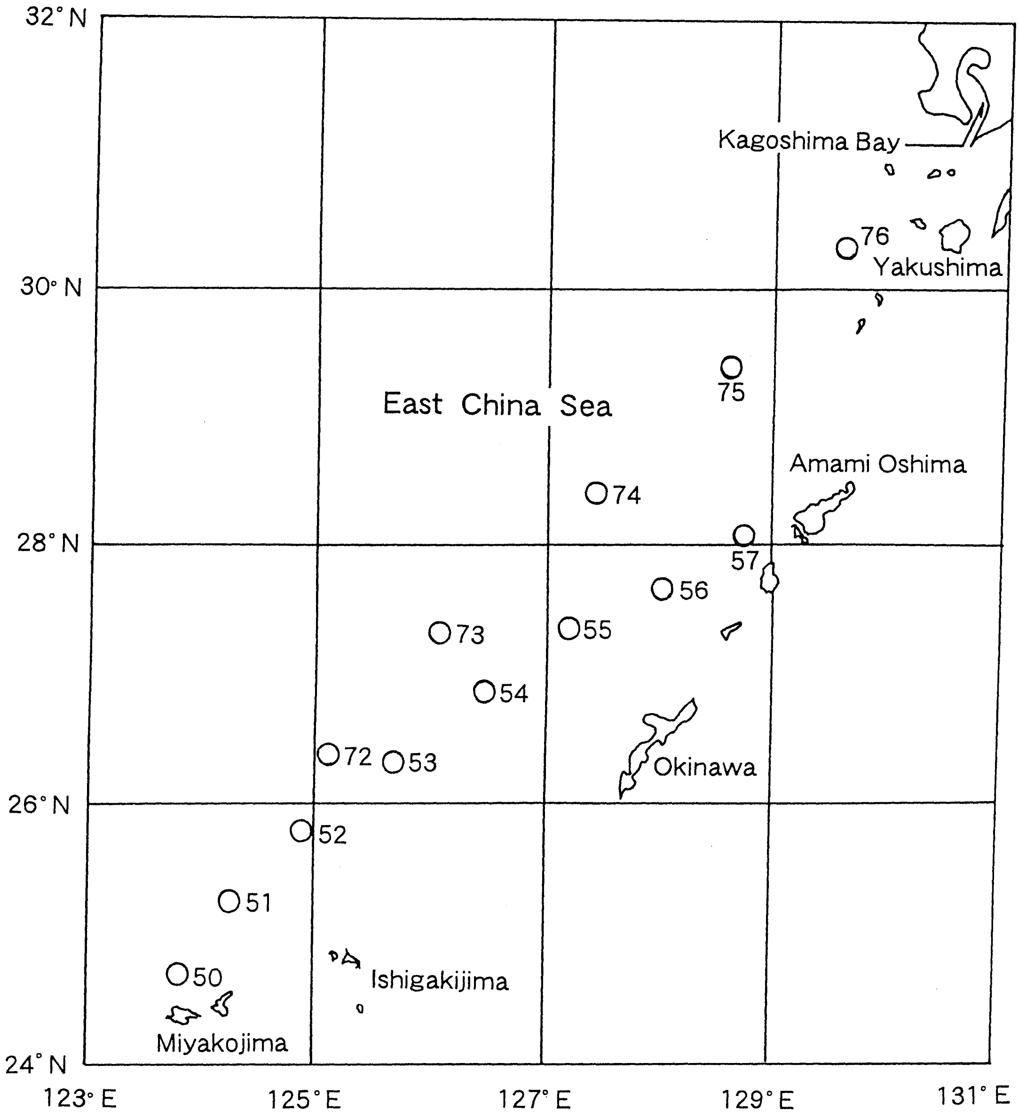


Fig. 2. Map of sampling stations for East China Sea.

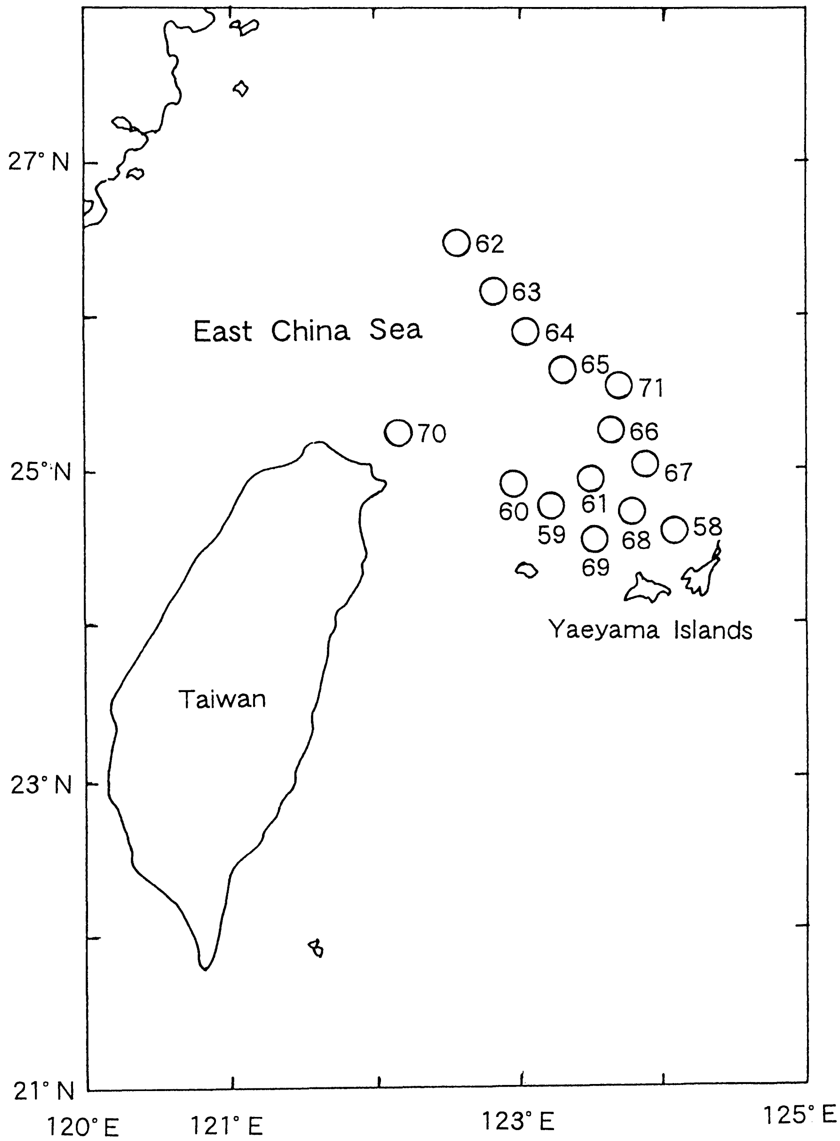


Fig. 3. Map of sampling stations for East China Sea.

The collected sea water samples were preserved in a polyethylene bottles, which were excluded beforehand with approximately 2 mol/l nitric acid for two weeks and then washed thoroughly with water. A 10 ml of concentrated hydrochloric 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 arsenic. Regarding antimony, however, we had no definite information as to any differences between filtered and unfiltered samples.

Analytical Procedure for Arsenic and Antimony in Sea Water.

The contents of arsenic and antimony 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 analyzed by hydride generation-atomic absorption spectrometry with hydrogen-nitrogen flame using sodium borohydride solution as reductant[24), 25)].

Determination of Arsenic (III + V).

A sea water sample was placed in a reaction vessel. In this solution, 10 mℓ of 35% hydrochloric acid and 5 mℓ of 40% potassium iodide solution were added and the reaction vessel was then put into a hydride generator. Then, 1 mℓ of 3% sodium borohydride in 0.01 molℓ/ℓ sodium hydroxide solution was injected with a syringe over a period of 20 s while stirring with a bar. Arsine evolved was introduced into quartz cell by passing nitrogen through the reaction vessel in 70 s after injecting 3% sodium borohydride. The arsine was atomized in a hydrogen-nitrogen flame of an atomic absorption spectrometer and the arsenic (III + V) was determined at a wavelength of 193.7 nm.

Determination of Antimony (III + V).

A sea water sample was placed in a reaction vessel. In this solution, 5 mℓ of 35% hydrochloric acid and 2.5 mℓ of 40% potassium iodide solution were added. The vessel was then put into a hydride generator and the antimony (III + V) was treated in the same way as during the determination of arsenic (III + V). The atomic absorption for antimony was done at a wavelength of 217.6 nm.

Results and Discussion

Contents of Arsenic and Antimony in Sea Water of Kagoshima Bay and the Open Sea Water (East China Sea).

The contents of arsenic and antimony in sea water samples taken from Kagoshima Bay and the East China Sea were analyzed. The samples were collected during the period 1981～1990. Sampling stations of Kagoshima Bay and the open sea (East China Sea) are shown in Figs. 1～ 3. The analytical results for arsenic and antimony are shown in Tables 1 ～ 2.

The arsenic and antimony contents of Kagoshima Bay and the East China Sea are summarized in Table 3. In the following discussion, Kagoshima Bay is divide into two sections by the line connecting Kagoshima City and Sakurajima; the southern part (Stn. 1 ～11, 33～37) and the northern part (Stn. 12～32, 38～44). And then considerable fumarolic activity is observed around Stations 38 and 40 in the Northern Kagoshima Bay.

Table 1. Contents of arsenic and antimony in sea water of Kagoshima Bay

Stn. No.	Station		Date	Depth (m)	W. T. ℃	pH	As μg/ℓ	Sb μg/ℓ	Remarks
1	31°30.3' N,	130°33.7' E	Oct. 15. '81	0	24.0	8.2	1.0	–	South. Kago. Bay
2	31°27.4' N,	130°35.4' E	Oct. 15. '81	0	24.1	8.2	1.3	–	South. Kago. Bay
3	31°24.1' N,	130°37.3' E	Oct. 15. '81	0	24.6	8.2	0.9	–	South. Kago. Bay
3	31°24.1' N,	130°37.3' E	Oct. 15. '81	20	24.4	8.2	1.0	–	South. Kago. Bay
3	31°24.1' N,	130°37.3' E	Oct. 15. '81	50	23.3	8.1	1.5	–	South. Kago. Bay
3	31°24.1' N,	130°37.3' E	Oct. 15. '81	100	17.3	8.0	1.5	–	South. Kago. Bay
3	31°24.1' N,	130°37.3' E	Oct. 15. '81	200	15.7	7.9	1.6	–	South. Kago. Bay
4	31°21.3' N,	130°39.1' E	Oct. 15. '81	0	25.0	8.3	0.5	–	South. Kago. Bay
5	31°18.0' N,	130°41.0' E	Oct. 15. '81	0	24.3	8.2	1.3	–	South. Kago. Bay
6	31°13.7' N,	130°43.9' E	Oct. 15. '81	0	24.8	8.3	0.8	–	South. Kago. Bay
7	31°19.7' N,	130°45.2' E	Oct. 15. '81	0	24.8	8.2	0.8	–	South. Kago. Bay
8	31°24.4' N,	130°42.2' E	Oct. 15. '81	0	25.0	8.1	1.5	–	South. Kago. Bay
9	31°27.8' N,	130°40.7' E	Oct. 15. '81	0	25.6	8.1	1.1	–	South. Kago. Bay
10	31°30.9' N,	130°38.4' E	Oct. 15. '81	0	25.8	8.1	1.8	–	South. Kago. Bay
11	31°33.2' N,	130°35.0' E	Oct. 15. '81	0	24.5	8.1	1.7	–	South. Kago. Bay
12	31°36.2' N,	130°35.5' E	Oct. 16. '81	0	23.3	8.1	2.1	–	North. Kago. Bay
13	31°38.5' N,	130°38.3' E	Oct. 16. '81	0	23.2	8.2	1.2	–	North. Kago. Bay
14	31°40.5' N,	130°40.7' E	Oct. 16. '81	0	23.5	8.2	2.8	–	North. Kago. Bay
15	31°39.2' N,	130°46.3' E	Oct. 16. '81	0	24.4	8.1	0.9	–	North. Kago. Bay
15	31°39.2' N,	130°46.3' E	Oct. 16. '81	20	24.2	8.1	1.9	–	North. Kago. Bay
15	31°39.2' N,	130°46.3' E	Oct. 16. '81	50	23.1	8.1	2.1	–	North. Kago. Bay
15	31°39.2' N,	130°46.3' E	Oct. 16. '81	100	17.0	7.7	2.8	–	North. Kago. Bay
15	31°39.2' N,	130°46.3' E	Oct. 16. '81	190	16.0	6.8	4.5	–	North. Kago. Bay
16	31°39.3' N,	130°46.0' E	Nov. 18. '82	0	22.0	8.2	1.7	–	North. Kago. Bay
16	31°39.3' N,	130°46.0' E	Nov. 18. '82	50	18.5	8.1	1.3	–	North. Kago. Bay
16	31°39.3' N,	130°46.0' E	Nov. 18. '82	100	17.5	7.6	2.1	–	North. Kago. Bay
16	31°39.3' N,	130°46.0' E	Nov. 18. '82	150	16.8	7.2	1.9	–	North. Kago. Bay
16	31°39.3' N,	130°46.0' E	Nov. 18. '82	200	16.8	6.7	2.7	–	North. Kago. Bay
17	31°39.9' N,	130°49.0' E	Nov. 18. '82	0	22.1	8.2	1.4	–	North. Kago. Bay
18	31°39.9' N,	130°44.8' E	Nov. 18. '82	0	21.5	8.3	1.6	–	North. Kago. Bay
19	31°39.9' N,	130°44.0' E	Nov. 18. '82	0	21.4	8.3	1.5	–	North. Kago. Bay
20	31°39.9' N,	130°42.7' E	Nov. 18. '82	0	21.5	8.3	1.5	–	North. Kago. Bay
21	31°39.9' N,	130°41.1' E	Nov. 18. '82	0	21.8	8.2	1.3	–	North. Kago. Bay
22	31°39.9' N,	130°38.9' E	Nov. 18. '82	0	22.0	8.2	1.4	–	North. Kago. Bay

Table 1. (Coninued)

Stn. No.	Station		Date	Depth (m)	W. T. ℃	pH	As μg/ℓ	Sb μg/ℓ	Remarks
23	31°38.0' N,	130°37.7' E	Nov. 18. '82	0	22.0	8.2	1.6	—	North. Kago. Bay
24	31°37.0' N,	130°36.6' E	Nov. 18. '82	0	21.5	8.3	1.5	—	North. Kago. Bay
25	31°36.0' N,	130°35.5' E	Nov. 18. '82	0	21.4	8.3	1.4	—	North. Kago. Bay
26	31°39.3' N,	130°46.1' E	Dec. 02. '83	0	19.6	8.2	1.7	0.27	North. Kago. Bay
26	31°39.3' N,	130°46.1' E	Dec. 02. '83	50	19.1	8.1	1.6	0.23	North. Kago. Bay
26	31°39.3' N,	130°46.1' E	Dec. 02. '83	100	16.9	7.7	2.1	0.14	North. Kago. Bay
26	31°39.3' N,	130°46.1' E	Dec. 02. '83	150	16.0	7.3	2.0	0.14	North. Kago. Bay
27	31°41.0' N,	130°44.3' E	Dec. 02. '83	0	19.1	8.3	1.5	0.10	North. Kago. Bay
28	31°40.5' N,	130°42.1' E	Dec. 02. '83	0	18.9	8.3	1.4	0.25	North. Kago. Bay
29	31°39.5' N,	130°40.1' E	Dec. 02. '83	0	19.2	8.3	1.4	0.12	North. Kago. Bay
30	31°38.7' N,	130°37.6' E	Dec. 02. '83	0	19.4	8.2	1.6	0.23	North. Kago. Bay
31	31°38.7' N,	130°38.5' E	Dec. 02. '83	0	19.6	8.1	1.5	0.20	North. Kago. Bay
32	31°36.5' N,	130°36.2' E	Dec. 02. '83	0	19.7	8.2	1.7	0.27	North. Kago. Bay
33	31°24.4' N,	130°39.1' E	Dec. 06. '85	0	18.6	8.2	1.3	0.35	South. Kago. Bay
33	31°24.4' N,	130°39.1' E	Dec. 06. '85	20	18.7	8.2	1.8	0.38	South. Kago. Bay
33	31°24.4' N,	130°39.1' E	Dec. 06. '85	60	18.7	8.1	1.6	0.27	South. Kago. Bay
33	31°24.4' N,	130°39.1' E	Dec. 06. '85	100	16.3	8.0	1.4	0.31	South. Kago. Bay
33	31°24.4' N,	130°39.1' E	Dec. 06. '85	150	15.4	7.9	1.5	0.27	South. Kago. Bay
33	31°24.4' N,	130°39.1' E	Dec. 06. '85	200	15.2	7.9	1.6	0.42	South. Kago. Bay
34	31°22.1' N,	130°37.2' E	Dec. 07. '85	0	19.3	8.2	1.5	0.46	South. Kago. Bay
35	31°24.9' N,	130°34.9' E	Dec. 07. '85	0	19.3	8.1	1.3	0.35	South. Kago. Bay
36	31°27.6' N,	130°33.9' E	Dec. 07. '85	0	18.9	8.1	1.7	0.42	South. Kago. Bay
37	31°31.5' N,	130°40.5' E	Dec. 08. '85	0	17.5	8.2	1.4	0.33	South. Kago. Bay
37	31°31.5' N,	130°40.5' E	Dec. 08. '85	30	17.4	8.2	1.5	0.27	South. Kago. Bay
37	31°31.5' N,	130°40.5 E	Dec. 08. '85	60	17.1	8.1	1.4	0.42	South. Kago. Bay
37	31°31.5' N,	130°40.5' E	Dec. 08. '85	90	16.5	8.1	1.5	0.27	South. Kago. Bay
37	31°31.5' N,	130°40.5' E	Dec. 08. '85	130	14.7	8.0	1.7	0.33	South. Kago. Bay
37	31°31.5' N,	130°40.5' E	Dec. 08. '85	160	14.8	7.9	1.7	0.42	South. Kago. Bay
38	31°38.9' N,	130°46.2' E	Dec. 08. '85	0	18.7	8.1	1.3	0.27	North. Kago. Bay
38	31°38.9' N,	130°46.2' E	Dec. 08. '85	30	18.6	8.0	1.2	0.27	North. Kago. Bay
38	31°38.9' N,	130°46.2' E	Dec. 08. '85	70	18.5	7.9	1.6	0.36	North. Kago. Bay
38	31°38.9' N,	130°46.2' E	Dec. 08. '85	110	16.9	7.5	1.8	0.42	North. Kago. Bay
38	31°38.9' N,	130°46.2' E	Dec. 08. '85	150	16.3	7.0	2.0	0.42	North. Kago. Bay
38	31°38.9' N,	130°46.2' E	Dec. 08. '85	190	16.2	6.8	2.9	0.96	North. Kago. Bay

Table 1. (Coninued)

Stn. No.	Station		Date	Depth (m)	W. T. ℃	pH	As μg/ℓ	Sb μg/ℓ	Remarks
38	31°38.9' N,	130°46.2' E	Dec. 08. '85	196	16.2	6.8	8.8	2.16	North. Kago. Bay
39	31°39.6' N,	130°46.1' E	Feb. 06. '86	0	13.9	7.8	1.7	0.11	North. Kago. Bay
39	31°39.6' N,	130°46.1' E	Feb. 06. '86	40	13.2	7.8	1.9	0.10	North. Kago. Bay
39	31°39.6' N,	130°46.1' E	Feb. 06. '86	80	13.0	7.9	1.8	0.10	North. Kago. Bay
39	31°39.6' N,	130°46.1' E	Feb. 06. '86	110	13.2	7.9	1.7	0.10	North. Kago. Bay
39	31°39.6' N,	130°46.1' E	Feb. 06. '86	140	13.2	7.9	1.6	0.14	North. Kago. Bay
39	31°39.6' N,	130°46.1' E	Feb. 06. '86	170	13.0	7.9	1.9	0.11	North. Kago. Bay
39	31°39.6' N,	130°46.1' E	Feb. 06. '86	200	13.3	7.9	1.6	0.10	North. Kago. Bay
40	31°39.7' N,	130°44.2' E	Oct. 28. '87	0	23.0	8.2	1.0	0.14	North. Kago. Bay
40	31°39.7' N,	130°44.2' E	Oct. 28. '87	50	21.9	8.1	1.2	0.15	North. Kago. Bay
40	31°39.7' N,	130°44.2' E	Oct. 28. '87	100	16.6	7.6	2.0	0.15	North. Kago. Bay
40	31°39.7' N,	130°44.2' E	Oct. 28. '87	150	16.0	7.2	2.3	0.30	North. Kago. Bay
40	31°39.7' N,	130°44.2' E	Oct. 28. '87	170	15.9	7.1	2.4	0.27	North. Kago. Bay
40	31°39.7' N,	130°44.2' E	Oct. 28. '87	190	15.8	6.8	2.7	0.43	North. Kago. Bay
40	31°39.7' N,	130°44.2' E	Oct. 28. '87	200	15.9	6.7	3.2	1.30	North. Kago. Bay
41	31°39.5' N,	130°43.1' E	Oct. 28. '87	0	23.0	8.2	1.0	0.14	North. Kago. Bay
42	31°39.7' N,	130°41.2' E	Oct. 28. '87	0	23.0	8.2	0.9	0.19	North. Kago. Bay
43	31°39.6' N,	130°39.0' E	Oct. 28. '87	0	23.1	8.2	1.0	0.12	North. Kago. Bay
44	31°39.4' N,	130°46.1' E	Jun. 30. '90	0	26.0	8.3	0.5	0.18	North. Kago. Bay
44	31°39.4' N,	130°46.1' E	Jun. 30. '90	200	19.6	6.8	1.6	0.95	North. Kago. Bay
44	31°39.4' N,	130°46.1' E	Jun. 30. '90	200	19.8	7.0	1.8	0.78	North. Kago. Bay
44	31°39.4' N,	130°46.1' E	Jun. 30. '90	200	19.9	6.6	2.3	1.20	North. Kago. Bay
44	31°39.4' N,	130°46.1' E	Jun. 30. '90	200	19.1	6.8	1.6	0.90	North. Kago. Bay

Table 2. Contents of arsenic and antimony in sea water of the East China Sea

Stn. No.	Station		Date	Depth (m)	W. T. ℃	pH	As μg/ℓ	Sb μg/ℓ	Remarks
50	24° 39.4' N,	123° 49.8' E	Oct. 17. '82	0	27.0	8.2	1.3	–	East China Sea
51	25° 16.3' N,	124° 17.0' E	Oct. 17. '82	0	27.5	8.3	1.4	–	East China Sea
52	25° 48.6' N,	124° 56.8' E	Oct. 17. '82	0	26.5	8.3	1.4	–	East China Sea
53	26° 18.6' N,	125° 41.9' E	Oct. 18. '82	0	26.8	8.3	1.5	–	East China Sea
54	26° 51.3' N,	126° 28.0' E	Oct. 18. '82	0	26.0	8.3	1.4	–	East China Sea
55	27° 23.3' N,	127° 11.6' E	Oct. 18. '82	0	26.5	8.3	1.7	–	East China Sea
56	27° 39.7' N,	128° 02.5' E	Oct. 18. '82	0	25.9	8.3	1.4	–	East China Sea
57	28° 03.5' N,	128° 47.5' E	Oct. 18. '82	0	26.0	8.3	1.5	–	East China Sea
58	24° 44.0' N,	124° 02.0' E	Oct. 07. '83	0	29.5	8.3	1.2	0.16	East China Sea
58	24° 44.0' N,	124° 02.0' E	Oct. 07. '83	50	30.1	8.2	1.1	0.21	East China Sea
58	24° 44.0' N,	124° 02.0' E	Oct. 07. '83	100	28.0	8.2	1.2	0.18	East China Sea
58	24° 44.0' N,	124° 02.0' E	Oct. 07. '83	500	18.0	7.9	1.6	0.16	East China Sea
58	24° 44.0' N,	124° 02.0' E	Oct. 07. '83	1,000	10.2	7.4	1.6	0.25	East China Sea
59	24° 54.0' N,	123° 22.0' E	Oct. 07. '83	0	30.0	8.2	1.0	0.17	East China Sea
59	24° 54.0' N,	123° 22.0' E	Oct. 07. '83	50	28.5	8.2	1.2	0.18	East China Sea
59	24° 54.0' N,	123° 22.0' E	Oct. 07. '83	100	25.0	8.1	1.2	0.18	East China Sea
59	24° 54.0' N,	123° 22.0' E	Oct. 07. '83	500	18.1	7.6	1.6	0.20	East China Sea
59	24° 54.0' N,	123° 22.0' E	Oct. 07. '83	1,000	11.0	7.5	1.7	0.26	East China Sea
60	25° 01.0' N,	122° 58.0' E	Oct. 07. '83	0	29.6	8.3	1.2	0.17	East China Sea
60	25° 01.0' N,	122° 58.0' E	Oct. 07. '83	50	29.0	8.3	1.5	0.30	East China Sea
60	25° 01.0' N,	122° 58.0' E	Oct. 07. '83	100	24.5	8.3	1.6	0.18	East China Sea
60	25° 01.0' N,	122° 58.0' E	Oct. 07. '83	500	14.5	7.6	1.8	0.20	East China Sea
60	25° 01.0' N,	122° 58.0' E	Oct. 07. '83	1,000	9.5	7.4	2.0	0.28	East China Sea
61	25° 09.0' N,	123° 30.0' E	Oct. 22. '83	0	29.2	8.3	1.2	0.21	East China Sea
61	25° 09.0' N,	123° 30.0' E	Oct. 22. '83	50	28.8	8.3	1.3	0.17	East China Sea
61	25° 09.0' N,	123° 30.0' E	Oct. 22. '83	100	24.9	8.2	1.6	0.28	East China Sea
61	25° 09.0' N,	123° 30.0' E	Oct. 22. '83	500	14.3	7.7	1.5	0.28	East China Sea
61	25° 09.0' N,	123° 30.0' E	Oct. 22. '83	1,000	9.0	7.5	2.1	0.61	East China Sea
62	26° 31.0' N,	122° 30.0' E	Aug. 04. '84	0	29.8	8.3	1.1	0.33	East China Sea
62	26° 31.0' N,	122° 30.0' E	Aug. 04. '84	50	25.6	8.3	1.2	0.25	East China Sea
63	26° 13.4' N,	122° 45.4' E	Aug. 04. '84	0	28.6	8.3	1.2	0.39	East China Sea
63	26° 13.4' N,	122° 45.4' E	Aug. 04. '84	50	23.2	8.2	1.8	0.37	East China Sea
64	26° 00.0' N,	123° 00.0' E	Aug. 04. '84	0	30.0	8.3	1.5	0.26	East China Sea
64	26° 00.0' N,	123° 00.0' E	Aug. 04. '84	50	25.4	8.3	1.6	0.31	East China Sea

Table 2. (Continued)

Stn. No.	Station		Date	Depth (m)	W. T. ℃	pH	As μg/ℓ	Sb μg/ℓ	Remarks
65	25° 46.5' N,	123° 15.6' E	Aug. 04. '84	0	30.4	8.3	1.2	0.34	East China Sea
65	25° 46.5' N,	123° 15.6' E	Aug. 04. '84	50	28.3	8.3	1.5	0.31	East China Sea
65	25° 46.5' N,	123° 15.6' E	Aug. 04. '84	100	23.0	8.2	1.6	0.31	East China Sea
66	25° 23.6' N,	123° 35.5' E	Aug. 04. '84	0	30.2	8.3	1.0	0.28	East China Sea
66	25° 23.6' N,	123° 35.5' E	Aug. 04. '84	50	27.0	8.3	1.5	0.29	East China Sea
66	25° 23.6' N,	123° 35.5' E	Aug. 04. '84	100	23.7	8.2	1.5	0.26	East China Sea
66	25° 23.6' N,	123° 35.5' E	Aug. 04. '84	500	14.2	8.0	1.5	0.28	East China Sea
66	25° 23.6' N,	123° 35.5' E	Aug. 04. '84	1,000	10.0	7.8	2.2	0.26	East China Sea
67	25° 09.9' N,	123° 51.8' E	Aug. 03. '84	0	30.1	8.3	1.2	0.29	East China Sea
67	25° 09.9' N,	123° 51.8' E	Aug. 03. '84	50	26.6	8.3	1.5	0.22	East China Sea
67	25° 09.9' N,	123° 51.8' E	Aug. 03. '84	100	24.1	8.3	1.3	0.17	East China Sea
67	25° 09.9' N,	123° 51.8' E	Aug. 03. '84	200	20.9	8.2	1.3	0.24	East China Sea
67	25° 09.9' N,	123° 51.8' E	Aug. 03. '84	500	15.0	8.1	1.5	0.28	East China Sea
67	25° 09.9' N,	123° 51.8' E	Aug. 03. '84	1,000	9.7	7.7	1.7	0.31	East China Sea
68	24° 52.6' N,	123° 45.7' E	Jul. 28. '84	0	31.0	8.3	1.2	0.17	East China Sea
68	24° 52.6' N,	123° 45.7' E	Jul. 28. '84	50	28.4	8.3	1.3	0.21	East China Sea
68	24° 52.6' N,	123° 45.7' E	Jul. 28. '84	100	24.0	8.2	1.5	0.21	East China Sea
68	24° 52.6' N,	123° 45.7' E	Jul. 28. '84	200	21.0	8.2	1.6	0.19	East China Sea
68	24° 52.6' N,	123° 45.7' E	Jul. 28. '84	500	14.3	8.0	1.9	0.26	East China Sea
68	24° 52.6' N,	123° 45.7' E	Jul. 28. '84	1,000	10.0	7.8	2.0	0.27	East China Sea
69	24° 40.1' N,	123° 30.1' E	Jul. 28. '84	0	30.4	8.3	1.3	0.15	East China Sea
69	24° 40.1' N,	123° 30.1' E	Jul. 28. '84	50	26.9	8.3	1.3	0.17	East China Sea
69	24° 40.1' N,	123° 30.1' E	Jul. 28. '84	100	23.2	8.2	1.3	0.21	East China Sea
69	24° 40.1' N,	123° 30.1' E	Jul. 28. '84	200	20.4	8.2	1.5	0.23	East China Sea
69	24° 40.1' N,	123° 30.1' E	Jul. 28. '84	500	14.5	8.0	1.6	0.25	East China Sea
69	24° 40.1' N,	123° 30.1' E	Jul. 28. '84	1,000	9.6	7.8	1.7	0.27	East China Sea
70	25° 15.8' N,	122° 09.1' E	Sept. 11. '85	0	28.1	8.1	1.0	0.28	East China Sea
71	25° 40.4' N,	123° 45.4' E	Sept. 11. '85	0	28.3	8.2	1.1	0.23	East China Sea
72	26° 22.1' N,	125° 12.2' E	Sept. 12. '85	0	28.9	8.1	1.1	0.26	East China Sea
73	27° 21.5' N,	126° 16.7' E	Sept. 12. '85	0	28.1	8.1	1.0	0.27	East China Sea
74	28° 23.2' N,	127° 24.2' E	Sept. 12. '85	0	30.0	8.2	1.0	0.18	East China Sea
75	29° 22.4' N,	128° 38.5' E	Sept. 12. '85	0	29.2	8.2	1.1	0.18	East China Sea
76	30° 17.9' N,	129° 40.9' E	Sept. 13. '85	0	28.2	8.2	1.1	0.17	East China Sea

Table 3. Average values of arsenic and antimony contents in sea water of Kagoshima Bay and the open ocean (East China Sea)

Locality		As $\mu g/\ell$			Sb $\mu g/\ell$	
Kagoshima Bay	Range	0.5～2.8	(0.5～8.8)	Range	0.10～0.46	(0.10～2.16)
	X_A	1.3_6	(1.7_2)	X_A	0.23_7	(0.37_1)
	X_G	1.3_0	(1.5_8)	X_G	0.21_4	(0.27_5)
	n	44	(91)	n	19	(54)
Open ocean (East China Sea)	Range	1.0～1.7	(1.0～2.2)	Range	0.15～0.39	(0.15～0.61)
	X_A	1.2_3	(1.4_2)	X_A	0.23_6	(0.24_6)
	X_G	1.2_2	(1.4_0)	X_G	0.22_7	(0.23_7)
	n	27	(67)	n	19	(59)

X_A: Arithmetic mean, X_G: Geometric mean, n: No. of samples, Without (   ): Surface water, (   ): Include each class of depth.

The ranges of arsenic and antimony contents for 19～44 surface water samples taken from Kagoshima Bay are 0.5～2.8 $\mu g/\ell$, 0.10～0.46 $\mu g/\ell$, respectively. The arithmetic mean and geometric mean are 1.3_6, 0.23_7 $\mu g/\ell$ and 1.30, 0.21_4 $\mu g/\ell$, respectively.

The ranges of arsenic and antimony contents for 19～27 surface water samples taken from East China Sea are 1.0～1.7 $\mu g/\ell$ and 0.15～0.39 $\mu g/\ell$, respectively. The arithmetic mean and geometric mean are 1.2_3, 0.23_6 and 1.2_2, 0.22_7 $\mu g/\ell$, respectively.

Levels of arsenic and antimony including each class of depth were found to be in the range of 0.5～8.8 $\mu g/\ell$ (geometric mean 1.5_8) and 0.10～2.16 $\mu g/\ell$ (geometric mean 0.27_5) for 54～91 samples taken from Kagoshima Bay and 1.0～2.2 $\mu g/\ell$ (geometric mean 1.4_0) and 0.15～0.61 $\mu g/\ell$ (geometric mean 0.23_7) for 59～67 samples taken from the East China Sea, respectively.

Table 4 shows summarizing arsenic and antimony contents including each class of depth of Northern Kagoshima Bay and Southern Kagoshima Bay. Arsenic contents (geometric mean) of Northern Kagoshima Bay is 1.3 times higher than Southern Kagoshima Bay. But, antimony contents (geometric mean) in Southern Kagoshima Bay is higher than Northern Kagoshima Bay. This cause does not become clear currently.

Vertical Distribution of Arsenic and Antimony in Sea Water of Kagoshima Bay.

Table 4. Average values of arsenic and antimony contents in sea water of Kagoshima Bay and the open ocean (East China Sea)

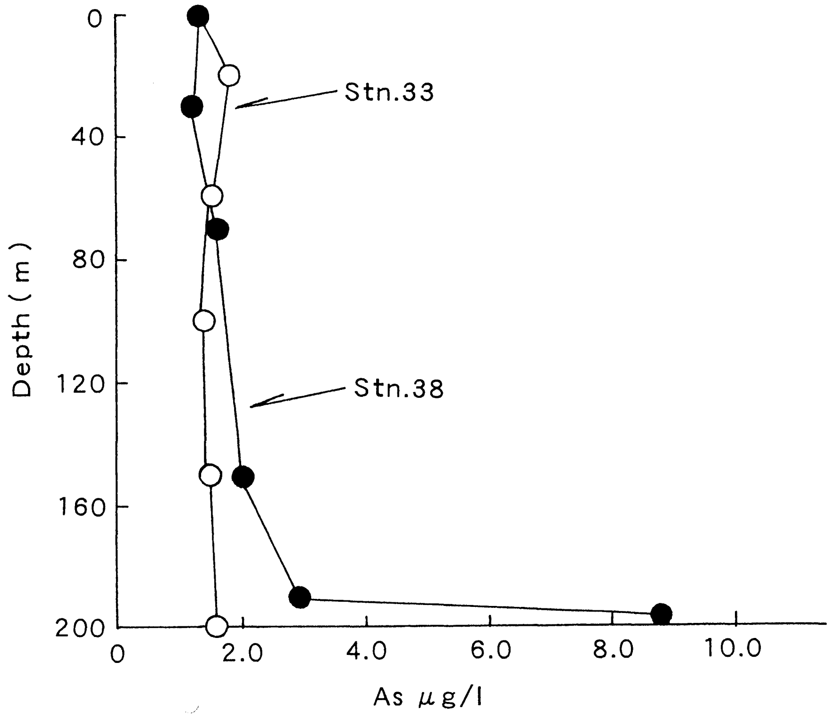
Locality	As $\mu g/\ell$			Sb $\mu g/\ell$		
Kagoshima Bay (Northern)	Range	0.5～2.8	(0.5～8.8)	Range	0.10～0.27	(0.10～2.16)
	X_A	1.4_3	(1.8_9)	X_A	0.18_5	(0.37_9)
	X_G	1.3_7	(1.7_1)	X_G	0.17_4	(0.25_2)
	n	28	(61)	n	14	(39)
Kagoshima Bay (Southern)	Range	0.5～1.8	(0.5～1.8)	Range	0.33～0.46	(0.27～0.46)
	X_A	1.2_4	(1.3_7)	X_A	0.38_2	(0.35_1)
	X_G	1.1_8	(1.3_3)	X_G	0.37_9	(0.34_6)
	n	16	(30)	n	5	(15)

X_A: Arithmetic mean, X_G: Geometric mean, n: No. of samples, Without ( ): Surface water, ( ): Include each class of depth.

Fig. 4 shows the vertical distribution of arsenic and antimony contained in sea waters from Stn. 33 and 38 of Kagoshima Bay. The vertical profiles of arsenic and antimony contents have increased appreciably in the depth and its contents are high in the hot position 200 m deep near the fumarole in the part of Northern Kagoshima Bay.

Mutual Correlation between Arsenic and Antimony Contents in Sea Water of Kagoshima Bay and East China Sea.

In sea water of Kagoshima Bay , there is a high positive correlation between the arsenic and antimony contents including each class of depth (correlation coefficient, 0.77). However, the correlation coefficient between the arsenic and antimony contents was 0.39 in sea water of East China Sea. It may be considered that factors such as geological circumstances and the intricate submarine topography of Kagoshima Bay.



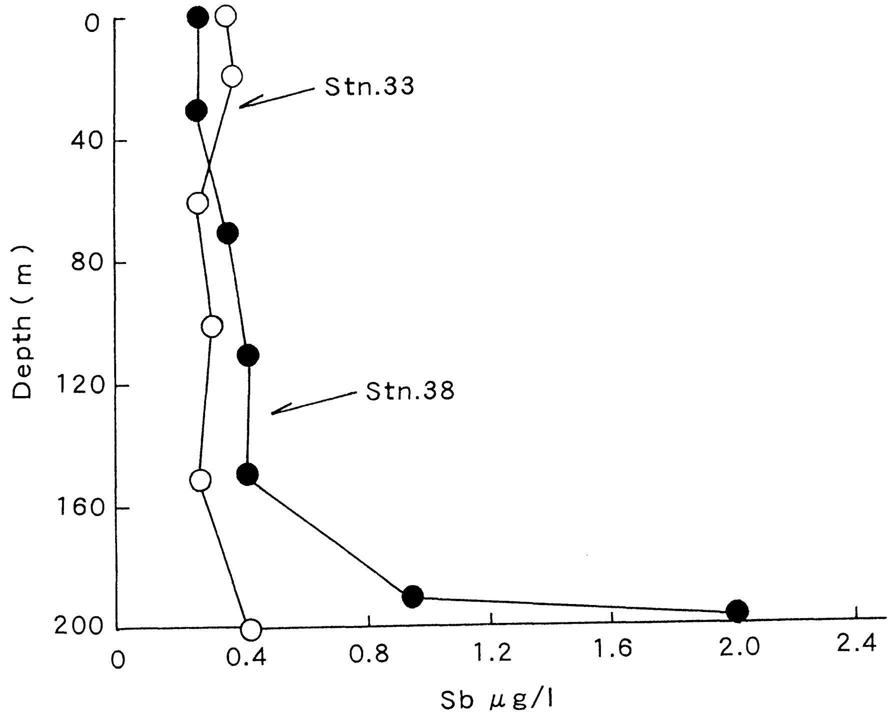


Fig. 4. Vertical profiles of arsenic and antimony contents in sea water of Kagoshima Bay.

● : Northern Kagoshima Bay

○ : Southern Kagoshima Bay

Conclusion

We have determined the acid dissolved arsenic and antimony content in sea sea water samples from Kagoshima Bay and East China Sea by hydride generation atomic absorption spectrometry.

Levels of arsenic and antimony including each class of depth were found to be in the range of 0.5~8.8 $\mu g/\ell$ (geometric mean 1.5_8) and 0.10~2.16 $\mu g/\ell$ (geometric mean 0.27_5) for 54~91 samples taken from Kagoshima Bay and 1.0~2.2 $\mu g/\ell$ (geometric mean 1.4_0) and 0.15~0.61 $\mu g/\ell$ (geometric mean 0.23_7) for 59~67 samples taken from the East China Sea, respectively.

In comparison of mean levels of arsenic and antimony contents of Kagoshima Bay and East China Sea, arsenic and antimony contents of Kagoshima Bay were slightly higher than East China Sea. There is a high positive correlation (correlation coefficient, 0.77) between the arsenic and antimony contents including each class of depth of Kagoshima Bay. Levels of arsenic and antimony contents of near the fumarole (200 m deep) for Northern Kagoshima Bay were slightly higher than those for Southern Kagoshima Bay. This suggests that these components have been supplied as a result of volcanic activity which both took place in the past and are under way at present.

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