Jurnal of Coastal Development
Volume 11 Number 3, June 2008 : 104-112
ISSN : 1720-1041

DISTRIBUTION OF SEDIMENT, BENTHIC FORAMINIFERA AND MERCURY IN THE SOUTH YATSUSHIRO SEA, KYUSHU, JAPAN

Rifardi

Department. of Marine Science, Faculty of Fisheries and Marine Sciences, Riau University Indonesia. Kampus Bina Widya Sp. Panam Pekanbaru-Riau Indonesia

Received :April, 23, 2008 ; Accepted: May, 29, 2008

ABSTACTS

Bottom sediment samples were collected at 74 stations in the South Yatsushiro Sea, off the west coast of central Kyushu Island, Japan using gravity corer. 62 core samples were used for bottom sediments analysis and for determination of mercury content. Among these samples, only 5 core samples were used for this study in an attempt to clarify the relationship between the vertical distributions of benthic foraminiferal assemblages (Bulimina denudata) and mercury contents in core sediments. The distribution pattern of sediment median diameter and of the maximum mercury content at some layers of each core show that the fine-grained sediment polluted by mercury were transported both northeastward and southward by weak longshore currents and spread toward north and west across the northern and souhtern part of the South Yatsushiro Sea. Bulimina denudata shows the highest frequency at every layer which has high mercury content ranging from 0.14 to 3.46 ppm, and is comparatively low at all unpolluted layers. The frequency of Bulimina denudata slightly decreased at the layers showing more than 3 ppm. All these signals suggest that Bulimina denudata does not prefer the bottom sediments showing high mercury contents but tolerates mercury pollution.

Keywords: *Bottom sediment, benthich forminifera, mercury.*

Correspondence: Phone : +62-761-862620 e-mail : fardi64@yahoo.co.id

INTRODUCTION

The South Yatsushiro Sea, a semi-closed inland sea, is located off the west coast of central Kyushu Island, Japan. Mercury-contaminated effluent was discharged into Minamata Bay from a chemical plant (Shinnihon Chisso Hiryo Co.) over a 20-year period until 1965, causing Minamata disease. Rifardi *et al*. (1998) and Rifardi and Oki (1998) clarified the relation between characteristics of sediments and environmental conditions, based on the analysis of 62 core samples taken from 74 stations in the South Yatsushiro Sea. Further, they roughly estimated the sedimentation rates of each station by the first appearance of high mercury contents and showed the distribution of the maximum mercury content analyzed at some layers of each core. Tomiyasu *et al*. (2000) reported that the surface sediment associated with the mercury contamination is not stable and apparently still moving even though 30 years have passed since the discharge of mercury-contaminated effluent ceased.The

 ISSN : 1720-1041

main purpose of this study is to clarify the relationship between the vertical distributions of benthic foraminiferal assemblages (*Bulimina denudata*) and mercury contents in core sediments of the South Yatsushiro Sea, Kyushu Island, Japan.

Physiographic Setting Of The Study Area

Yatsushiro, a semi-enclosed inland sea, is located off the west coast of central Kyushu Island, Japan (**Fig. 1)**. It is elongate in outline with a length of about 75 km from south to north and a width of about 10 to 20 km. The northern part of the sea has a rather flat bottom topography less than 30 m in depth and is occupied by rather low-salinity water masses due to fresh water influence from the Kuma river with a large drainage area **(Fig. 1).**

Climatologically, the Yatsushiro Kai is referable to the region of humid mesothermal (subtropical) climate. Annual mean temperature is 16.2°C, mean temperature in winter is 6.0°C and that in summer is 25.8°C. The rainy season is from early June and middle July in Kumamoto area (Rifardi *et al*. 1998).

The area studied is restricted within the southern part of the Yatsushiro Kai, being of about 39 km long and about 14 km wide. It is located between the lines of 32°08' 00"N to 32°23'00"N Lat. and between 130°12'00"E to 130°29'00"E Long. This inland sea has five outlets through straits (Karajiro Seto, Gannoshiri Seto, Mefuki Seto, Ikara Seto and Kurono Seto) leading to the East China Sea **(Fig. 1).** The studied area has a rather flat bottom topography and gets gradually shallower eastward (**Fig. 2)**. The Sashiki, Tsunagi, Minamata and Komenotsu rivers flow into the eastern part, all of which have rather large drainage areas as shown in (**Fig. 1)**. On the other hand, the rivers with small drainage areas flow into the southern part of the study area, namely the Euchi and Noda rivers, and a few small rivers on the islands to the west, which separate Yatsushiro Kai from the East China Sea.

Strong tidal currents flow through the straits of the western and southern parts of the area. The velocity of the flood current coming into Yatsushiro Kai, reaches 1.1 knot in the Gannoshiri Seto, 0.8 knot in the Mefuki Seto, and 4.9 knot in the Kurono Seto. On the contrary, the velocity of the ebb current reaches 1.5 knot, 2.0 knot, and 4.8 knot at each straits respectively (Rifardi, 2002).

MATERIALS AND METHODS

Bottom sediment samples used for the study were taken by Rifardi *et al.* (1998) from 74 stations in The South Yatsushiro Sea, Kyushu Island, Japan with depths from 14 to 54 m from 4 to 6 March 1996 **(Fig. 2).** All the samples were colected by using the gravity corer made by Hisanaga Co., Ltd, Kagoshima. For the present study, only five core samples from five stations were used for the analysis of benthic forminifera, namely stasion 19, 23, 24, 38 and 40 because the maximum mercury content (ppm) which have been analysed at some layers of each core, are recognized at these stasions.

Bottom sediment analyses.

Each sediment samples was sieved by the 2,000 μm and 63 μm screens under water shower and then divided into gravel, sand and mud fractions. The size frequency distribution of sand fraction was analyzed by the Emery settling tube method, while that of mud fraction by Particle Size Analyzer. The results of these grain size analyses was summarized by the Md Ø (median diameter) using the graphical method of Folk and Ward (1957).

ISSN : 1720-1041

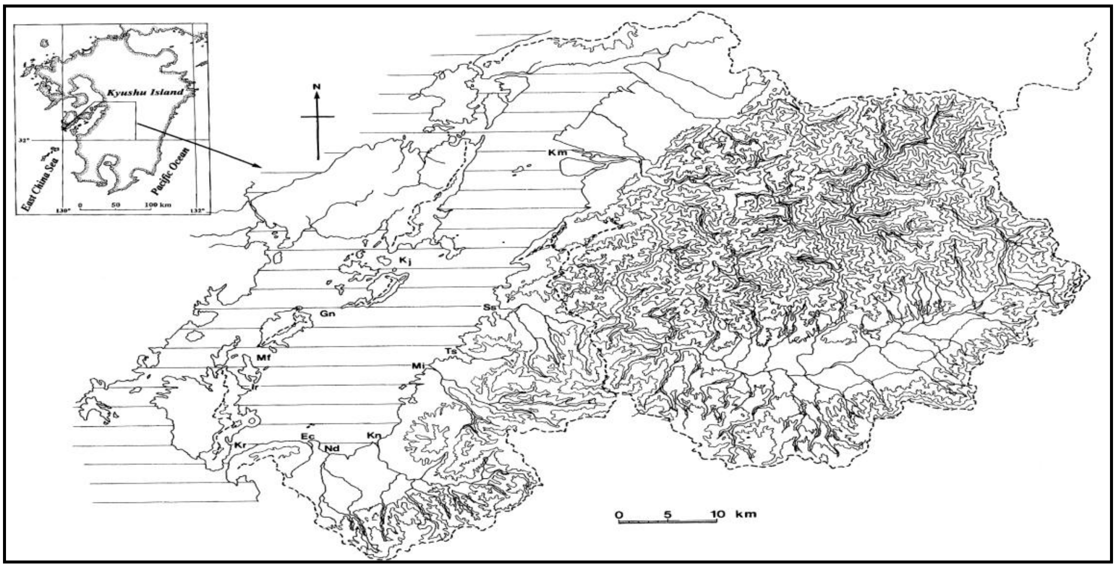

Fig. 1. Index map of the study area (after Rifardi e*t al*.1998; Kj: Karajiro Seto; Gn: Ganoshiri Seto; Mf: Mefuki Seto; Ir: Ikara Seto; Kr: Kurono Seto; Ec: Euchi River: Nd: Noda River; Kn: Komenotsu River: Mi: Minamata River; Ts: Tsunagi River; Ss: Sashiki River; Km: Kuma River; ----------: watershed).

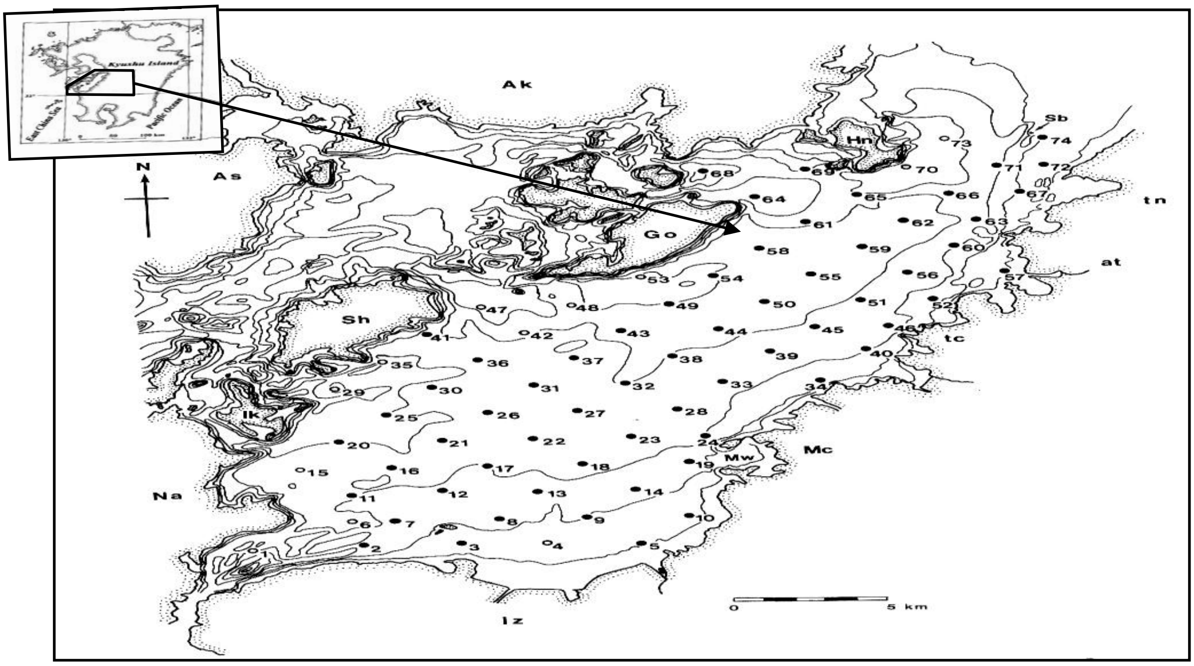

Fig. 2 Bathymery map showing the sampling stastions (after Rifardi e*t al*. 1998; circle: sediment samples could not be taken at the stastions; contour interval 10 m; Ak: Amakusa-Kamshima; As: Amakusa-shimoshima; Hn: Hino-shima; Sb: Shiba-shima; Go: Goshonourajima; Sh: Shishi-jima; Ik: Ikara-jima: Na: Nagashima; Iz: Izumi City; Mc: Minamata City; Mw: Minamata Wan; Mi: Minamata River; tc: Tsunagi-cho; at: Ashikita-cho).

 ISSN : 1720-1041

Benthic foraminifera analysis

Five cores (Station 19, 23, 24, 38 dan 40) were used for the analysis of benthic foraminifers. Sediment sample at 12 layers of 2-3, 5-6, 8-9, 13-14, 18-19, 23-24, 28-29, 33-34, 38-39, 43-44, 48-49 and 53-54 of core samples, which is approximately 10 cc of wet sediments, was preserved in alcohol. Each sample was washed through a 200-mesh sieve, and ovendried. More than 200 individuals of benthic foraminifera were picked out at random from every sediment sample. All the individual were spread on a tray, and were counted and identified based on some references such as Barker (1960), Loebich and Tappan (1988), Oki (1989), Kobayashi (1992), Hatta and Ujiie (1992), Ujiie and Rifardi (1993).

Mercury content analysis.

Mercury contents at 12 layers of 2-3, 5-6, 8-9, 13-14, 18-19, 23-24, 28-29, 33-34, 38-39, 43-44, 48-49 and 53-54 of core sampler were measured in laboratory (Rifardi *et al*. 1998). The procedure for determination of total mercury is based on the method proposed by Akagi and Nishimura (1991) as follow: a known a mount of sample was placed in a 50 ml volumetric flask, to which 2 ml of 1:1 nitric acid-perchloric acid solution and 5 ml of concentrated surfuric acid was added, and heated on a hot plate at 230ºC for 30 min. After cooling, the digested sample was made up to 50 ml with water and the mercury in a stable aliquot of the resulting solution (<20 ml) was analysed by CVAAS (Rifardi *et al.* 1998 and Tomiyasu *et al.,* 2000). The precision and accuracy of the technique has been repeatedly verified by inter-laboratory calibration exercises (Matsuo *et al*., 1989; Malm *et al*., 1995).

RESULTS AND DISCUSSION

Results

Results of mechanical analysis of the 62 bottom sediments show that the bottom sediments in the South Yatsushiro Sea were characterized by fine to very fine sand (*Md Ø* : > 2-4 Ø: Fig. 3). The areas with the fine-grained sediments (*Md Ø* : > 4 Ø) were found in the northeastern and northewestern parts under the influence of weak currents system; and the other areas were characterized by coarse-grained sediments influenced by strong tidal currents (Rifardi *et al*. 1998).

The distribution of the maximum mercury content which have been analysed at some layers of each core (**Fig. 4**) show the same tendency to the distribution of median diameter (**Fig. 3**). Judging from the distribution patterns, the fine-grained sediment polluted by mercury were transported both northeastward and southward by weak longshore currents and spread toward north and west across the northern and souhtern part of the South Yatsushiro Sea. These facts harmonize quite well with the current system based on the character of sediments in the sea. Rifardi *et al.* (1998) the general trend of the current system in the South Yatsushiro Sea is the following: 1) the areas near the straits characterized by coarse sediments under the influence of strong tidal and bottom currents; 2) the southern part and the off the mouth of the Minamata River, both of which are characterized by relatively coarse sediments under the influence of longshore currents and poorly sorted sediments supplied by the Komenotsu and Minamata Rivers; 3) the northern and eastern parts characterized by fine-grained sediments accumulated under condition of rather stagnant water masses; 4) the central area, characterized by relatively fine sediments and a large number of planktic empty tests deposited on the sea bottom under the

Jurnal of Coastal Development
Volume 11 Number 3, June 2008 : 104-112
ISSN : 1720-1041

condition of rather weak tidal current systems; 5) the northern part characterized by gravels or gravelly sand which were derived from shallow coastal areas.

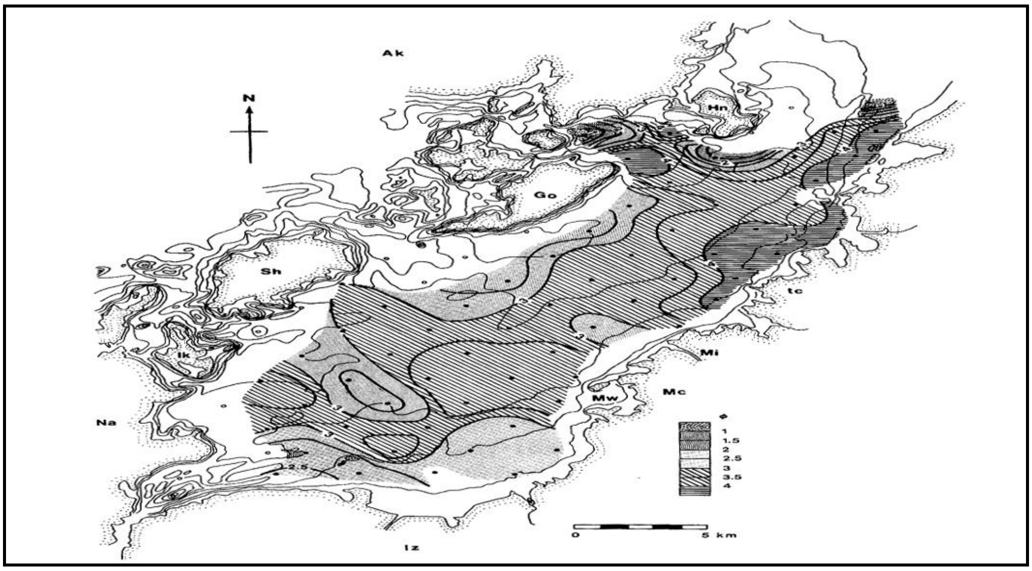

Fig. 3 Distribution of the median diameter ((Md Ø) of bottom surface sediments (after Rifardi *et al*. 1998).

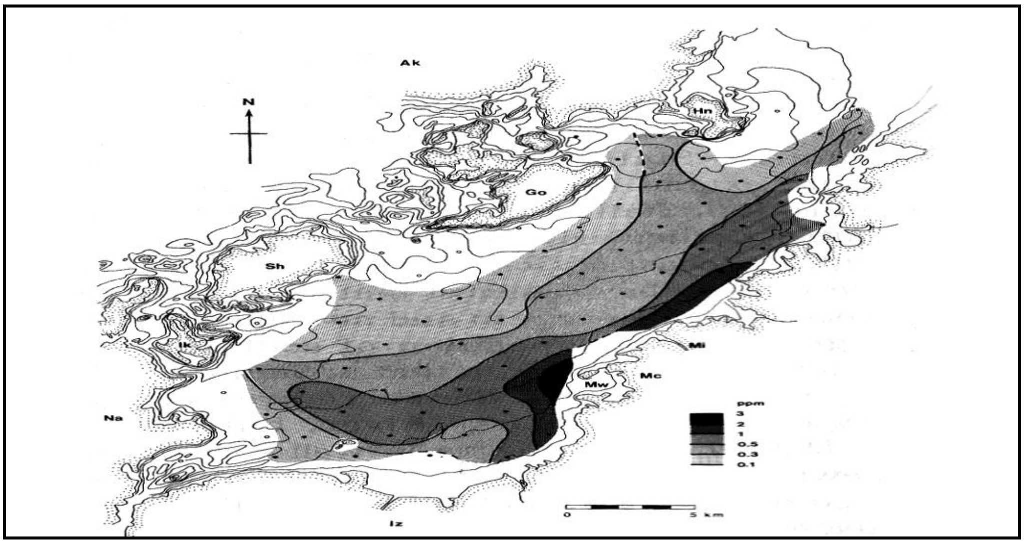

Fig. 4 Distribution of the maximum mercury content (ppm) which have been analysed at some layers of each core (after Rifardi e*t al*.1998).

Five cores (Station 19, 23, 24, 38 dan 40) were used for the analysis of benthic foraminifers. They showed the higher mercury content at some layer of the upper part of the core **(Table. 1 and Fig. 5).** Two cores were taken from the stations 19 and 24, which showed more than 3 ppm of the mercury content, one was from the station 40 which showed 1.79 ppm and two were from the stations 23 and 38 which showed less than 0.7 ppm. In the lower part of the cores, the mercury content fell sharply and showed no apparent trends.

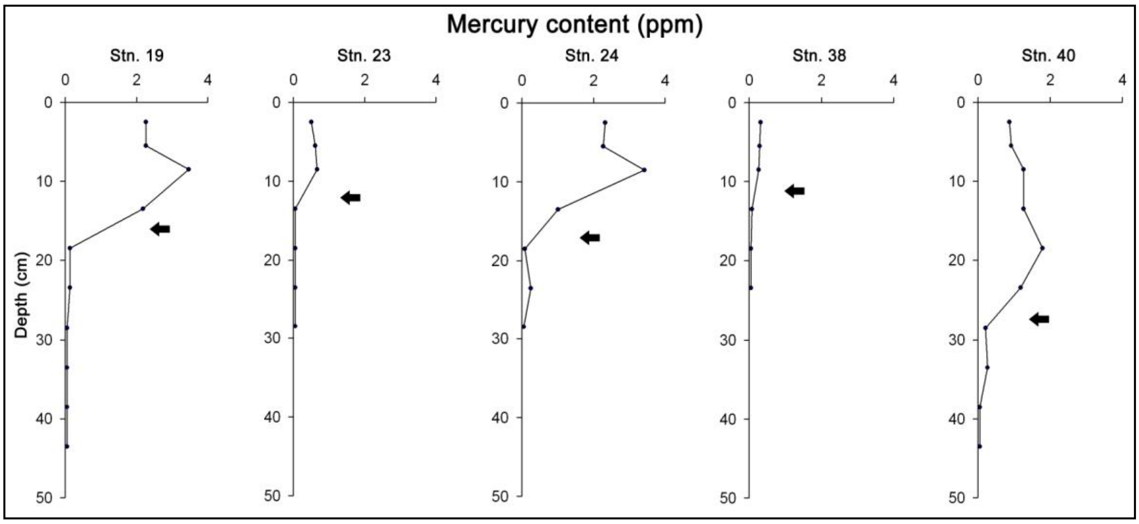

Fig. 5 Vertical distribution of mercury contents in core samples (arrow: first appearance of high mercury contents)

Since 1946, methyl mercury had been discharged into the Minamata Bay (Minamata Wan: Mw) as part of the Yatsushiro Sea through the drainpipes from Minamata Factory of Shinnihon Chisso Hiryo Co., Ltd. Mercury contents of less than 0.1 ppm (0.036-0.094 ppm) in the deepest part of the cores have been regarded as the background level of mercury for the Yatsushiro Sea. The first appearance of high mercury contents at each core sample indicates the arrival time of pollutants at the points. Each sampling point has a time-lag depending on the distance from the drainage of the factory and currents system in the area. It is a reason why the mercury contents were decreased sharply in station 19, 23 and 24. In addition to, the higher mercury contents were obtained at station 19, 23, and 24 due to location of these stations near the sources of the pollution, (**Fig. 2**). High mercury content was also recognized at station 40 located northeastern from the source. It is caused by the fine-grained sediment polluted by mercury were transported northeastward by weak longshore currents as explained above. Sato *et al*. (1997) determined the content of mercury in five organs of the mussel *Mytilus galloprovinciales* for four filed population in Minamata City in 1995. In that study, the content of mercury in adductor mussel was highest in population located in the vicinity of Minamata Bay.

Vertical distribution of mercury contents in core samples at each stations (19, 23, 24, 38 and 40) are difference **(Fig. 5).** This differentiation is caused by different sedimentation (depositional) rate at each station, as explained by Tomiyasu *et al.* (2000) mercury discharged from the chemical plant (the sources of the pollution) was adsorbed by particles and deposited in the sediment. After discharge ceased, the content of mercury in the sediment decreased gradually probably as uncontaminated or less contaminated particles were deposited. Sedimentation (depositional) rate in the stations are as following: station 19 (24 cm/50 year), 23 (9 cm/50 year), 24 (24 cm/50 year), 38 (9 cm/50 year), and station 40 (34 cm/50 year), Rifardi *et al.* (1998).

Jurnal of Coastal Development
Volume 11 Number 3, June 2008 : 104-112 ISSN : 1720-1041

Vertical changes of the benthic foraminiferal assemblages were examined at a few layers of each core. The results of the examination was summarized into the number of individual and species of benthic forminiferal, and frequency of *Bulimina denudata*, together with mercury content in **Table 1**. Down core changes of frequency of *Bulimina denudata* (%) are shown in **Fig 6.**

Table 1. Analytical results of mercury determination in core samples and the down core changes of frequency of *Bulimina denudate*

Station	Layer (cm)	Mercury content (ppm)	Number of Individual	Number of Species	Frequency of *B. denutada* (%)
	2 – 3	2.28	201	59	26.3
	8 – 9	3.46	234	46	14.4
19	23 – 24	0.14	649	54	14.0
	28 – 29	0.06	463	54	4.9
	43 – 44	0.06	1014	45	0.9
	2 – 3	0.5	579	72	18.8
	8 – 9	0.67	3200	64	14.5
23	13 – 14	0.06	4040	57	3.0
	18 – 19	0.05	3113	67	2.8
	28 – 29	0.05	1567	88	0.3
	2 – 3	2.33	189	65	15.4
24	8 – 9	3.43	2322	60	9.2
	28 – 29	0.06	1181	47	0
	2 – 3	0.32	1811	82	3.3
	5 – 6	0.39	4129	88	4.2
38	8 – 9	0.27	4580	87	3.5
	13 – 14	66.5	6775	80	2.2
	18 – 19	66.7	4380	73	1.4
40	2 – 3	0.86	130	38	26.5
	18 – 19	1.79	486	37	20.6
	22 – 34	0.26	880	55	12.7
	38 – 39	0.06	579	43	4.1

If the (**Fig. 5)** overlay to (**Fig. 6)**, it become clear that at stations 19, 23, 24 and 40, *Bulimina denudata* shows the highest frequency at every layer which has high mercury content ranging from 0.14 to 3.46 ppm, and is comparatively low at all unpolluted layers except for one layer of Station 19. Mercury contents of less than 0.1 ppm (0.036-0.094 ppm) in the deepest part of the sediment cores have been regarded as the background level of mercury for theYatsushiro Sea sediment, and the sediment containing mercury at content above 0.1 ppm have been considered to be polluted (Rifardi *et al*. 1998; Tomiyasu *et al.* 2000).

The mercury content did not change significantly at a core depth greater than 28 cm with average being only 0.058 ppm. Apparently, the lower part of the core was deposited prior to industrial development and accordingly, the mercury content at the part was taken as the background level (Tomiyasu *et al*. 2000). At Station 38 located in the central part of the sea, only *Discorbis mira* is predominant (more than 4.5 %) at every layer, but shows comparatively high frequencies (3.5%, 4.2 %) at two layers, which have high mercury content (0.27, 0.39ppm).

 ISSN : 1720-1041

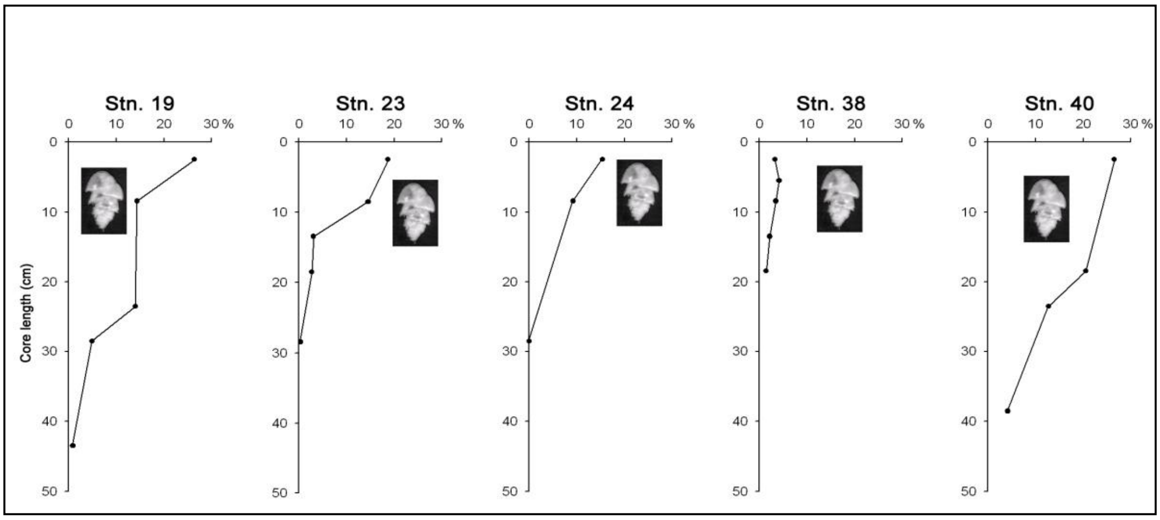

Fig. 6 Down core changes of frequency of *Bulimina denudata* (: *Bulimina denudata*)

Though the oceanographic conditions and sedimentary environments (Rifardi *et al*. 1998) hardly showed difference before and after discharge of mercury-contaminated effluent, the frequency of *Bulimina denudata* abruptly increased at the layers showing high mercury contents. This fact suggests that *Bulimina denudata* is quite within the bounds of possibility for indicator of mercury pollution. But the frequency of *Bulimina denudata* slightly decreased at the layers showing more than 3ppm. These facts are assumed to support the idea that *Bulimina denudata* does not prefer the bottom sediments showing high mercury contents but tolerates mercury pollution compared with other species.

CONCLUSION

In general, the relationship between the vertical distributions of benthic foraminiferal assemblages and high mercury contents in core sediments of the South Yatsushiro Sea, Kyushu Island, Japan shows positive corellation. The frequency of *Bulimina denudata* abruptly increased at the sediments showing high mercury contents, but the frequency of this species tend to be decreasing at the sediments showing mercury contents more than 3 ppm. It is still in questionable whether *Bulimina denudata* can be a species indicator of mercury pollution.

ACKOWLEDGEMENTS

I wish to express my deep gratitude to Prof. Kimihiko Oki, Professor of Kagoshima University, Japan for valuable suggestions concerning the theme and content of this paper.

REFERENCES

Barker, R. W., 1960: Taxonomic notes on the species figured by H. B. BRADY in his report on the foraminifera dredged by H.M.S. *Challenger* during the years 1873-1876. *Soc. Econ. Paleont. Mineral., Special Pub*., 9. 1-238.

Folk, R.L and Ward, W.C., 1957: Brazos River bar: a study significance of grain size parameter. *Jour. Sed. Pet*., 27:3-26.

Hatta, A. and Ujiie, H., 1992: Benthic foraminifera from coaral seas between Ishigaki and Iriomote Islands, southern Ryukyu Island Arc, northwestern Pacific. *Bull. Coll. Sci., Univ. Ryukyus*, 53, 49-119

Kobayashi, M., 1992: Preliminary Result on the Distribution Pattern of Benthic Foraminifera, in the Yatsushiro-kai, Western Kyushu, Japan. *Kumamoto Jour. Sci. Geol*., 13 (2), 13-24.

Loeblich, A. R., Jr. and Tappan, H., 1988: *Foraminiferal Genera and Their Distribution*. Van Nostrand Reinhold Co., N.Y., 970 p.; plate vol. 212p; 847 pls.

Oki, K., 1989: Ecological analysis of benthonic foraminifera in Kagashima Bay, South Kyushu, Japan. *South Pacific Study*, 10 (1) : 1-191.

Rifardi, Oki, K. and Tomiyasu, T., 1998. Sedimentary Environments Based on Textures Surface Sediments and Sedimentation rates in the South Yatsushiro Kai (Sea), Southwest Kyushu, Japan. *Jour. Sedimentol. Soc. Japan*. (48): 67-84.

Rifardi and Oki, K., 1998: Relative sedimentation rates and taphonomy inferred from the L/Tl values of benthic foraminifers in the southern Yatsushiro Kai (Sea), southwest Kyushu, Japan. *Fossils*, (65) 10-30.

Rifardi. 2002. Ecological Analysis of Living Benthic Foraminifera in Surface Sediments from the South Yatsushiro Kai (Sea), Southwest Kyushu, Japan. *Journal of Coastal Development. Research Institute Diponegoro University.* 5(3)117-129.

Sato, M., Hiraguchi, K., Takashi, T., Akagi, H., 1997. Distribution of Total Mercury and Methylmercury in Tissu of *Mytulus galloprovincialis*. *Environ. Sci.* (5), 225-237.

Tomiyasu, T., Nagano, A., Yonehara, N., Sakamoto, H., Rifardi, Oki, K. and Akagi, H., 2000: Mercury contamination in the Yatsushiro Sea, south-western Japan: spatial variations of mercury in sediment.*The Science of the Total Environment*, (257), 121-132.

Ujiie, H and Rifardi, D., 1993: Some benthic foraminifera fron the Oura River Estuary and its Environs, Okinawa. *Bull. Coll. Sci., Univ. Ryukyus*, (56) 121-243.