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Heavy Metals in Mussels in the Korean Coastal Waters

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韓國沿岸 眞珠담치의 重金屬含量

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Abstract: Heavy metal contents in soft tissues of mussels, *Mytilus edulis*, of Imweon, Banweol, Jinhae Bay and Yeosu in Korea were determined during 1981~82. The heavy metals measured were Cd, Cr, Cu, Pb, Zn, Mn and Fe. Depuration of mussel samples in clean seawater was needed immediately after collection for the complete excretion of gut contents. The 48hr depuration was adequate in the present study. Of the four study areas, Imweon showed the highest levels of Cd, Cr and Cu, and the lowest levels of Mn and Fe. Yeosu showed the highest Pb, Mn and Fe contents. In Jinhae Bay, St. 9 showed the greatest Pb, Zn, Mn and Fe contents, whereas the highest levels of Cd, Cr, and Cu were recorded at Sts. 7, 4 and 2, respectively. The concentrations of metals, except Cu, in mussels decreased with the growth of shell size.

要約 : 동해안의 임원, 서해안의 반월, 그리고 남해안의 진해만과 여수 등지에서 진주담치 시료를 채취하여 생체에 함유되어 있는 중금속 함량을 1981~82년에 걸쳐 조사하였다. 조사한 중금속은 Cd, Cr, Cu, Pb, Zn, Mn, Fe 등 7가지였다. 시료채취시 시료는 깨끗한 해수에 담가 청장(depuration) 시키는 것이 좋으며 시간은 48시간 정도가 적당하였다. 진주담치중의 중금속 함량은 임원해역의 자연산이 Cd, Cr, Cu 등이 특히 높았으나 Mn과 Fe 등은 조사지역 중에서 가장 낮았다. 반면에 여수는 Pb, Mn, Fe 등의 함량이 높은 것으로 나타났다. 진해만에서는 마산만 입구의 양식 진주담치도 중금속 함량이 비교적 낮은 것으로 조사되었다. 그리고 중금속들은 Cu를 제외하고는 진주담치가 성장해 감에 따라 건중량 농도가 감소하는 것으로 나타났다.

INTRODUCTION

Studies on the trace metal levels of different water bodies may be carried out using samples of water, sediments, or members of the indigenous biota, called indicator or sentinel organisms. The use of indicator organisms has certain advantages over that of water or sediments in defining the trace metal abundance in an area. The organisms provide a record of trace metal accumulation integrated over a period of months, eliminating the need for frequent sampling, as in water analysis. Furthermore, most of the trace metals have seawater concentrations in the range from parts per quadrillion (10^{-15} g/g) to parts per trillion (10^{-12} g/g) (Golderg et al., 1978). Although methodologies for the measurements of trace metals at these low levels in seawater are being developed, they are not yet in routine use.

During the last decade, there have been a number of studies on the use of indicator organisms, such as mussels and oysters, to monitor the seawater pollution from heavy metals (Cunningham and Tripp, 1975; Chow et al., 1976; Phillips, 1977; 1978; 1979; Goldberg et al., 1978; Hung et al., 1981). In Korea, there have been a few studies on analyzing the heavy metal levels in marine biota (Won, 1973; Do et al., 1981). However, no systematic study has

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been made on the use of indicator organisms to evaluate the pollution burden of heavy metals on coastal water.

The present paper reports the use of bivalve mussels, *Mytilus edulis*, as an indicator organism to monitor the water pollution from heavy metals in the four coastal areas of Korea.

SAMPLING AND ANALYTICAL METHODS

Mussel samples were collected from Imweon, Jinhae Bay, Yeosu, and Banweol during Octover, 1981-April, 1982 (Fig. 1). In Jinhae Bay, the locations of sampling sites are shown in Fig. 2. The species of mussels were *Mytilus edulis*. Most of mussel samples were obtained from the aquaculture farms, while those from Imweon were wild ones.

The mussel samples were depurated in clean seawater immediately after collection in the field over 24 hours for the purpose of the complete excretion of gut contents. These may include digested and undigested food, and sediment particles, all of which may be rich in trace metals. After depuration the samples were put into the plastic bags, frozen and transported to the laboratory for analysis.

In the laboratory, ten grams of the homogenized sample from 10 individuals were taken in a porcelain crucible and dried in an oven for 12 hours at 105°C. The dried sample was weighed, then charred in a muffle furnace for three hours at 550°C. At this stage, the color of samples changed into grey. It was then transferred to a 15ml pyrex tube, 10ml of 1 N HNO_3 was added, and the solution was shaken by an electric shaker for 1 min. After 1-hr standing, the concentrations of heavy metals in solution were determined by flame atomic absorption spectrophotometry (AAS) with Varian Model 875 with background corrector or flameless AAS with carbon rod atomizer.

Heavy metals determined in the soft tissues of mussels were cadmium(Cd), chromium(Cr), copper(Cu), lead(Pb), zinc(Zn), manganese (Mn), and iron(Fe). All metals were determined by flame AAS except lead, which was measured by flameless AAS. The metal concentrations were represented as ppm dry weight.

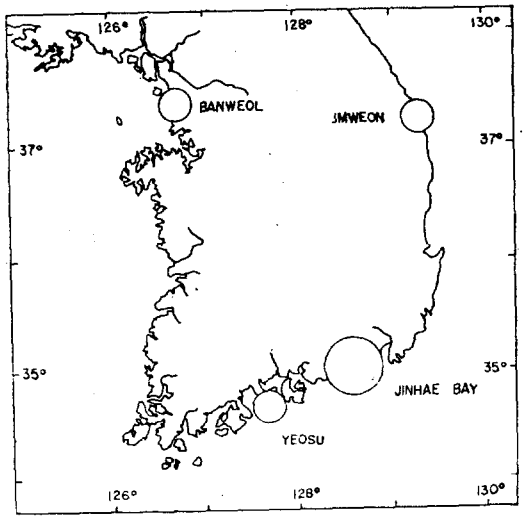

Fig. 1. Sampling sites in Korea.

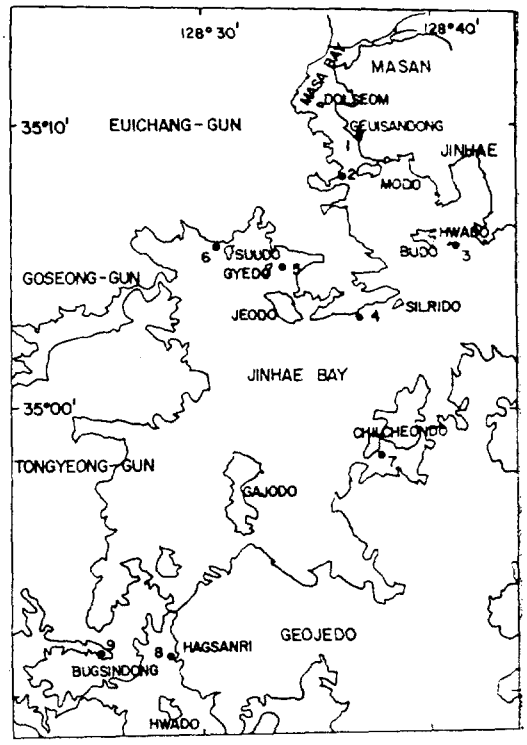

Fig. 2. Sampling stations in Jinhae Bay

RESULTS AND DISCUSSION

Depuration

Depuration of mussel samples in clean seawater is considered to be needed immediately after collection in the field for the complete excretion of gut contents. The variation of metal concentrations in mussels was tested during the depuration period. Samples were stored in a large plastic box with clean seawater for 72 hours. The seawater was replaced every two hours for the first eight hours, and every eight hours for the rest. A batch of samples was taken out from the box every 24 hours for the analysis of heavy metals in mussels. This result is shown in Fig. 3.

During the depuration period, heavy metal contents in the soft tissues of mussels decreased with time, except Pb. The Cd concentration dropped from 1.4 ppm to 1.1 ppm in 24 hours, and to 0.7ppm in 48 hours, but no further reduction was observed. The Cr concentration decreased from 2.3ppm to 2.0ppm in 24 hours, and after this, only a small variation was observed. Similar trends also appeared with Cu and Fe. With Mn, however, a significant decrease in concentration was shown with the depuration time. The initial conconcentration, 11.4 ppm, was reduced to 7.8ppm in 24 hr, to 6.0ppm in 48 hr, and to 4.7ppm in 72 hr. With Pb, on the other hand, the concentration increased with time. This may be due to the contamination from the container. The Zn concentration decreased from 71ppm to 62ppm in 48 hr, and no further significant variation was observed after 48 hr.

The above results indicated that the depuration period of 48 hr is recommended in analyzing mussel samples for heavy metals.

Heavy metals in mussels in the coastal areas

Heavy metal levels in the soft tissues of mussels were determined in Imweon of the East Coast, Jinhae Bay and Yeosu of the South Coast, and Banweol of the West Coast. The sampling time, frequency, and results of heavy metal analyses are given in Table 1.

Cadmium and Chromium

The ranges of Cd and Cr concentrations in mussels of the whole study areas were 1.1-2.9 ppm and 1.3-8.3ppm, respectively (Table 1). The Cd ard Cr levels were the highest in Imweon, then Banweol, Yeosu and Jinhae Bay

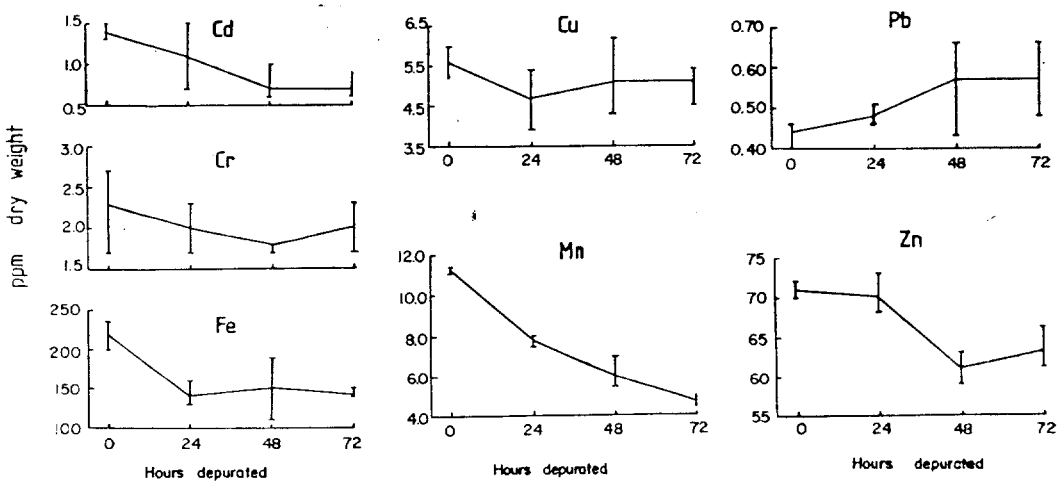

Fig. 3. Depuration of heavy metals in mussels, *M.edulis*.

Table 1. Heavy metal concentrations in soft tissues of mussels, *Mytilus edulis* (ppm dry weight).

Sampling		Meat weight(g, wet)		Water content (%)	Cd	Cr	Cu	Pb	Zn	Mn	Fe
Site	Time	Range	Mean								
Imweon	Oct. 81	6.53~10.04	7.56	85.9	2.9	4.4	6.6	1.12	59	5.5	170
Banweol	Apr. '82	8.25~18.03	10.77	83.7	2.5	4.1	5.9	0.65	72	17.7	430
Yeosu	Mar. '82	7.20~18.00	11.18	83.8	2.4	3.6	3.7	1.14	50	17.8	790
Jinhae Bay											
St. 1	Oct. '81	3.21~ 8.91	5.52	85.2	1.1	2.1	4.8	1.70	75	35.1	250
	Mar. '82	9.17~19.07	13.50	79.8	1.1	2.3	4.5	0.42	69	11.3	220
St. 2	Nov. '81	3.97~ 7.66	5.36	87.8	1.3	2.3	5.9	1.59	103	31.3	480
	Mar. '82	4.59~ 8.76	6.55	83.4	1.8	3.1	7.8	0.67	80	15.0	430
St. 3	Mar. '82	3.61~15.12	8.06	84.2	2.1	2.8	3.4	0.77	71	10.5	370
St. 4	Nov. '81	5.45~12.07	7.77	84.4	2.9	8.3	4.6	1.25	83	23.5	750
	Feb. '82	4.67~ 9.55	7.78	85.0	1.4	5.0	5.2	0.43	67	14.0	640
	Mar. '82	5.97~20.25	11.40	85.4	1.3	5.7	5.7	0.27	52	8.0	100
St. 5	Mar. '82	3.98~17.25	7.28	84.9	1.9	2.0	5.0	2.07	45	9.9	570
St. 6	Mar. '82	5.70~18.90	11.07	82.1	1.8	1.3	6.5	0.64	57	12.9	480
St. 7	Mar. '82	5.07~ 8.73	6.54	83.3	2.7	2.7	6.1	1.50	69	12.6	520
St. 8	Mar. '82	3.02~11.19	4.54	87.0	2.0	2.1	4.7	0.75	70	13.9	600
St. 9	Nov. '81	5.12~15.74	10.31	84.6	2.3	2.3	4.7	2.75	108	21.2	740
Mean*	Mar. '82	3.02~20.25	8.81	83.9	1.9	2.7	5.4	1.09	69	12.8	450

* Mean of Jinhae Bay, based on data of March '82.

in the decreasing order. In Jinhae Bay, St 7 of Chilcheonsudo and St. 4 near Silrido showd the highest levels of Cd(2.7 ppm) and Cr(5.7 ppm) in March, 1982. In contrast, St. 1 in Masan Bay gave the lowest Cd values in mussels, although a high content was expected from the high Cd concentration in water.

With the shell growth, the Cd and Cr levels in mussels, increased at St. 2, whereas they decreased at St. 4 with no significant variation at St. 1.

The mean concentration of Cd in Jinhae Bay (0.36 ppm wet weight) in the present study was slightly lower than that of Do et al.(1981; 0.40ppm wet weight) in July, 1980 in Masan Bay. In contrast, the mean value of Cr in Jinhae Bay(0.52 ppm wet weight) was higher than that of Do et al. (0.3ppm wet weight) in the same area.

The mean value of Cd in bivalves was reported as 2 ppm (Bryan, 1976), and, compared with this value, Banweol, Yeosu and Imweon showed slightly higher levels of Cd, whereas Jinhae Bay represented a little lower levels. The Cd levels of this study, however, were considerably lower than those in the polluted Bristol Channel in the United Kingdom (17.9 ppm; Nickless et al., 1972) (Table 2).

Copper and Lead

The ranges of Cu and Pb concentrations in mussels were 3.4-7.8 ppm and 0.27-2.75 ppm, respectively. The Cu levels were the highest in Imweon, followed by Banweol, Jinhae Bay, and Yeosu in the decreasing order. There was no appreciable difference in Pb contents between the study areas, except Banweol which showed the lowest Pb value. In Jinhae Bay the highest levels were recorded at St. 2 for Cu and St. 9 for Pb.

The Pb contents in mussels decreased greatly with the shell growth at Sts. 1, 2 and 4. But the Cu values increased with the growth of

Table 2. Comparison of metal concentrations in mussels from Korean Coastal Waters to those in mussels from elsewhere in the world (ppm dry weight)

Sampling location	Cd	Cr	Cu	Pb	Zn	Mn	Fe	Source
Niewpoort, Belgium	0.58	3.0	8.3	2.4	130	—	—	Meeus-Verdinne *et al.* (1983)
Trondheimsfjorden, Norway	<1~5	4~49	5~88	—	85~359	—	—	Lande (1977)
Bristol Channel, UK[1]	4~60	—	—	1~30	62~250	—	—	Nickless *et al.* (1972)
Poole Harbour, UK	4~65	—	—	7~19	94~162	3~5	87~154	Boyden (1975)
Peel, Isle of Man, UK[2]	2.5	—	16.5	197.6	301	—	—	Soothgate *et al.* (1983)
Scotland, UK	0.90~4.55	—	3.35~41.0	1.5~22.0	32.5~235	—	—	Topping (1983)
England, UK	1.0~31.0	—	3.5~34.5	2.5~175	50~450	—	—	Topping (1983)
N. Ireland, UK	0.60~3.10	—	3.9~13.5	1.65~16.0	51~235	—	—	Topping (1983)
Wales, UK	1.5~83.5	—	5.5~17.5	ND-124	70~260	—	—	Topping (1983)
Narragansett, USA[3]	1.7	—	10.2	4.1	138	15.0	170	Goldberg *et al.* (1978)
La Jolla, USA	2.0	—	7.8	2.9	177	3.9*	170*	Goldberg *et al.* (1978)
S. California Bight, USA	5.6	1.8	6.9	1.8	113	—	—	Gordoin *et al.* (1980)
Tasmania, Australia	13	—	9.5	75	177	—	—	Cooper *al et.* (1982)
Tasman Bay, New Zealand	<10	16	9	12	91	27	1960	Brooks *et al.* (1965)
Penang Is., Malaysia	5.6	6.5	ND	18.3	117	23.5	489	Silvalingam (1982)
Raysut, Oman	7.6	3.1	4.0	ND	37.5	3.3	60	Burns *et al.* (1982)
Shindai coast, Taiwan[4]	3.06	—	8.19	61.13	—	—	—	Hung *et al.* (1981)
Goseong, South Coast	0.87	—	5.87	6.43	—	—	—	Won (1973)
Sogcho, East Coast	0.10	—	3.96	6.00	—	—	—	Won (1973)
Jinhae, South Coast	0.59	—	5.57	8.93	—	—	—	Won (1973)
Imweon, East Coast	2.9	4.4	6.6	1.12	59	5.5	170	This study
Jinhae Bay, South Coast	1.9	2.7	5.4	1.09	69	12.8	450	This study
Yeosu, South Coast	2.4	3.6	3.7	1.14	50	17.8	790	This study
Banweol, West Coast	2.5	4.1	5.9	0.65	72	17.7	430	This study

1 Polluted area, 2 Mining area, 3 Mean value, 4 Data from shell length 6~7cm, *Data from Moss Landing Marine Lab, ND: Not Detected

body size at Sts. 2 and 4., whereas they decreased at St. 1.

The mean concentrations of Cu (1.06ppm wet weight) and Pb (0.21ppm wet weight) in mussels in Jinhae Bay of this study were lower than those by Won (1973; Cu 1.14ppm, Pb 1.25ppm wet weight) or Do et al. (1981; Cu 1.40ppm, Pb 0.9ppm wet weight) in the same area. Goldberg et al. (1978) reported the Cu and Pb contents in mussels in Narragansett Bay in the USA to be 10.2ppm and 4.1ppm, respectively (Table 2). These values were much higher than those in the present study. And the Cu and Pb levels of this study were much lower (Table 2), than those of Cooper et al. (1982) surveyed in Tasmanian mussels in Australia (Cu 9.5ppm, Pb 75ppm).

Zinc, Manganese and Iron

The ranges of Zn, Mn and Fe concentrations in mussels of the whole study areas were 45-108ppm, 5.5-35.1ppm, and 100-790ppm, respectively. The Zn levels were the highest in Banweol, followed by Jinhae Bay, Imweon, and Yeosu in the decreasing order. In contrast, the Mn and Fe values were the highest in Yeosu, and Imweon showed the lowest.

In Jinhae Bay surveyed in March St. 9 at Bugsindong in Chungmu showed the highest Zn, and Fe values, whereas St. 4 near Silrido gave the relatively low levels of these metals.

The variations of Zn, Mn and Fe contents with the maturity of mussels at Sts. 1, 2 and 4 were nearly the same and these metal levels decreased with the shell growth.

The mean Zn concentration in Jinhae Bay of this study (13.2ppm wet weight) was much lower than that of Do et al. (30.1ppm wet weight) in Masan Bay. In contrast, the mean level of Mn in Jinhae Bay of the present study (2.46ppm wet weight) was slightly higher that of Do et al. (1.97ppm wet weight). In the USA, Goldberg et al. (1978) reported that the Zn, Mn, and Fe contents in mussels in Narragansett Bay of the East Coast were 138ppm, 15.0ppm, and 170ppm, respectively, whereas the Zn and Fe contents in Point La Jolla of the West Coast were 177ppm and 170ppm, respectively (Table 2). Compared with these results, the present study showed much lower Zn levels, similar Mn values, and much higher Fe levels.

Comparison of heavy metal concentrations in mussels from the Korean coastal waters was made with those in mussels from various coastal waters in the world (Table 2). This comparison can afford only an approximate idea on the relative pollution of the different water masses, as the sampling and analytical schemes for most studies were different from those of the present study.

The data show that heavy metal levels from this study are relatively low, suggesting that the pollution from heavy metals in the Korean coastal waters is not critical. However, more efforts should be given to monitor the metal pollution in the Korean coastal waters using indicator organisms.

CONCLUSIONS

Depuration of mussel samples in clean seawater was needed immediately after collection for the complete excretion of gut contents. In the present study, the adequate depuration period was shown to be 48hr.

Among the four study areas of Imweon, Banweol, Yeosu, and Jinhae Bay, Imweon of the East Coast showed the highest levels of Cd, Cr, and Cu, and the lowest values of Mn and Fe. In contrast, Yeosu showed the highest Pb, Mn, and Fe contents. In Jinhae Bay St. 9 showed the highest values of Pb and Zn, whereas the greatest levels of Cr and Cu were recorded at Sts. 4 and 2, respectively. It was interesting to note that St. 1 in Masan Bay showed relatively low levels of metal contents.

With the growth of mussels, the metal levels, except Cu, generally decreased. In general, the heavy metal contents in mussels in the Korean coastal waters were relatively low, compared with those from elsewhere in the world.

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