# Study on the Heavy Metal Concentration in Mussels and Oysters from the Korean Coastal Waters

Hee-Gu CHOI · Joo-Suck PARK and Pil-Yong LEE
*National Fisheries Research and Development Agency, Kijang-up, Yangsan-gun, Kyongsangnam-do 626-900, Korea*

This study dealt with the concentration of heavy metals in mussels, *Mylitus edulis* and oysters, *Crassostrea gigas*, in different habitats around the Korean coastal waters during 1985~1989.

The high levels of heavy metal concentration in two bivalves were found at Station 1, 2, 5, 23 and 25, while the low levels were found at stations in Chinhae Bay. Oysters were more effective bioaccumulators of Cu, Zn and Hg than mussels showing the ratios of 16:1 for Cu, 1.63:1 for Cd, 1.36:1 for Pb, 7.61:1 for Zn and 2.08:1 for Hg. The larger mussels were, the higher the concentrations of five metals.

## Introduction

Some bivalve mollusks accumulate heavy metals, and thus they are commonly used as biological indicators of heavy metal pollution(Tabolt, 1978). The mussel is a sedentary, filter-feeding bivalve that can serve as a reliable environmental indicator of water quality and has been extensively studied as a bioassay animal due to its wide distribution and comparatively easy sample collection(Phillips, 1977, 1978; Davis, 1978; Flowler & Oregioni, 1979; Martincic et al., 1980). Because of those kinds of factors mentioned above, Goldberg(1980) proposed a global monitoring program, "Mussel Watch" to establish the assessment of environment.

In Korea, the assessment of the heavy metal concentrations in various marine organisms has been carried out since early 1970's by many authors(Cho & Kim, 1971; Kim, 1972; Won, 1973; Kim & Won, 1974; Lee et al., 1975; Kim, 1979; NFRDA, 1974, 1977, 1979, 1980, 1983, 1985; Hwang, 1983; Jo, 1984; Lee et al., 1988). The National Fisheries Research and Development Agency(NFRDA) has regularly monitored the heavy metal concentrations in the Korean coastal waters especially for shellfish growing areas and the vicinity of heavy industrial complex. Since 1980, the NFRDA has been involved in the "Mussel Watch" program based on WESTPAC project.

The present study is the result of the "Mussel Watch" program of the NFRDA during the period of 1985~1989. The concentrations of Cu, Cd, Pb, Zn and Hg were analyzed in mussels and oysters collected from the different areas that are exposed to various levels of contamination. In addition, to investigate the difference of uptake ratio of heavy metals in mussles and oysters at the same sites, the comparison of the heavy metal concentrations between mussels and oysters from the same sites was made, and the accumulation capacity of the heavy metal concentrations in bivalves was estimated through the analysis of heavy metals in seawater.

## Materials and Methods

Samples of mussels, *Mitylus edulis* and oysters, *Crassostrea gigas* were collected at 25 stations in February during 5 years from 1985 to 1989(Fig. 1 and Table 1). The samples were transported to the laboratory in a cold box and stored below -20 ℃

in a refrigerator until analysis. The heavy metal concentrations in bivalves between mussels and oysters from the same sites were compared. The sampling sites of Station 2 from the eastern coast, Station 11 from the southern coast and Station 22 from the western coast were selected to compare geographical differences. From these 3 coasts, samples were seasonally collected four times every year in February, April, August and November from 1985 to 1989. Mussels taken were 3~6 *cm* in length and 5~8 *g* in weight; oysters were 5~7 *cm* in length and 5.5~7.0 *g* in weight. These samples were similarly taken to minimize the inconsistency of heavy metal concentration reading caused by size variation. The concentrations of five elements of heavy metal in relation to the size of mussels were also investigated at Station 2, 6 and 22. The samples were divided into 3 shell-length groups: the large group, 5~6 *cm*, the medium group, 4~5 *cm* and the small group, 3~4 *cm*.

The frozen samples were thawed and measured,

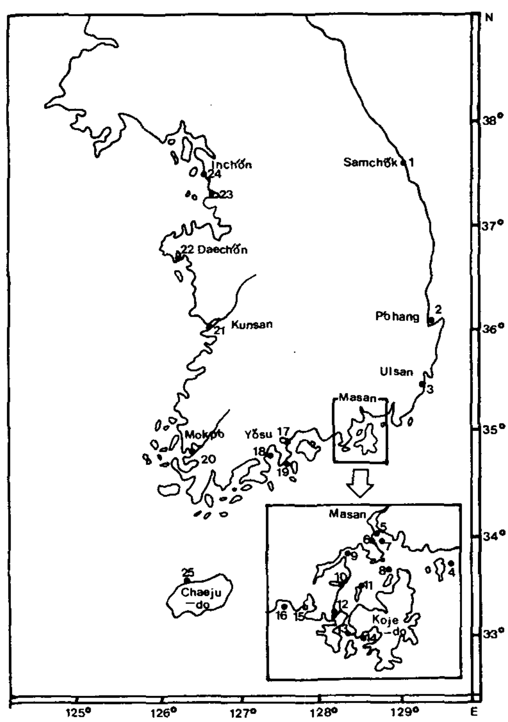


Fig. 1. Map showing sampling stations for mussels and oysters in the Korean coastal waters

and the shells were removed with a stainless steel knife before homogenization. The atomic absorption spectrophotometric method has been used for the analysis of heavy metals.

For the determination of Cu, Cd, Pb and Zn in the bivalves, ca. 20~30 *g* of blended sample was weighed, digested with 20 *ml* of conc-$HNO_3$, and heated just to boiling. The resulting residue was redissolved in 5 *ml* of conc-$HClO_4$, filtered 90-*mm* Whatman NO. 5 filter paper and then made up to 100 *ml* with distilled water for analysis by an atomic absorption spectrophotometer. For the determination of Hg, 20 *g* of shellfish meat was weighed, digested with 20 *ml* of conc-$HNO_3$ plus 20 *ml* of conc-$H_2SO_4$, and heated in an Erlenmeyer flask attached with a reflux condensor. After cooling, the sample was heated again with 50 *ml* distilled water and 10 *ml* 10% urea, and then 1 *g* $KMNO_4$ was added. After reducing excess $KMNO_4$ with eough hy-

Table 1. List of sampling stations for mussels and oysters with local name

| St. No. | Local name | Mussel | Oyster |
|---|---|---|---|
| 1 | Samch'ŏk Imwon | ○ | ○ |
| 2 | Yongil Bay | ○ | ○ |
| 3 | Ulju Ijin | ○ | – |
| 4 | Kadŏk-do | ○ | – |
| 5 | Masan-dolsŭm | ○ | – |
| 6 | Masan-Dŭkdong | ○ | – |
| 7 | Namp'o | ○ | – |
| 8 | Ch'ilch'ŏn-do | ○ | – |
| 9 | Chindong Bay | ○ | ○ |
| 10 | Dangdong | ○ | ○ |
| 11 | Kajo-do | ○ | ○ |
| 12 | Wonmum Bay | ○ | ○ |
| 13 | Hansan-Ogu | ○ | ○ |
| 14 | Hansan-Naegan | – | ○ |
| 15 | Kosŏng Bay | ○ | ○ |
| 16 | Charan Bay | ○ | ○ |
| 17 | Kwangyang Bay | ○ | ○ |
| 18 | Yŏsa Bay | ○ | ○ |
| 19 | Kamak Bay | ○ | ○ |
| 20 | Youngsan-downstream | ○ | ○ |
| 21 | Kŭm-downstream | – | ○ |
| 22 | Ch'ŏnsu Bay | ○ | ○ |
| 23 | Banwol Bay | – | ○ |
| 24 | Inch'ŏn-wolmido | – | ○ |
| 25 | Cheju | ○ | – |

droxylamine sulfate solution, the sample was made up to 300 *ml* for the analysis.

For the determination of Cu, Cd, Pb and Zn in the seawater, 800 *ml* of seawater was transferred into 1L separatory funnel and adjusted to pH ca. 4.5 by addition of ammonia solution mixed with 5 *ml* of 25% potassium sodium tartrate and 3~5 drops of bromophenol blue(BPB). 10 *ml* of 1% sodium diethyl dithiocarbamate(DDTC) was added for the formation of a chelatic bond. Then, 50 *ml* methylisobuthyl-ketone(MIBK) was added to separate into aqueous and organic layers. The organic layer was collected for the determination of Cu, Cd, Pb and Zn.

## Results and Discussion

*Distribution of Heavy Metal Concentrations in Mussels and Oysters*

Mean values of heavy metals such as Cu, Cd, Pb, Zn and Hg were shown in Table 2, 3. In all sampling sites, the concentrations of heavy metals in oysters were generally higher than those in mussels. Ikebe et al.(1977) also reported that oysters contained higher concentrations of heavy metals than mussels. Regarding the distribution of heavy metal concentrations at 25 stations, both mussels and oysters at Station 3, 5, 23 and 24 from the natural shellfish grounds showed higher values in all the

Table 2. Concentrations of heavy metals in mussels (*Mitylus edulis*) from the Korean coastal waters in February during 1985~1989

(unit: *mg/kg*, wet wt)

| St. | | *1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cu | 85 | 1.78 | 1.00 | 2.44 | 2.41 | 1.73 | 1.36 | 1.39 | 1.32 | 1.34 | 1.29 | 1.21 | 1.20 | 1.20 | 1.21 | 1.04 | 0.78 | 1.00 | 0.94 | 2.01 | 0.20 |
| | 86 | 1.26 | 0.63 | 2.15 | - | 1.04 | 0.56 | 0.76 | 0.59 | 1.13 | 1.02 | 0.72 | 0.48 | 0.46 | 0.86 | 0.70 | 0.51 | 0.40 | 0.67 | 0.79 | 1.57 |
| | 87 | 1.26 | 0.86 | 1.13 | 2.65 | 0.79 | 0.74 | 0.79 | 0.84 | 0.82 | 0.71 | 0.75 | 0.56 | 0.60 | 0.52 | 0.96 | 0.64 | 0.48 | 0.26 | 1.45 | 0.68 |
| | 88 | 1.44 | 0.55 | 0.77 | 0.91 | 1.08 | 0.60 | 0.53 | 0.56 | 1.46 | 0.61 | 0.58 | 0.97 | 0.98 | 1.14 | 0.95 | 0.54 | 0.50 | - | 1.03 | 1.57 |
| | 89 | 1.30 | 1.23 | 3.77 | - | 1.21 | 1.00 | 0.83 | 1.01 | 0.74 | 0.92 | 0.47 | 1.35 | - | - | - | - | - | 1.85 | 1.00 | 2.47 |
| | M | 1.41 | 0.85 | 2.05 | 1.99 | 1.17 | 0.85 | 0.86 | 0.86 | 1.10 | 0.91 | 0.75 | 0.91 | 0.81 | 0.93 | 0.91 | 0.62 | 0.60 | 0.93 | 1.26 | 1.30 |
| Cd | 85 | 0.49 | 0.22 | 0.94 | 0.39 | 0.46 | 0.27 | 0.34 | 0.30 | 0.31 | 0.29 | 0.32 | 0.30 | 0.24 | 0.20 | 0.30 | 0.35 | 0.37 | 0.32 | 0.39 | 0.20 |
| | 86 | 0.36 | 0.18 | 0.29 | - | 0.24 | 0.16 | 0.22 | 0.21 | 0.14 | 0.39 | 0.25 | 0.16 | 0.11 | 0.09 | 0.20 | 0.17 | 0.09 | 0.29 | 0.39 | 0.16 |
| | 87 | 0.16 | 0.24 | 0.37 | 0.29 | 0.17 | 0.24 | 0.17 | 0.32 | 0.14 | 0.21 | 0.17 | 0.24 | 0.16 | 0.20 | 0.26 | 0.20 | 0.27 | 0.34 | 0.48 | 0.20 |
| | 88 | 0.48 | 0.29 | 0.16 | 0.24 | 0.22 | 0.18 | 0.28 | 0.27 | 0.35 | 0.40 | 0.40 | 0.35 | 0.26 | 0.23 | 0.20 | 0.26 | 0.25 | - | 0.35 | 0.36 |
| | 89 | 0.42 | 0.44 | 0.91 | - | 0.24 | 0.20 | 0.21 | 0.32 | 0.31 | 0.29 | 0.28 | 0.71 | - | - | - | - | - | 0.32 | 0.41 | 1.13 |
| | M | 0.38 | 0.27 | 0.53 | 0.31 | 0.27 | 0.21 | 0.24 | 0.28 | 0.25 | 0.30 | 0.28 | 0.28 | 0.19 | 0.18 | 0.24 | 0.25 | 0.25 | 0.32 | 0.40 | 0.41 |
| Pb | 85 | 0.74 | 0.80 | 0.99 | 0.56 | 0.73 | 0.50 | 0.60 | 0.74 | 0.37 | 0.57 | 0.64 | 0.27 | 0.30 | 0.27 | 0.68 | 0.62 | 0.81 | 0.51 | 0.77 | 0.29 |
| | 86 | 0.41 | 0.40 | 0.36 | - | 0.54 | 0.47 | 0.36 | 0.44 | 0.30 | 0.26 | 0.28 | 0.36 | 0.35 | 0.42 | 0.28 | 0.40 | 0.32 | 0.36 | 0.51 | 0.26 |
| | 87 | 0.30 | 0.28 | 0.98 | 0.36 | 0.44 | 0.28 | 0.30 | 0.30 | 0.28 | 0.38 | 0.32 | 0.34 | 0.36 | 0.28 | 0.24 | 0.32 | 0.36 | 0.34 | 0.63 | 0.38 |
| | 88 | 0.78 | 0.20 | 0.97 | 0.28 | 0.68 | 0.53 | 0.47 | 0.29 | 0.30 | 0.44 | 0.54 | 0.33 | 0.24 | 0.20 | 0.18 | 0.67 | 0.26 | - | 0.31 | 1.82 |
| | 89 | 0.46 | 0.43 | 1.33 | - | 0.29 | 0.14 | 0.19 | 0.26 | 0.19 | 0.23 | 0.36 | 0.45 | - | - | - | - | - | 0.48 | 0.24 | 0.36 |
| | M | 0.54 | 0.42 | 0.93 | 0.40 | 0.54 | 0.38 | 0.38 | 0.41 | 0.29 | 0.38 | 0.43 | 0.35 | 0.31 | 0.29 | 0.35 | 0.50 | 0.44 | 0.42 | 0.49 | 0.62 |
| Zn | 85 | 20.04 | 22.20 | 24.98 | 17.32 | 15.69 | 12.63 | 19.64 | 13.27 | 10.11 | 10.48 | 14.12 | 11.04 | 10.22 | 11.00 | 17.87 | 14.22 | 19.66 | 20.01 | 19.63 | 12.39 |
| | 86 | 22.64 | 22.46 | 7.24 | - | 13.24 | 15.30 | 1.176 | 12.54 | 16.86 | 17.79 | 14.62 | 10.47 | 10.40 | 9.67 | 9.15 | 19.20 | 11.20 | 24.48 | 11.67 | 8.10 |
| | 87 | 19.84 | 8.36 | 13.38 | 17.48 | 2.67 | 3.43 | 3.26 | 4.15 | 3.26 | 2.14 | 2.14 | 3.26 | 3.26 | 3.44 | 3.64 | 4.14 | 5.30 | 2.14 | 4.91 | 3.47 |
| | 88 | 23.67 | 23.18 | 20.61 | 22.01 | 20.30 | 18.35 | 9.69 | 8.05 | 12.16 | 10.83 | 16.91 | 11.13 | 13.74 | 14.69 | 10.35 | 7.94 | 8.03 | - | 9.64 | 27.98 |
| | 89 | 18.24 | 35.30 | 53.68 | - | 22.56 | 17.28 | 10.78 | 11.56 | 7.26 | 11.16 | 13.93 | 14.88 | - | - | - | - | - | 14.38 | 10.73 | 11.09 |
| | M | 20.89 | 22.30 | 23.98 | 18.94 | 14.89 | 13.40 | 11.03 | 9.91 | 9.93 | 10.48 | 12.34 | 10.16 | 9.41 | 9.70 | 10.25 | 11.38 | 11.05 | 15.25 | 11.32 | 12.99 |
| Hg | 85 | 0.011 | 0.018 | 0.031 | 0.017 | 0.014 | 0.011 | 0.013 | 0.014 | 0.006 | 0.009 | 0.011 | 0.007 | 0.010 | 0.007 | 0.014 | 0.010 | 0.013 | 0.014 | 0.015 | 0.007 |
| | 86 | 0.011 | 0.010 | 0.010 | - | 0.010 | 0.007 | 0.008 | 0.010 | 0.005 | 0.008 | 0.008 | 0.012 | 0.011 | 0.008 | 0.010 | 0.008 | 0.010 | 0.012 | 0.009 | 0.008 |
| | 87 | 0.014 | 0.024 | 0.017 | 0.008 | 0.009 | 0.008 | 0.007 | 0.014 | 0.008 | 0.009 | 0.005 | 0.012 | 0.010 | 0.012 | 0.010 | 0.012 | 0.014 | 0.012 | 0.014 | 0.009 |
| | 88 | 0.003 | 0.015 | 0.023 | 0.007 | 0.008 | 0.005 | 0.008 | 0.024 | 0.006 | 0.009 | 0.007 | 0.014 | 0.009 | 0.008 | 0.006 | 0.007 | 0.007 | - | 0.011 | 0.007 |
| | 89 | 0.003 | 0.021 | 0.023 | - | 0.015 | 0.005 | 0.003 | 0.013 | 0.002 | 0.003 | 0.007 | 0.009 | - | - | - | - | - | 0.009 | 0.010 | 0.006 |
| | M | 0.008 | 0.018 | 0.021 | 0.011 | 0.011 | 0.007 | 0.008 | 0.015 | 0.005 | 0.008 | 0.008 | 0.011 | 0.010 | 0.009 | 0.010 | 0.009 | 0.011 | 0.012 | 0.012 | 0.007 |

*Only *Mitylus coruscus* was collected

M: Mean

heavy metals. These stations were close to the sites where effluent was discharged. However, stations around the western part of Chinhae Bay and Kamak Bay where mussels and oysters have long been cultivated had low levels of the concentrations.

The regional differences of the concentrations of heavy metals in the three regions; the eastern coast, the western coast and the southern coast, were given in Table 4. The eastern coast and the western coast showed higher levels than the southern coast in both mussels and oysters. Lee et al. of KORDI(1988) also reported the higher values of Cu and Cd in the western coast. They took samples from Daech'ŏn and Manlipo, and mentioned that the higher concentration of heavy metals resulted from the suspended solids that were abundant in the region. However, in the present study, the higher values of Cu and Cd were found in the sites near the industrial complexes, and thus the concentrations of heavy metals seem to be closely related to the industrial effluents.

During the period of study, no significant annual variation of heavy metal concentrations was found (Table 5). However, Cu concentration in mussels has increased 4.0 times compared with the data of 1972 at Station 1 but decreased 6.6 times compared with the data of 1982 at Station 6. The cause of this decrease needs further study. The concentrations of Cu, Cd and Zn in oysters had a general increase compared with the previous data at Station 11, 13 and 16.

To compare the present results with the previous ones, the data on dry basis have been multiplied by a respective mean conversion factor; 0.17 for mussels and 0.20 for oysters according to Hwang(1983). These comparative data revealed that there were similarities in values of Cu with

Table 3. Concentrations of heavy metals in oysters (*Crassostrea gigas*) from the Korean coastal waters in February during 1985~1989

(unit: *mg/kg*, wet wt)

| | St. | 1 | 2 | 4 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 85 | 18.40 | 19.40 | 3.65 | - | 4.00 | 3.49 | 4.11 | 4.47 | 4.24 | 4.29 | 4.99 | 8.76 | 8.19 | 3.96 | 14.60 | 10.21 | 14.20 | 24.65 | 10.43 |
| | 86 | 25.26 | 18.99 | 18.26 | 9.20 | 8.95 | 9.02 | 7.59 | 8.01 | 13.30 | 9.25 | 8.46 | 14.45 | 6.30 | 6.35 | 21.77 | 21.50 | 39.35 | 56.60 | 29.55 |
| Cu | 87 | 28.34 | 28.40 | 6.23 | 3.53 | 3.26 | 3.89 | 3.79 | 9.26 | - | 11.35 | 10.20 | 19.47 | 8.15 | 5.23 | 23.45 | 18.25 | 22.65 | 32.36 | 22.34 |
| | 88 | - | 23.74 | - | 6.52 | - | 14.44 | 3.96 | 6.66 | - | 9.73 | 9.96 | - | - | 3.58 | - | 28.94 | 22.54 | 38.89 | 45.69 |
| | M | 24.00 | 22.69 | 9.38 | 6.42 | 5.40 | 7.71 | 4.86 | 7.10 | 8.77 | 8.66 | 8.40 | 14.23 | 7.55 | 4.78 | 19.94 | 19.73 | 24.69 | 38.13 | 27.00 |
| | 85 | 0.42 | 0.60 | 0.47 | - | 0.31 | 0.27 | 0.42 | 0.30 | 0.29 | 0.20 | 0.32 | 0.47 | 0.32 | 0.43 | 0.47 | 0.49 | 0.54 | 1.11 | 0.83 |
| | 86 | 1.45 | 0.41 | 0.94 | 0.76 | 1.00 | 0.29 | 1.15 | 0.42 | 0.25 | 0.25 | 0.42 | 1.10 | 0.45 | 0.54 | 1.35 | 1.20 | 0.57 | 1.27 | 0.84 |
| Cd | 87 | 0.89 | 0.94 | 0.67 | 0.38 | 0.40 | 0.37 | 0.36 | 0.42 | - | 0.36 | 0.32 | 0.76 | 0.26 | 0.38 | 0.55 | 0.79 | 0.48 | 0.98 | 1.02 |
| | 88 | - | 0.13 | - | 0.69 | - | 0.52 | 0.68 | 0.67 | - | 0.54 | 0.62 | - | - | 0.40 | - | 0.99 | 0.70 | 0.35 | 1.89 |
| | M | 0.92 | 0.52 | 0.69 | 0.61 | 0.45 | 0.36 | 0.65 | 0.45 | 0.27 | 0.34 | 0.38 | 0.78 | 0.34 | 0.44 | 0.79 | 0.87 | 0.57 | 0.93 | 1.15 |
| | 85 | 0.59 | 0.64 | 0.76 | - | 0.40 | 0.59 | 0.64 | 0.32 | 0.39 | 0.41 | 0.37 | 0.43 | 0.36 | 0.37 | 0.46 | 0.49 | 0.57 | 1.64 | 0.80 |
| | 86 | 1.20 | 0.67 | 0.57 | 0.65 | 0.74 | 0.65 | 0.69 | 0.58 | 0.71 | 0.67 | 0.80 | 0.71 | 0.59 | 0.70 | 0.85 | 1.15 | 0.70 | 1.97 | 0.95 |
| Pb | 87 | 0.58 | 0.82 | 0.50 | 0.52 | 0.46 | 0.48 | 0.37 | 0.48 | - | 0.60 | 0.54 | 0.54 | 0.58 | 0.52 | 0.52 | 0.50 | 0.56 | 0.60 | 0.58 |
| | 88 | - | 0.10 | - | 0.22 | - | 0.58 | 0.46 | 0.26 | - | 0.19 | 0.28 | - | - | 0.20 | - | 1.22 | 0.29 | 0.57 | 2.95 |
| | M | 0.79 | 0.56 | 0.61 | 0.46 | 0.53 | 0.58 | 0.54 | 0.41 | 0.55 | 0.47 | 0.50 | 0.56 | 0.51 | 0.45 | 0.61 | 0.84 | 0.53 | 1.20 | 1.32 |
| | 85 | 110.43 | 99.49 | 99.42 | - | 69.46 | 74.30 | 70.27 | 74.24 | 62.78 | 70.41 | 71.66 | 84.24 | 72.63 | 64.36 | 94.63 | 95.42 | 80.46 | 148.23 | 94.69 |
| | 86 | 87.26 | 68.29 | 65.27 | 57.20 | 41.23 | 71.29 | 39.47 | 51.67 | 56.23 | 51.26 | 50.10 | 60.25 | 61.33 | 54.25 | 69.70 | 66.70 | 55.93 | 73.49 | 73.51 |
| Zn | 87 | 110.26 | 82.52 | 94.26 | 74.26 | 80.24 | 85.33 | 78.63 | 79.34 | - | 67.26 | 80.14 | 96.23 | 52.44 | 48.26 | 71.30 | 72.47 | 50.18 | 89.47 | 389.58 |
| | 88 | - | 27.59 | - | 84.28 | - | 158.53 | 75.13 | 54.70 | - | 64.04 | 49.91 | - | - | 37.78 | - | 116.61 | 126.37 | 277.00 | 360.92 |
| | M | 102.65 | 69.47 | 86.32 | 71.91 | 63.64 | 97.36 | 65.88 | 64.99 | 59.51 | 63.24 | 62.95 | 80.24 | 62.13 | 51.16 | 78.54 | 87.80 | 78.99 | 147.09 | 229.68 |
| | 85 | 0.020 | 0.024 | 0.042 | - | 0.011 | 0.019 | 0.010 | 0.009 | 0.010 | 0.010 | 0.009 | 0.019 | 0.015 | 0.020 | 0.012 | 0.027 | 0.026 | 0.079 | 0.034 |
| | 86 | 0.045 | 0.042 | 0.024 | 0.030 | 0.026 | 0.020 | 0.028 | 0.024 | 0.024 | 0.032 | 0.026 | 0.036 | 0.037 | 0.026 | 0.046 | 0.052 | 0.032 | 0.069 | 0.058 |
| Hg | 87 | 0.013 | 0.022 | 0.022 | 0.011 | 0.022 | 0.018 | 0.015 | 0.024 | - | 0.026 | 0.030 | 0.028 | 0.028 | 0.034 | 0.024 | 0.030 | 0.024 | 0.034 | 0.024 |
| | 88 | - | 0.005 | - | 0.013 | - | 0.012 | 0.002 | 0.011 | - | 0.016 | 0.003 | - | - | 0.009 | - | 0.011 | 0.023 | 0.026 | 0.022 |
| | M | 0.026 | 0.023 | 0.029 | 0.018 | 0.020 | 0.017 | 0.014 | 0.017 | 0.017 | 0.021 | 0.017 | 0.028 | 0.027 | 0.022 | 0.027 | 0.030 | 0.025 | 0.052 | 0.035 |

0.35~2.14 *mg/kg*, Cd with 0.083~0.571 *mg/kg* and Zn with 8.41~30.94 *mg/kg* in mussel reported by Lee et al. of KORDI(1988). On the other hand, the levels of Pb and Hg were lower than those of the present study. The difference of Pb levels between these studies seems to be occurred from the analytical method. The authors used the wet ash method, while Lee et al. of KORDI(1988) used the dry ash method. The study of Talbot & Chegwidden(1982) showed higher level than the present study, showing the ranges of 0.7~14.3 *mg/kg* for Cu, 0.1~5.5 *mg/kg* for Cd, 0.7~4.8 *kg/mg* for Pb and 17~149 *mg/kg* for Zn in mussels, and 2.6~40.1 *mg/kg* for Cu, 1.5~8.7 *mg/kg* for Cd, 0.8~3.2 *mg/kg* for Pb and 120~1,190 *mg/kg* for Zn in oysters.

*Heavy Metal Concentrations Between Mussels and Oysters*

The heavy metal concentrations between mussels and oysters from the same sites are shown in Fig. 2. The heavy metal concentrations of the figures presented were the mean values of 1985~1989. Seasonal variations did not represent regular trends in both mussels and oysters. Kamimura(1982) noted the seasonal irregularity of Cu values in sca-

Table 4. Regional comparisons of heavy metal concentrations in mussels and oysters (unit: *mg/kg*, wet wt)

| Species | Region | Cu | Cd | Pb | Zn | Hg |
|---|---|---|---|---|---|---|
| Mussel | Eastern Coast | 1.43 | 0.39 | 0.63 | 22.39 | 0.420 |
| | Southern Coast | 0.95 | 0.25 | 0.39 | 11.63 | 0.010 |
| | Western Coast | 1.10 | 0.36 | 0.46 | 13.29 | 0.012 |
| Oyster | Eastern Coast | 23.35 | 0.72 | 0.68 | 86.06 | 0.0492 |
| | Southern Coast | 7.77 | 0.48 | 0.51 | 70.94 | 0.0210 |
| | Western Coast | 25.90 | 0.86 | 0.90 | 139.42 | 0.0340 |

Table 5. Comparisons of heavy metal concentrations of the present results and those of the previous ones (unit: *mg/kg*, wet wt)

| | Station | Cu | | | Cd | | | Pb | | | Zn | | | Hg | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1972 | 1982 | 1989 | 1972 | 1982 | 1989 | 1972 | 1982 | 1989 | 1972 | 1982 | 1989 | 1972 | 1982 | 1989 |
| Mussel | St. 1 | 7.09 | | 28.34 | 0.26 | | 0.89 | 0.84 | | 0.58 | | | 110.26 | 0.080 | | 0.013 |
| | St. 6 | | 8.00 | 1.21 | | 0.11 | 0.24 | | 0.49 | 0.29 | | 18.40 | 22.26 | | 0.020 | 0.015 |
| | St. 7 | | 4.00 | 1.00 | | 0.08 | 0.20 | | 0.35 | 0.14 | | 9.60 | 17.28 | | <0.010 | 0.005 |
| | St. 8 | | 2.00 | 0.83 | | 0.30 | 0.21 | | 0.62 | 0.19 | | 8.10 | 10.78 | | <0.010 | 0.003 |
| | St. 10 | | 3.20 | 0.74 | | 0.07 | 0.31 | | 0.26 | 0.19 | | 11.90 | 7.26 | | 0.020 | 0.002 |
| | St. 11 | | 3.30 | 0.92 | | 0.07 | 0.29 | | 0.27 | 0.23 | | 12.80 | 11.16 | | 0.020 | 0.003 |
| | St. 12 | | 0.80 | 0.47 | | 0.04 | 0.28 | | 0.24 | 0.36 | | 13.80 | 13.93 | | 0.020 | 0.007 |
| | St. 13 | | 1.00 | 1.35 | | 0.03 | 0.71 | | 0.32 | 0.45 | | 12.30 | 14.88 | | 0.080 | 0.009 |
| | St. 15* | 1.14 | 1.80 | 0.90 | 0.17 | 0.03 | 0.26 | 1.25 | 0.29 | 0.24 | | 8.90 | 13.74 | 0.080 | <0.010 | 0.009 |
| | St. 16* | | 1.10 | 1.14 | | 0.03 | 0.23 | | 0.36 | 0.20 | | 10.50 | 14.69 | | 0.030 | 0.008 |
| Oyster | St. 11* | | 2.60 | 14.44 | | 0.14 | 0.52 | | 0.28 | 0.58 | | 10.90 | 158.53 | | <0.010 | 0.012 |
| | St. 12* | | 3.30 | 3.96 | | 0.14 | 0.68 | | 0.32 | 0.46 | | 13.80 | 75.13 | | 0.080 | 0.002 |
| | St. 13* | | 3.00 | 6.66 | | 0.25 | 0.67 | | 0.45 | 0.26 | | 14.50 | 54.70 | | 0.080 | 0.011 |
| | St. 15* | | 2.10 | 9.73 | | 0.34 | 0.54 | | 0.32 | 0.19 | | 13.70 | 64.04 | | 0.070 | 0.016 |
| | St. 16* | | 2.80 | 9.96 | | 0.34 | 0.62 | | 0.40 | 0.28 | | 14.90 | 49.91 | | 0.130 | 0.003 |
| | St. 21* | 28.69 | | 28.94 | 0.17 | | 0.99 | 0.38 | | 1.22 | | | 116.61 | 0.160 | | 0.011 |
| | St. 24* | 28.50 | | 45.69 | 0.20 | | 1.89 | 1.08 | | 2.95 | | | 360.92 | 0.130 | | 0.022 |

* 1988; 1): Data in 1972 were originated from won(1973); 2): Data in 1982 were originated from NFRDA(1985)

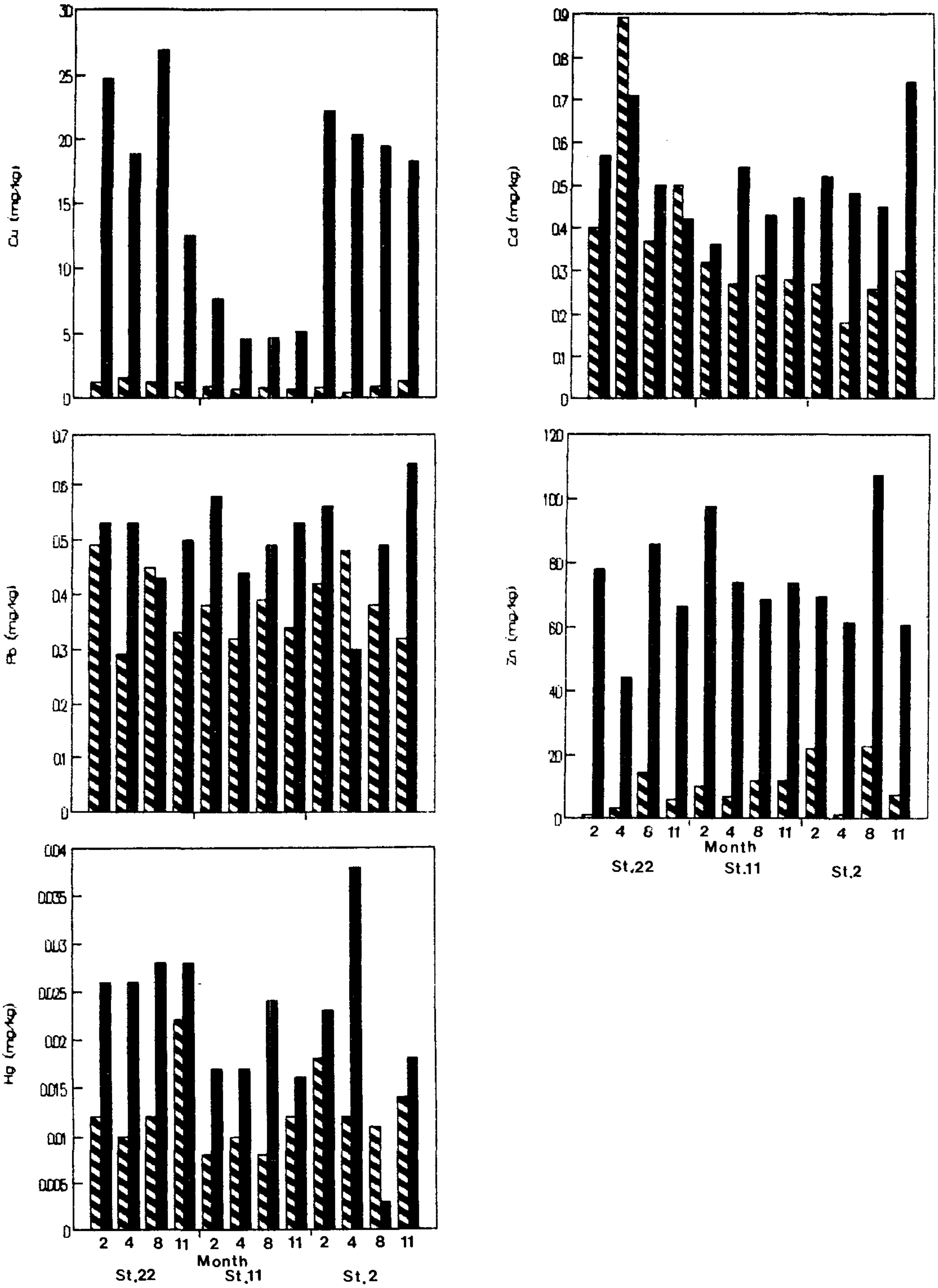


Fig. 2. Seasonal variations of heavy metal concentrations between mussels and oysters

llops, showing a decreasing trend in proportion to the growth of scallops for 5 or 6 months after hanging scallops, and an increasing trend after that period. However, Hwang(1983) reported that from June to October in Hansan-Koje Bay, Cu, Cd and Zn values increased. Pb value showed the same trend after an initial decrease. Hg value had no regular pattern according to oyster growth.

The ratios of the heavy metal concentrations in oysters to those in mussels were 5.27:1~42.63:1 (mean 16.04:1) for copper, 0.80:1~2.67:1(mean 1.63:1) for cadmium, 0.63:1~2.00:1(mean 1.36:1) for lead, 2.95:1~12.88:1(mean 7.61:1) for zinc, and 1.27:1~3.17:1(mean 2.08:1) for mercury. The highest uptake element by oyster was Cu and the next was Zn and Hg. Martinic et al.(1980) showed the similar uptake ratio in Cu, reporting that the ratios were 16:1 for Cu, 3:1 for Cd, 2:1 for Pb and 10:1 for Zn in the Lim Channel. Hwang(1983) who studied in Hansan-Koje Bay reported lower ratios than the present results in the five elements. Higher accumulation for Cu in oysters has been previously noted by Ikuta(1968) who reported that Cu concentration was 60~900 *mg/kg*, and concluded that the temporary increases were due to the inflow of industrial effluents into the sea. Tanaka (1974) also found that oysters had higher accumulation capacity of Cu and Zn than mussels. The highest ratio among three stations was found at Station 2 affected by influx of industrial effluent and sewage, but the lowest ratio was found at Station 11 remote from pollutants. These results indicated that the more polluted the habitat for bivalves was, the higher the uptake ratios between mussels and oysters were.

*Comparison of Heavy Metal Concentrations with the Size Variation and Accumulation Factors of Bivalves*

Concentrations of heavy metals in mussels by different size of three groups are shown in Fig. 3. The larger mussels were, the higher the concentrations of five heavy metals. In particular, this trend was clear for Cu and Zn concentrations in mussels at Station 22. In the study on the changes of heavy metal concentrations in the short-neck clam according to the shell length growth, Kumagai & Saeki(1981) reported that Cu and Zn kept constant, while Hg and Cd increased with short-neck clam growth. They noted that the constant levels in Cu and Zn in spite of the shell length growth were attributed to the essential elements for the growth of the organisms. In the present study, however, all elements in mussels increased with the

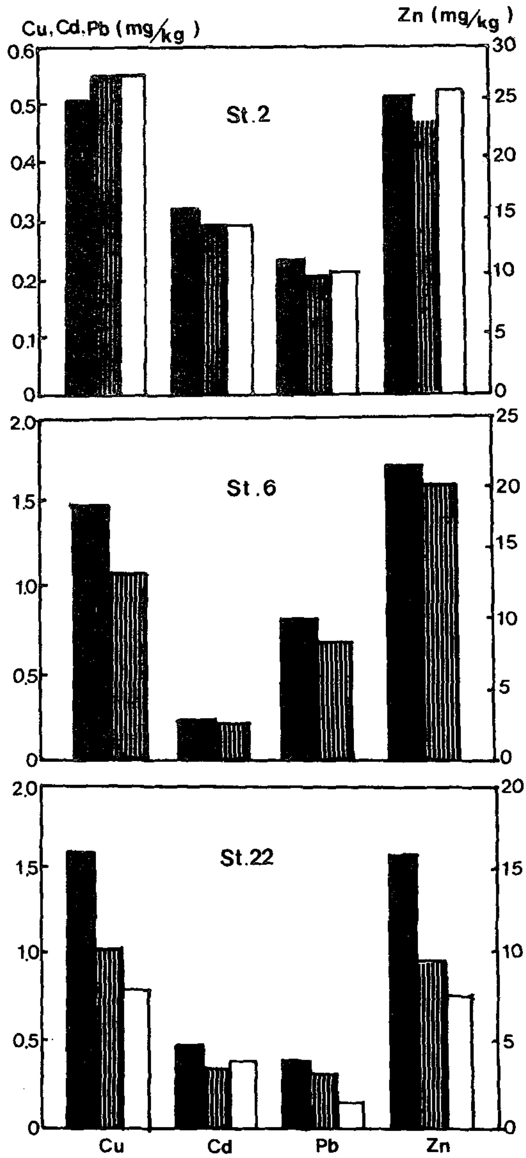


Fig. 3. Comparisons of heavy metal concentrations in mussels by different shell-size.
(■ Large, ■ Medium, □ Small)

growth of its shell size. These results showed that the mussel has a good response ability on the environmental conditions.

The accumulation factors of Cu, Cd, Pb, Zn and Hg concentrations in the bivalves are shown in Table 6. The accumulation factors in mussels ranged from 172 to 1,611 and those in oysters from 148 to 12,923 except Hg with below 50. These results were lower than Jo' study(1983) in Onsan area. However, the accumulation factors showed the same orders as three to five orders of magnitute. The highest concentration ratio at Station 24 and the lowest one at Station 11 were the same pattern of heavy metal concentrations in the bivalves. In the comparisons of the accumulation factors of five elements, those of Zn were the highest.

Table 6. Accumulation factors of heavy metal concentrations in bivalves in February, 1988

| St | Cu | | | Cd | | | Pb | | | Zn | | | Hg | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | M/S (μg/l) | O/S | S | M/S (μg/l) | O/S | S | M/S (μg/l) | O/S | S | M/S (μg/l) | O/S | S | M/S (μg/l) | O/S |
| 2 | 6.00 | 92 | 3,957 | 0.60 | 483 | 217 | 6.40 | 36 | 16 | 14.30 | 1,780 | 1,923 | 0.40 | 34 | 13 |
| 6 | 5.10 | 290 | - | 0.40 | 600 | - | 2.90 | 283 | - | 9.20 | 2,372 | - | 0.40 | 33 | - |
| 8 | 4.70 | 113 | - | 0.40 | 700 | - | 3.90 | 121 | - | 10.90 | 889 | - | 0.40 | 21 | - |
| 9 | 4.40 | 127 | 1,482 | 0.40 | 675 | 1,725 | 2.20 | 132 | 100 | 12.10 | 665 | 6,965 | 0.30 | 80 | 44 |
| 10 | 4.70 | 311 | - | 0.50 | 750 | - | 4.10 | 73 | - | 10.10 | 1,204 | - | 0.30 | 21 | - |
| 11 | 5.90 | 103 | 2,447 | 0.40 | 1,000 | 1,300 | 3.60 | 122 | 161 | 10.60 | 1,022 | 14,956 | 0.30 | 30 | - |
| 13 | 3.20 | 303 | 2,081 | 0.21 | 1,667 | 3,190 | 2.60 | 127 | 100 | 6.70 | 1,661 | 8,164 | 0.50 | 28 | 22 |
| 15 | 4.20 | 233 | 2,317 | 0.23 | 1,130 | 2,348 | 1.80 | 133 | 106 | 6.80 | 2,021 | 9,418 | 0.30 | 30 | 52 |
| 16 | 4.10 | 278 | 1,171 | 0.31 | 742 | 1,355 | 2.40 | 83 | 63 | 4.90 | 2,998 | 12,216 | 0.20 | 40 | 36 |
| 17 | 2.70 | 352 | - | 0.09 | 2,222 | - | 4.80 | 38 | - | 14.40 | 719 | - | 0.30 | 21 | - |
| 18 | 4.50 | 120 | - | 0.30 | 867 | - | 3.50 | 191 | - | 9.50 | 836 | - | 0.40 | 16 | - |
| 19 | 4.60 | 109 | 778 | 0.42 | 595 | 952 | 3.48 | 75 | 57 | 8.80 | 913 | 4,407 | 0.40 | 18 | 23 |
| 22 | 5.20 | 306 | 4,335 | 0.43 | 1,093 | 3,372 | 4.60 | 85 | 63 | 5.90 | 2,671 | 21,419 | 0.30 | 33 | 75 |
| 24 | 6.40 | 303 | 7,139 | 0.43 | 2,488 | 4,395 | 4.40 | 566 | 670 | 9.80 | 2,126 | 36,829 | 0.40 | 19 | 55 |
| 25 | 4.10 | 383 | - | 0.20 | 1,800 | - | 3.50 | 520 | - | 12.20 | 2,293 | - | 0.20 | 33 | - |

S: Seawater, M: Mussel, O: Oyster

## References


Cho, H. S. 1984. Heavy metal pollution on Onsan coastal area. MS thesis, Pusan National University, 42pp.

Cho, Y. K. and C. K. Kim. 1971. Accumulation of heavy metal in shellfish 1. On the copper content in green oysters. Bull. Korean Fish. Soc. 4, 61~65.

Davies, I. M. and J. M. Pirie. 1978. The mussel *Mytilus edulis* as a bioassay organism for mercury in seawater. Mar. Pollu. Bull. 9, 128~132.

Flowler, S. and R. Oregioni. 1979. Trace metals in mussels from the N. W. Mediterranean. Mar. Pollu. Bull. 7, 26~29.

Goldberg, E. D. 1980. The international mussel watch. National Academy of science, Washington, D. C.

Hwang, K. C. 1983. Heavy metal content of oyster, *Crossostrea gigas*, and sea water in Hansan-Geoje Bay. MS thesis, Pusan National University, 37pp.

Ikebe, K. Y. Tanaka, R. Tanaka and N. Kunita. 1977. Contents of heavy metals in Foods(VI), Content of heavy metals in fishes, shellfishes, meats, poultries and whales. J. Hygi. Soc. Japan, 18, 86~89.

Ikuta, K. 1968. Studies on accumulation of heavy metals in aquatic organisms II. On accumulation of copper and zinc in oysters. Bull. Japan Soc. Sci. Fish. 34, 112～116.

Kamimura, S. 1981. Variation of copper levels in cultured juvenile scallops with their growth. Bull. Japan Soc. Sci. Fish. 47, 1379～1381.

Kim, C. Y. 1972. Studies on the contents of mercury, cadmium, lead, and copper in edible seaweeds in Korea. Bull. Korea Fish. Soc. 5, 88～96.

Kim, C. Y. and J. H. Won. 1974. Concentrations of mercury, cadmium, lead and copper in the surrounding seawater and in seaweeds, *Undaria pinnatifida* and *Sargassum fulvellum* from Suyeong Bay in Busan. Bull. Korean Fish. Soc. 7, 169～177.

Kim, J. M. 1979. The toxicity of mercury and cadmium on two freshwater fishes, carp and loach. Bull. of KORDI, 1, 15～21.

Korea Ocean Research and Development Institute. 1988. A study on the coastal water pollution and monitoring. BSPG 00057-184-4, 7～65.

Martincic, D., H. W. Nurnberg, M. Stoeppler and M. Brabica. 1980. Toxic metal levels in bivalves and their ambient water from the Lim Channel. Thal. Jugo. 16, 297～315.

National Fisheries Research and Development Agency, Korea. 1975. Survey of water pollution in surrounding waters of Korea. Tech. Rep. NFRDA, 30, 133～140.

National Fisheries Research and Development Agency, Korea. 1977. Survey of water pollution in Korean water. Tech. Rep. 34, 53～67.

National Fisheries Research and Development Agency, Korea. 1979. Survey of water pollution in surrounding waters of Korea. Tech. Rep. 47, 92～100.

National Fisheries Research and Development Agency, Korea. 1980. Survey of water pollution in surrounding water of Korea. Tech. Rep. 52, 90～99.

National Fisheries Research and Development Agney, Korea. 1983. Comprehensive study on marine pollution for the conservation of the Korean coastal ecosystem with respect to culture areas and fishing grounds. Tech. Rep. 58, 495～579.

National Fisheries Research and Development Agency, Korea. 1985. Comprehensive study on marine pollution for the conservation of the Korean coastal ecosystem with respect to culture areas and fishing grounds. Tech. Rep. 63, 229～346.

Phillips, D. J. H. 1977. The common mussel *Mylitus edulis* as an indicator of trace metals in Scandinanian waters. I. Zinc and cadmium. Mar. Biol. 43, 283～291.

Phillips, D. J. H. 1978. The common mussel *Mylitus edulis* as an indicator of trace metals in Scandinanian waters. II. Lead, iron, and manganese. Mar. Biol. 46, 147～156.

Talbot, V. and A. Chegwidden. 1982. Cadmium and other heavy metal concentrations in selected biota from Cockburn Sound, Western Australia. Aust. J. Mar. Freshw. Res. 33, 779～788.

Tanaka, Y., K. Ikebe, R. Tanaka and N. Kunita. 1974. Contents of heavy metals in foods(III), Contents of heavy metals in fishes and shellfishes. J. Hygi. Soc. Japan, 15, 390～393.

Won, J. H. 1973. The concentrations of mercury, cadmium, lead and copper in fish and shellfish of Korea. Bull. Korean Fish. Soc. 6, 1～19.

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# 한국연안 진주담치와 굴의 중금속농도에 관한 연구

최희구 · 박주석 · 이필용
국립수산진흥원, 해양자원부

1985～1989년간 한국연안의 서로 다른 서식지로부터 채집된 진주담치 *Mytilus edulis*와 굴 *Crassostrea gigas*중의 중금속 농도를 알아보았다.

두이매패류에서 가장 높은 중금속농도는 조사점 1, 2, 5, 23 그리고 25에서 발견되었던 반면 가장 낮은 중금속농도는 진해만 주위의 조사점에서 발견되었다. 5개년간 굴과 진주담치의 평균중금속농도비는 Cu 16:1, Cd 1.63:1, Pb 1.36:1, Zn 7.61:1 그리고 Hg 2.08:1로서 굴이 진주담치보다 Cu, Zn, Hg에서 보다 효과적인 생물농축자로 나타났다. 진주담치의 크기별 분포는 크기가 클수록 중금속농도도 증가하였다.