The Journal of the Oceanological Society of Korea
Vol 21, No. 3, p. 125-130, September 1986.

# Heavy Metals in the Surface Waters of Kwangyang Bay During 1983-84

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## 光陽湾 表層 海水中의 重金属 含量

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*Abstract*

The concentrations of Cu, Pb and Zn in the surface waters of Kwangyang Bay were determined bimonthly at 20 stations during 1983-84. The ranges and mean concentrations were <0.03 - 2.68 μg/l, 1.08 μg/l for Cu, < 0.03 -7.19 μg/l, 0.76 μg/l for Pb and 0.3 -23.1 μg/l, 5.6 μg/l for Zn, respectively. The slightly higher levels of heavy metals studied were shown in Sueo and Seomjin River Estuaries. Analysis of correlation coefficients showed that Cu, Pb and Zn were closely associated not only to one another but also to SS and COD in seawater.

요약 : 1983년 1월부터 1984년 12월까지 광양만의 20개 정점 표층에서 Cu, Pb, Zn 등의 중금속 함량을 16회에 걸쳐 조사하였다.

전 조사기간을 통한 각 원소의 변동범위와 평균농도는 Cu : <0.03 - 2.68 μg/l, 1.08 μg/l, Pb : <0.03 - 7.19 μg/l, 0.76 μg/l, Zn : 0.3 - 23.1 μg/l, 5.6 μg/l 였다. 광양만의 중금속 농도는 전반적으로 낮았으나 일반 해역보다는 수어천 하구 및 섬진강 하구등 담수의 영향을 많이 받는 해역에서 다소 높은 농도를 나타내었다.

통계학적 상관관계를 보면 Cu, Pb, Zn는 상호간은 물론 SS와 COD와도 유의성 있는 상관관계를 나타내었다.

## INTRODUCTION

Estuaries are an important stage in the supply to the oceans of trace elements including heavy metals from continental weathering and man's activities. In addition, many industrial complexes for heavy and chemical industries have been established along the coastlines of Korea over the last two decades, thereby increasing the pollution load on the coastal environment.

Kwangyang Bay is one of such polluted areas in Korea. And Kwangyang Steel Mill Site was reclaimed during 1983-84. The present study, which was conducted as a part of the environmental survey during the Kwangyang Steel Mill Site Construction, reports on the distribution of heavy metals, such as Cu, Pb and Zn in the surface waters of Kwangyang Bay during Jan., 1983-Dec., 1984. The results are compared with data from elsewhere in the world. Other parameters measured include suspended solids (SS) and chemical oxygen demand (COD) and are related to

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the concentrations of heavy metals.

## SAMPLING AND ANALYTICAL METHODS

The locations of sampling stations in Kwangyang Bay are shown in Fig. 1. The surface water samples were collected 16 times monthly or bimonthly during the period from Jan., 1983-Dec., 1984. Samples collected were placed in 2 l-polyethylene bottles which were pre-acid-washed, and acidified by adding 2 ml of conc. $HNO_3$. Heavy metals in the samples were concentrated by the Fe-APDC coprecipitation method and were determined by flame atomic absorption spectrophotometry (Lee *et al.*, 1980), with a varian Model 875 atomic absorption spectrophotometer with deuterium-source automatic background correction.

## RESULTS AND DISCUSSION

The ranges and annual mean concentrations of Cu, Pb and Zn are shown in Table 1-3. In the present study the metals determined show very similar spatial distribution trend. Of the stations, St. 10 of Sueo River

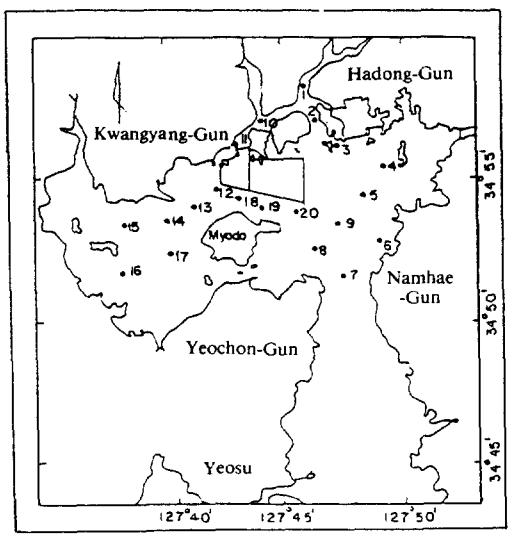


Fig. 1. Map showing the sampling stations in Kwangyang Bay.

Table 1. Ranges and mean concentrations of copper in the surface waters of Kwangyang Bay during 1983-84 ($\mu g/l$)

| Year / St. | 1983 Range | 1983 Mean | 1984 Range | 1984 Mean | Total Mean |
|---|---|---|---|---|---|
| 1 | 0.89-3.13 | 1.61 | 0.56-2.01 | 1.11 | 1.44 |
| 2 | 0.78-2.19 | 1.17 | 0.23-1.25 | 0.62 | 0.96 |
| 3 | <0.03-1.95 | 1.10 | 1.50-1.56 | 0.93 | 1.03 |
| 4 | 0.31-1.67 | 1.23 | 0.63-1.56 | 0.98 | 1.13 |
| 5 | 0.54-2.34 | 1.00 | 0.56-1.06 | 0.73 | 0.95 |
| 6 | 0.04-2.00 | 0.87 | 0.23-1.56 | 0.68 | 0.81 |
| 7 | <0.03-2.50 | 1.05 | 0.39-1.56 | 0.83 | 0.97 |
| 8 | 0.16-2.50 | 1.23 | 0.03-2.47 | 1.05 | 1.14 |
| 9 | 0.36-2.50 | 1.03 | 0.50-1.06 | 0.78 | 0.95 |
| 10 | 0.78-5.00 | 2.40 | 0.56-1.97 | 1.28 | 1.97 |
| 11 | 0.42-2.94 | 1.40 | 0.60-1.56 | 1.14 | 1.30 |
| 12 | 0.42-1.90 | 1.10 | 0.05-1.89 | 0.82 | 1.00 |
| 13 | 0.19-4.10 | 1.19 | 0.23-1.56 | 0.87 | 1.07 |
| 14 | 0.36-4.38 | 1.40 | 0.47-2.68 | 1.12 | 1.29 |
| 15 | 0.31-1.56 | 1.00 | 0.05-2.27 | 0.98 | 0.99 |
| 16 | 0.31-1.56 | 0.76 | 0.23-1.17 | 0.70 | 0.74 |
| 17 | 0.13-1.56 | 0.82 | 0.30-2.08 | 0.86 | 0.84 |
| 18 | 0.21-1.79 | 0.85 | 0.23-1.56 | 0.89 | 0.87 |
| 19 | <0.03-2.23 | 0.92 | 0.31-2.08 | 1.00 | 0.95 |
| 20 | <0.03-3.88 | 1.56 | 0.05-0.78 | 0.46 | 1.15 |
| Total | <0.03-5.00 | 1.14 | 0.03-2.68 | 0.89 | 1.08 |

Table 2. Ranges and mean concentrations of lead in the surface waters of Kwangyang Bay during 1983-84 ($\mu g/l$)

| Year / St. | 1983 Range | 1983 Mean | 1984 Range | 1984 Mean | Total Mean |
|---|---|---|---|---|---|
| 1 | 0.16-1.36 | 0.72 | 0.19-0.75 | 0.47 | 0.64 |
| 2 | 0.40-2.90 | 1.11 | 0.22-1.25 | 0.54 | 0.90 |
| 3 | 0.19-2.31 | 0.80 | 0.15-1.58 | 0.96 | 0.86 |
| 4 | <0.03-1.79 | 0.86 | 0.04-3.91 | 0.87 | 0.87 |
| 5 | 0.20-1.56 | 0.68 | 0.04-1.25 | 0.38 | 0.57 |
| 6 | <0.03-1.20 | 0.58 | 0.04-1.32 | 0.53 | 0.56 |
| 7 | 0.30-2.34 | 0.99 | 0.05-1.25 | 0.43 | 0.78 |
| 8 | 0.62-1.80 | 0.92 | 0.05-0.63 | 0.31 | 0.74 |
| 9 | 0.30-1.56 | 0.82 | 0.05-0.63 | 0.26 | 0.63 |
| 10 | 0.62-7.19 | 1.97 | 0.05-3.91 | 0.98 | 1.60 |
| 11 | 0.30-1.92 | 1.01 | 0.29-1.30 | 0.66 | 0.87 |
| 12 | <0.03-4.80 | 1.23 | 0.20-3.91 | 1.06 | 1.17 |
| 13 | 0.21-1.62 | 0.81 | <0.03-1.25 | 0.31 | 0.62 |
| 14 | <0.03-3.00 | 0.82 | 0.05-1.25 | 0.38 | 0.65 |
| 15 | <0.03-1.61 | 1.18 | 0.06-0.63 | 0.39 | 0.60 |
| 16 | 0.25-1.56 | 0.75 | <0.03-0.63 | 0.30 | 0.58 |
| 17 | 0.20-1.36 | 0.68 | <0.03-0.81 | 0.25 | 0.52 |
| 18 | 0.20-3.90 | 1.17 | <0.03-0.63 | 0.23 | 0.82 |
| 19 | 0.19-2.03 | 0.93 | <0.03-0.63 | 0.25 | 0.68 |
| 20 | 0.30-1.80 | 0.72 | <0.03-0.63 | 0.17 | 0.51 |
| Total | <0.03-7.19 | 0.94 | <0.03-3.91 | 0.49 | 0.76 |

Table 3. Ranges and mean concentrations of zinc in the surface waters of Kwangyang Bay during 1983-84 (μg/l).

| Year / St. | 1983 | | 1984 | | Total Mean |
|---|---|---|---|---|---|
| | Range | Mean | Range | Mean | |
| 1 | 4.9-15.4 | 9.6 | 1.3-12.1 | 5.2 | 8.1 |
| 2 | 4.1-23.1 | 7.2 | 1.3- 5.4 | 3.3 | 5.7 |
| 3 | 3.9-13.5 | 8.0 | 2.2-10.9 | 4.6 | 6.7 |
| 4 | 1.8-10.6 | 6.7 | 2.0- 5.5 | 3.7 | 5.6 |
| 5 | 1.4-15.3 | 5.7 | 1.1- 4.8 | 2.9 | 4.7 |
| 6 | 0.6-23.1 | 6.0 | 2.0- 4.6 | 3.0 | 4.9 |
| 7 | 1.9-22.6 | 7.9 | 2.1- 8.8 | 3.8 | 6.3 |
| 8 | 1.7- 8.5 | 5.1 | 2.1- 6.2 | 3.7 | 4.5 |
| 9 | 1.6-12.1 | 6.7 | 1.6- 6.7 | 2.6 | 5.5 |
| 10 | 3.1-19.7 | 10.3 | 3.9-12.2 | 7.7 | 9.4 |
| 11 | 2.7-19.0 | 9.8 | 2.3- 6.2 | 4.7 | 7.8 |
| 12 | 1.7- 8.6 | 5.4 | 1.6- 3.7 | 2.9 | 4.4 |
| 13 | 2.2-14.4 | 6.0 | 0.8- 4.0 | 2.4 | 4.6 |
| 14 | 2.0-15.6 | 8.3 | 1.9- 6.2 | 3.7 | 6.6 |
| 15 | 1.5-15.0 | 6.1 | 1.7- 6.0 | 3.6 | 5.2 |
| 16 | 0.6-19.4 | 7.1 | 0.5- 6.0 | 2.8 | 5.5 |
| 17 | 0.9-15.4 | 6.7 | 1.2- 4.5 | 2.6 | 5.2 |
| 18 | 0.9-11.3 | 5.4 | 1.6- 6.0 | 3.0 | 4.5 |
| 19 | 0.9-22.8 | 5.2 | 1.0- 5.2 | 2.7 | 4.3 |
| 20 | 0.9- 9.3 | 4.2 | 0.3- 3.1 | 2.0 | 3.4 |
| Total | 0.6-23.1 | 6.9 | 0.3-12.2 | 3.5 | 5.6 |

Estuary represents highest Cu, Pb and Zn levels in Kwangyang Bay. The mean metal levels of St. 10 are shown much higher than those of other stations. This is likely due to shallow depth (~2m), high SS contents (Table 4) and metal inputs through Sueo Stream. St. 1 of Seomjin River Estuary also shows relatively higher Cu and Zn levels than those of the rest of stations. The highest total mean COD is also recorded at this station (Table 4).

From the salinity data measured in this study but not shown here, 20 stations of Kwangyang Bay can be divided into two groups, estuarine waters (Sts. 1, 2, 3 and 10) and seawaters (Sts. 4-9 and 11-20). The salinity ranges of surface water at Sts. 1, 2, 3 and 10 were 5.60-29.80‰, 9.80-32.08‰, 14.00-32.28‰ and 18.73-32.50‰, respectively. Other stations except Sts. 1, 2, 3 and 10 showed more than 30‰ monthly mean salinities.

It is of interest to note in Figs. 2-4 that despite the metal levels are higher in estuarine

Table 4. Annual mean concentrations of SS and COD in the surface waters of Kwangyang Bay during 1983-84.

| Parameter / Year / St. | SS (mg/l) | | | COD (mg/l) | | |
|---|---|---|---|---|---|---|
| | 1983 | 1984 | Total mean | 1983 | 1984 | Total mean |
| 1 | 15.2 | 8.7 | 11.9 | 1.85 | 1.93 | 1.88 |
| 2 | 14.5 | 13.3 | 13.9 | 1.56 | 1.58 | 1.57 |
| 3 | 16.3 | 16.1 | 16.2 | 1.43 | 1.67 | 1.52 |
| 4 | 14.9 | 9.9 | 12.3 | 1.30 | 1.55 | 1.48 |
| 5 | 15.3 | 8.5 | 11.8 | 1.49 | 1.58 | 1.53 |
| 6 | 11.4 | 7.2 | 9.3 | 1.54 | 1.43 | 1.50 |
| 7 | 12.1 | 8.2 | 10.1 | 1.52 | 1.28 | 1.42 |
| 8 | 13.7 | 9.1 | 11.4 | 1.56 | 1.50 | 1.54 |
| 9 | 18.2 | 8.3 | 13.1 | 1.58 | 1.56 | 1.57 |
| 10 | 26.8 | 22.0 | 24.4 | 1.70 | 2.11 | 1.85 |
| 11 | 25.4 | 23.4 | 24.4 | 1.75 | 1.88 | 1.80 |
| 12 | 15.7 | 11.0 | 13.3 | 1.37 | 1.51 | 1.42 |
| 13 | 15.3 | 9.1 | 12.1 | 1.48 | 1.49 | 1.49 |
| 14 | 16.7 | 12.6 | 14.6 | 1.49 | 1.40 | 1.46 |
| 15 | 18.4 | 13.3 | 15.8 | 1.69 | 1.68 | 1.68 |
| 16 | 16.2 | 10.3 | 13.2 | 1.84 | 1.79 | 1.83 |
| 17 | 15.5 | 8.8 | 12.1 | 1.52 | 1.54 | 1.52 |
| 18 | 14.9 | 10.4 | 12.6 | 1.55 | 1.36 | 1.47 |
| 19 | 20.7 | 8.9 | 14.7 | 1.61 | 1.48 | 1.56 |
| 20 | 21.7 | 8.7 | 15.1 | 1.65 | 1.45 | 1.58 |
| Mean | 16.9 | 11.4 | 14.1 | 1.57 | 1.59 | 1.58 |

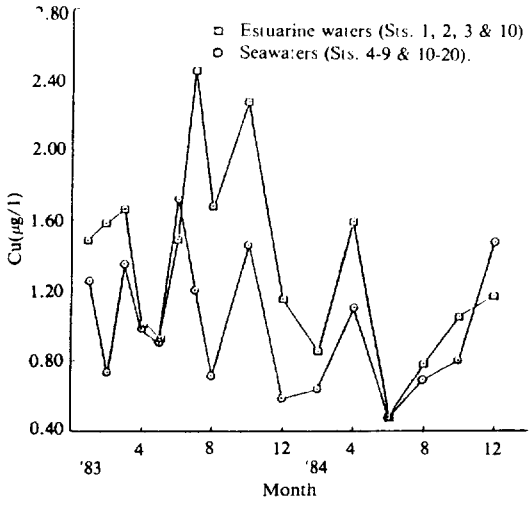


Fig. 2. Bimonthly variation of copper concentrations in estuarine waters and seawaters of Kwangyang Bay during Jan., 1983- Dec., 1984.

waters than in seawaters, bimonthly variation trends are very similar between the two groups. The annual mean concentrations of Cu, Pb and Zn were shown to be higher in 1983 over 1984. In particular, the mean levels of Pb and Zn of 1983 were nearly two times higher than those of 1984. Judging from SS contents (Table 4), this appears to be due to vigorous dredging activities during 1983 in

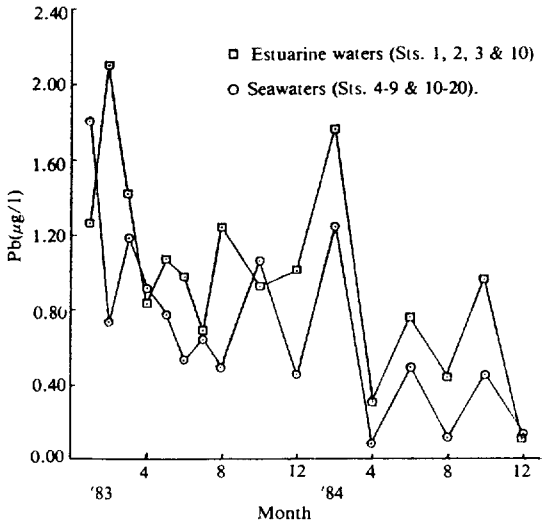


Fig. 3. Bimonthly variation of lead concentrations in estuarine waters and seawaters of Kwangyang Bay during Jan., 1983- Dec., 1984.

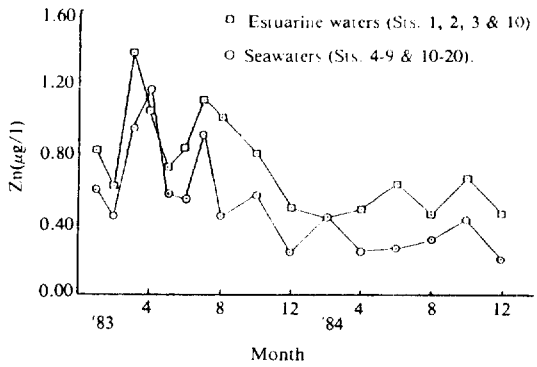


Fig. 4. Bimonthly variation of zinc concentrations in estuarine waters and seawaters of Kwangyang Bay during Jan., 1983- Dec., 1984.

Kwangyang Bay.

In the present study, all parameters measured show significant positive correlations with each other except Pb-COD (Table 5). In particular, SS exhibits significant relationship with Cu, Pb and Zn at the 99% level, indicating that the metal levels were partly controlled by SS contents through sorption or desorption during the dredging activities in Kwangyang Bay and sample preservation.

Table 6 presents the comparable concentrations of heavy metals in seawater in different regions of the world. In the Korean coastal waters, the highest levels of Cu and Zn are shown in the Masan Inner Bay where municipal and industrial wastewaters from Masan and Changwon Cities are introduced. Ulsan which has the Ulsan and Onsan Industrial Complexes along the coastlines shows highest Pb value, while Kwangyang Bay represents lowest Cu, Pb and Zn values in Korea. Compared with the heavy metal levels of the

Table 5. Correlation coefficients significant at the 99% level in Kwangyang Bay (N = 20)

| | Cu | Pb | Zn | SS | COD |
|---|---|---|---|---|---|
| Cu | 1.000 | | | | |
| Pb | 0.646 | 1.000 | | | |
| Zn | 0.735 | 0.545* | 1.000 | | |
| SS | 0.669 | 0.595 | 0.606 | 1.000 | |
| COD | 0.501* | — | 0.615 | 0.571 | 1.000 |

* Significant at the 95% level

Table 6. Comparable concentrations of heavy metals in seawater in different regions of the world ($\mu$g/l)

| Area | Cu | Pb | Zn | Source |
|---|---|---|---|---|
| Kwangyang Bay, Korea | 1.08 | 0.76 | 5.6 | This study |
| Banweol | 2.1 | 2.0 | 16.6 | Lee *et al.* (1981a) |
| Jinhae Bay | 1.7 | 1.8 | 16.2 | Lee *et al.* (1984) |
| Masan Inner Bay | 3.6 | 2.5 | 25.7 | Lee *et al.* (1984) |
| Mogpo | 2.0 | — | 9.9 | Lee *et al.* (1979) |
| Nagdong Estuary | 1.8 | 2.2 | 16.1 | Lee *et al.* (1981b) |
| Ulsan | 3.0 | 2.7 | 18.4 | Lee *et al.* (1981a) |
| Abu Dhabi, UAE | 0.46 | 0.04 | 0.12 | Fowler *et al.* (1984) |
| Chao Phraya River Estuary, Thailand | 2.3-5.5 | 4.7-16.2 | — | Menasveta *et al.* (1979) |
| Dokai Bay, Japan | 8.3 | 40.8 | — | Sakino *et al.* (1980) |
| Kanmon Straits, Japan | 5.4 | 1.5 | — | Sakino *et al.* (1980) |
| Bristol Channel, UK | 2.07 | 1.18 | 9.98 | Abdullah *et al.* (1972) |
| Cardigan Bay, UK | 1.72 | 2.24 | 7.46 | Abdullah *et al.* (1972) |
| Liverpool Bay, UK | 1.45 | 1.74 | 11.86 | Abdullah *et al.* (1972) |
| Elbe Estuary, Germany | 3.4 | 8.9 | 20.5 | Caspers (1975) |
| Eastern Mediterranean, Israel | 3.7 | 6.4 | 38.3 | Roth and Hornung (1977) |
| Fraser River Estuary, Canada | 1.3 | 0.24 | — | Fletcher and Holmes (1983) |
| San Diego Bay, U.S.A. | 0.5-3.6 | — | 0.6-3.8 | Zirino *et al.* (1978) |
| Unpolluted Seawater | 0.25 | 0.03 | 4.9 | Bowen (1979) |

foreign coastal waters, the mean concentrations of Cu, Pb and Zn in Kwangyang Bay are shown to be relatively low due to no significant pollutant source of heavy metals around the study areas.

## CONCLUSIONS

The mean concentrations of heavy metals in the surface seawaters of Kwangyang Bay during 1983-84 were 1.08 $\mu$g/l for Cu, 0.76 $\mu$g/l for Pb and 5.6 $\mu$g/l for Zn, respectively.

Of the stations, St. 10 of Sueo River Estuary shows highest levels of Cu, Pb and Zn likely due to shallow depth ($\sim$2m), high SS contents, and metal inputs through Sueo Stream. The heavy metal levels of estuarine waters including Sueo and Seomjin River Estuaries are slightly higher than those of seawaters in Kwangyang Bay. In addition, estuarine waters and seawaters show very similar monthly variation of the metal concentrations, indicating that the metal levels in seawater appear to be partly affected by river inputs.

Cu, Pb, and Zn show significant correlations not only with each other but also with SS.

Compared with the heavy metal levels of the different regions, the mean concentrations of Cu, Pb and Zn in Kwangyang Bay are shown to be relatively low.

## ACKNOWLEDGEMENT

This work is a part of the results of environmental survey during the Kwangyang Steel Mill Site Construction sponsored by Pohang Iron & Steel Co., LTD.

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*Received June 13, 1986*
*Accepted August 25, 1986*