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The Sediment Transport Pattern from a Large Industrial Complex to an Enclosed Bay

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Abstract

The movement of sediments in the stream crossing a large industrial complex to the mouth of Masan Bay was monitored for eight years. Sediment samples were seasonally collected in the period of 1992~1997 and 2001~2002. The heavy metal content of sediment was found to be higher at dry season with the peak on February and significantly decreased at rainy season. Metals content in stream sediments were rapidly decreased by large precipitation events in rainy season because the contaminants in the upstream sediments were transported to the dredged area of Masan Bay where is a typical enclosed bay in Korea. The increasing and decreasing tendency of heavy metals in sediment was repeatedly observed for six consecutive years. The heavy metals assessment of stream sediment provide us the information about the pollutant source, transport pattern and control strategy along the industrial complex. It was strongly suggested that the transportable stream sediments of an industrial area should be controlled as one of the important strategies to restore and manage the enclosed bay. Combined wastewaters have been collected and treated in a publicly owned treatment works (POTW) after industrial wastewater treatment at each location of industries since 1994. A field study was conducted to investigate the pollutant removal efficiency and performance of contact oxidation system installed and operated in two locations in the stream. The stream sediment quality was improved since then, and as a consequence the habitat of the estuary has been restored.

Keywords: Heavy metals, Industrial complex, Management, Sediment transport

1. Introduction

The semi-enclosed bay, Masan-Jinhae Bay is surrounded by land and islands. It has the area of 650 km^2 with the average depth of 5 m in the inner bay and 25 m in the central part. The reclamation of Masan Bay has caused sharp declines in the natural coastlines and shallows (Fig.1).

The prediction of transport of very fine sediments in coastal and estuarine areas is receiving a growing concern and numerical models are more and more asked to give reliable results, or are used as a decision tool, on three related issues[1)] estimation of accumulations of sediment to infer a cost of dredging, evaluation of disposal sites and fate of dumped materials water quality problems, where cohesive sediment play a major role by adsorption of heavy metals and chemical substances.

The sediment was mostly composed of fine silt of 0.005 mm or smaller size in Masan Bay area in Fig. 2.

Seasonal influences even complicate a little more the problem of long-term techniques. The likely importance of biological effects and seasonal influences on the predictability of the models remain to be assessed. The seasonal cycle of sediment transport was studied for a major stream coming into the inner bay through a large machinery industrial complex as a main source of persistent metals. The changing pattern of heavy metals in sediments from upstream to estuary can indicate the transport of sediment because heavy metals originated from machinery industries and included in the stream sediments give us reliable information to trace the sediment transport.

2. Materials and Methods

The metals Zn, Pb, Cu, and Cr were analyzed for this study because of toxic effects their abundance and toxic effects in the sediments of this industrialized and urbanized area by previous study.[2)] The superficial sediments were obtained by grab sampler at 10 sampling sites shown in Fig. 2. For analysis of the metals, sediment increments were dried at 105 °C for 5 hr and passed through a 32-mesh nylon sieve. One gram of sample was digested with a mixture of 5 mL of sulfuric acid and 5 mL of nitric acid in a Kijeldhal flask (200 mL volume). The concentration

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Fig. 1. Alterations of coastal line in the Masan Bay.

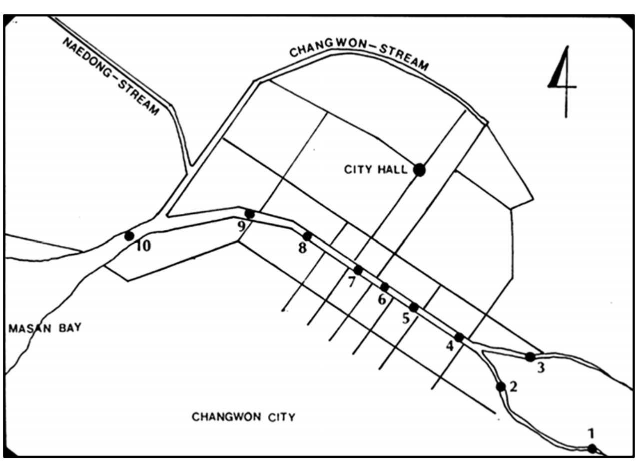

Fig. 2. Sampling sites of stream sediment originated from industries.

of heavy metals was determined by flame atomic absorption spectrophotometry (Model Shimazu AA-680, Japan). The accuracy of the method has been determined in the laboratory by standard materials of pond sediment [National Institute for Environmental Studies (NIES) Japan, N0. 22] and mussel (NIES No. 6). A contact oxidation system was installed and operated in the stream. The performance was investigated relating to the sediment accumulation downstream.

3. Results and Discussion

The mud sediment treatment was carried out from June 1990 to December 1994 entailed dredging, transportation, chemical coagulation and dumping in confined area for the restoration of Masan Bay and its estuaries. The total amount of sediment dredged was around 2,111,000 m^3. The total area dredged was 5,164,000 m^2 and the total cost 36 million dollars (Table 1).

The heavy metal contents of the sediment obtained on February, May, September and November each year from 1992 to 1997, and on February in 2001, May and September in 2002 were compared in Fig. 3. The difference of sediment heavy metals between 1997 and 2001/2002 showed a trend to have almost same level in average value except September. The average value of chromium on February was decreased sharply from 1997 to 2001.

When we observed seasonal variations of stream sediment with precipitation, all the metals showed the same trend. The heavy metals content of sediment was found to be higher at dry season with the peak on February and significantly decreased at rainy season. The temporary pattern of heavy metals and ignition loss in sediment was repeatedly measured for six years.

Long *et al.*[3)] reviewed and screened for possible inclusion in the biological effects data base for sediments. Using these data, two guideline values (ERL and ERM) were determined for nine trace metals, total PCBs, two pesticides, and 13 polynuclear aromatic hydrocarbons (PAHs). The lower 10th percentile of the effects data for each chemical was identified and referred to as the effects range-low (ERL). The median, or 50th percentile, of the effects was identified and are referred to as the effects range-median (ERM). Four metal species (Zn, Pb, Cu and Cr) were grouped by the guideline by Long et al.[3)] and are presented in Table 2. Average concentration of Zn during 1992~1994 (587.2 mg/kg) were higher than ERM guideline concentration (410 mg/kg). The adverse effect for the zinc was assumed to be

Table 1. Dredged volume of contaminated sediment from estuaries and Masan Bay from 1990 to 1994 (Unit : m^3)

Year	Dredged volume (m^3)	Area							
		Samho stream	Bongam stream	Sammi steel manufacture	Samho estuary	Free export zone	Tacoma shipbuilding	Cental pier	West pier
1990	264,450	49,280	142,680	76,490					
1991	736,741	8,559	77,242	1,270	386,734	262,936			
1992	230,000							230,000	
1993	376,000						376,000		
1994	500,048								500,048
Total	2,111,239	57,893	219,922	77,760	386,734	262,936	376,000	230,000	500,048

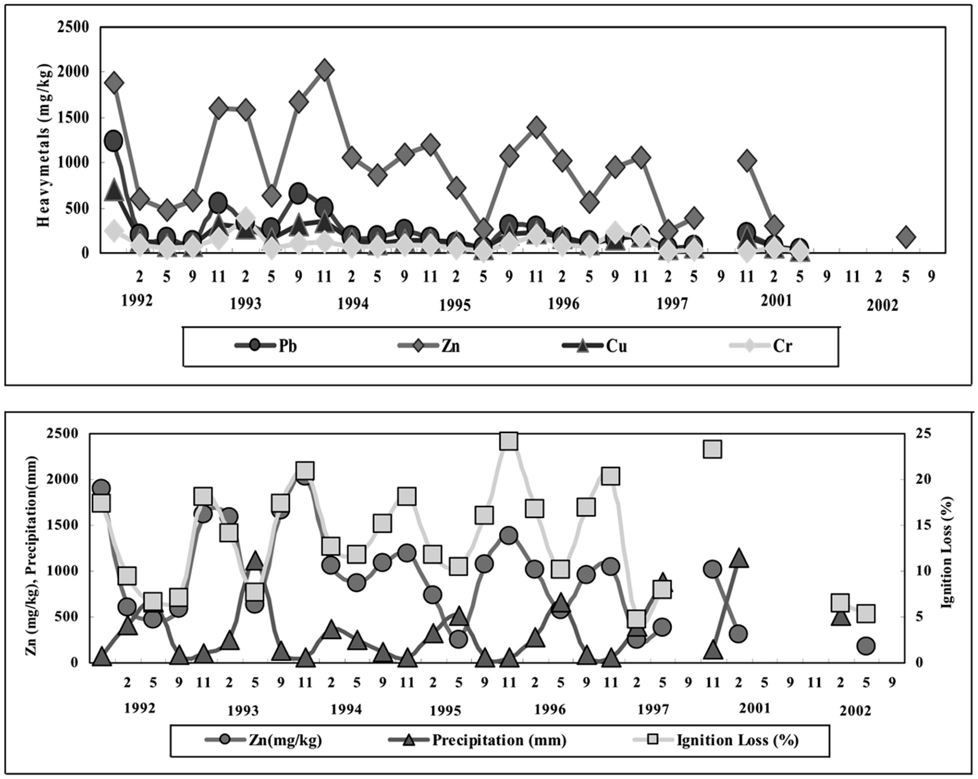

Fig. 3. Seasonal variation of Zinc, Lead, copper, chromium concentration and ignition loss in stream sediment with pertinent rainfall record.

same as the maximum ERM. The adverse effects for other metals were calculated in the same way when the measured concentrations were not within the guideline. The zinc concentration of surface sediment belongs to the concentration above ERM represents a probable effects range within which effects would frequently (69.8%) occur. The calculated adverse biological effects for Pb, Cu and Cr were 90.2%, 83.7% and 21.1%, respectively. The concentrations of sediment metals were decreased during the period of 2001~2002, thus, the adverse effects were changed to ERL~ERM for Zn, Pb, Cu and <ERL for Cr.

A field study was conducted to investigate the removal efficiency and performance of contact oxidation treatment system installed and operated in two locations of stream flowing to the Masan Bay. The removal of organic matters from stream water flowing to the already eutrophicated bay is getting more important in order to restore the water quality. The removal efficiencies of BOD, SS and ABS were 52~63%, 50~70% and 60~85%, respectively, whereas 10~25% of total nitrogen and 25~40% of total phosphorus were only removed. Flow rates to contact oxidation treatment showed seasonal and hourly variations. The treatment capacity installed is now enough to handle the present inflows, thus it was suggested that this system should be operated to supply only the volume of oxygen to require the actual loading to the treatment system and the aeration system would be intermittently operated for the improvement of nitrogen and phosphorus removal. It was found that flow rate should be controlled for detention time of contact oxidation to maintain at least more than 1.5 hr. A proper draw-out of sediment from the system was also an important operating parameter because of sludge accumulation in the following steps of contact oxidation process.

4. Conclusions

The transport and fate of contaminated sediments in estuary

Table 2. Toxicological effects of sediment by guideline values for the incidence of biological adverse effects

	Guideline (mg/kg)		Adverse effects (%)			Stream sediment			
						Concentration (mg/kg)		Adverse effects (%)	
	ERL	ERM	<ERL	ERL~ERM	>ERM	1992~1994	2001~2002	1992~1994	2001~2002
Zn	150.0	410.0	6.1	47.0	69.8	587.2	251.0	69.8	47.0
Pb	46.7	218.0	8.0	35.8	90.2	631.6	186.7	90.2	35.8
Cu	34.0	270.0	9.4	29.1	83.7	470.0	183.7	83.7	29.1
Cr	81.0	370.0	2.9	21.1	95.0	167.0	39.0	21.1	2.9

ERL, effect range-low; ERM, effect range-median.

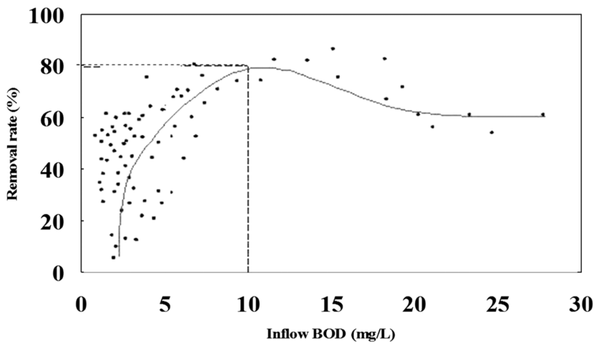

Fig. 4. Inflow BOD and removal rate.

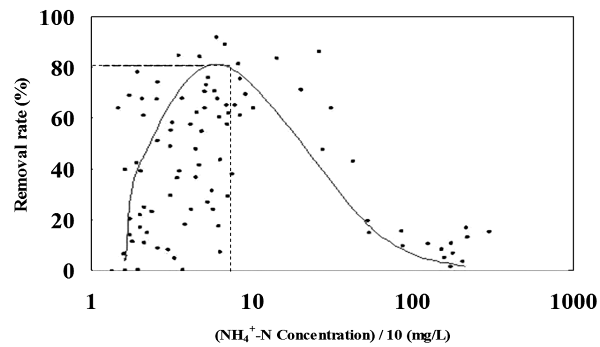

Fig. 5. Inflow NH_4+ concentration and removal rate.

is very important in managing and restoring. The seasonal pattern of metals content in stream sediment clearly indicates that the contaminated sediment is transported by precipitation down to the estuary. The operation of contact oxidation system installed in this stream since 1997 contributes to the improvement of stream water quality. The contaminated metals to be associated with biological effects were sorted. The potential of biological effects in the sediments obtained during the period of investigation from 1992~1997 was estimated as Zn 69.8%, Pb 90.2%, Cu 83.7%, and Cr 21.1%, respectively. This values were changed to Zn 47.0, Pb 35.8, Cu 29.1 and Cr 2.9 during the period 2001~2002. The stream sediment quality was recovered, and as a consequence the habitats of estuary such as fishes and birds have been restored.

Acknowledgements

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References

1. Teisson, C. A., Review of cohesive sediment transport models, In N. Burt, R. Parker & J. Watts (eds), Cohesive Sediments, John Wiley & Sons, pp. 367-381 (1997).
2. Lee, C. W., Yang, W. J., Kwon, Y. T., Min, B. Y., and Honda, K., "Metal distribution and contamination in sediments from estuaries of Masan Bay as a potential source of groundwater quality deterioration," *Oceans Research*, **12**(2), 97-104 (1990).
3. Long, E. R., Macdonald, D. D., Smith, S. L., and Caldar, F. D., "Incidence of adverse biological effects within ranges of chemical concentration in marine and estuarine sediments," *Environmental Management*, **19**, 81-97 (1995).