Ecological Risk Assessment of Heavy Metals to Freshwater Benthic Macroinvertebrate Assemblages Based on Field Survey in the Hasama River Basin, Miyagi, Japan.

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Introduction

Environmental water quality standard in Japan for zinc concentration relating to the conservation of aquatic organisms was established in 2003. The standard zinc concentration in the freshwater environment is **30 μg/L** determined by the chronic toxicity of a mayfly *Epeorus latifolium*.

In order to ascertain the validity of this standard, we need to understand the relationship between zinc concentrations and populations or communities of aquatic organisms in natural rivers. On riverine benthic macroinvertebrates, there is little data that can answer the issue in Japan.

In this study, we conducted two field surveys in 2004-2005 to assess ecological risks of heavy metals (especially zinc) on riverine benthic macroinvertebrate assemblages in the Hasama River basin, containing abandoned lead and zinc mine (Fig. 1). In this poster, results of the spring survey were presented.

Objective of this study … to evaluate effects of heavy-metal pollution (especially zinc) on riverine benthic macroinvertebrates at population- and community-levels.

Materials and Methods

Study Site
The Hasama River

◆Abandoned Hosokura Mine is located in the upstream region.
◆Spring water from bed of the stream near the mine had high concentrations of zinc (max. 4 mg/L), cadmium, copper and lead (Seino et al. 2004).
◆We selected 9 riffles as sampling sites (Fig. 1).

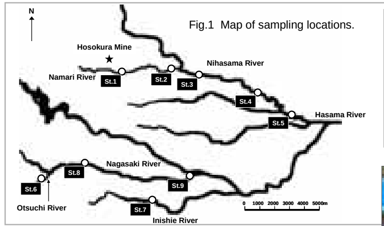


Fig.1 Map of sampling locations.

Benthic macroinvertebrates sampling

◆Benthic macroinvertebrates were collected from 5 stone (ϕ = 15 – 20 cm) using a surber net (mesh size = 0.25 mm) at each site.
◆Invertebrate metrics were calculated on each site (averages of 5 stones)

Community metrics: total taxon richness, total abundance, EPT richness (total taxon richness of Ephemeroptera, Plecoptera and Trichoptera), EPT abundance, abundance and taxonomic richness of the three major aquatic insects groups (Ephemeroptera, Trichoptera, and Chironomidae)

Population metrics: abundances of dominant taxa

Water quality

total concentrations of heavy metals (zinc, copper, cadmium, lead)
temperature, pH, DO, BOD, TOC, conductivity, hardness.

Physical environment

catchment area, stream width, riffle width, maximum stream depth, maximum current velocity, average water depth on sampling stones, average current velocity on sampling stones, average stone size

◆ We classified all 9 sites into one of 4 categories, based on relative heavy-metal concentrations and physical variables (Table 1).

HU (heavily-polluted upper) sites :St.1,2 ⇔ NU (not-polluted upper) sites :St.6,7
ML (moderately-polluted lower) sites :St.3,4,5 ⇔ NL (not-polluted lower) sites :St.8,9

Table.1 Some physicochemical variables and score of first principal component at sampling sites.

Site	Cu (μg/L)	Zn (μg/L)	Cd (μg/L)	Pb (μg/L)	pH	DO (mg/L)	Hardness (mg/L)	Catchment area (km^2)	Stream width (m)	PC1
1	5.2	447	2.79	11.4	7.9	9.1	831	11	9	1.80
2	4.4	377	3.97	6.2	7.7	8.9	806	18	8	1.53
3	1.9	136	1.23	2.1	7.8	10.5	262	101	16	-0.14
4	1.4	152	1.12	1.9	7.8	11.3	248	104	7	-0.13
5	1.3	126	0.90	2.4	7.7	10.1	232	128	12	-0.02
6	3.3	64	0.49	0.6	7.8	11.3	18	3	2	-0.57
7	0.3	5	N.D.	0.2	7.4	10.9	27	8	4	-0.77
8	N.D.	6	0.03	0.1	7.9	12.9	23	35	10	-1.00
9	0.3	6	0.01	0.2	7.8	11.3	25	41	10	-0.69

PC 1 Score

Data analysis

significance level α = .05

1. Continual response of invertebrate metrics to heavy-metal pollution

Principal component regression (PCR) was performed because of many high correlations between heavy-metal concentrations and physicochemical variables.

Principal component analysis (PCA)
for heavy metals and physicochemical variables

↓ all PCs

Stepwise multiple regression analysis
with forward selection (*Fin* = 4.0, *Fout* = 3.9)

↓

Test the significance of partial regression coefficient of PC1, which can be interpreted as "the influence of heavy metal pollution"

We could not separate the effects of zinc from those of other heavy metals.

Result of PCA

variable	PC 1	PC 2	PC 3	PC 4	PC 5
Cu	0.88	-	-	-	-
Zn	0.99	-	-	-	-
Cd	0.95	-	-	-	-
Pb	0.95	-	-	-	-
pH	-	0.93	-	-	-
DO	-0.89	-	-	-	-
BOD	-	-	0.92	-	-
TOC	-	-0.72	-	-	-0.43
Conductivity	0.99	-	-	-	-
Hardness	0.99	-	-	-	-
catchment area	-	-	-	0.76	0.55
Stream width	-	-	-	0.95	-
Riffle width	-	-	-	0.97	-
Stream depth	-	-	-	0.41	-
Stream Velocity	-	-	-0.61	0.43	-
Stone depth	-	-	-	-	0.98
Stone velocity	-	-	-	0.51	0.68
Stone size	-	-0.42	-	-0.47	-
Eigenvalue	6.61	2.15	1.56	3.48	2.14
Contribution (%)	37%	12%	9%	19%	12%

Only components with λ>1 and factor loadings exceeding |0.4| are shown.

2. Comparison of invertebrate metrics between polluted and unpolluted sites

We tested the effects at upper and lower sites separately, because of differences in potential fauna and heavy-metal concentrations between them.

One-way ANOVA among the 4 categories

↓ If category effect was significant

Planned comparisons → **HU sites (St.1,2) vs. NU sites (St.6,7)**
ML sites (St.3,4,5) vs. NL sites (St.8,9)

Results

Responses of Macroinvertebrate: Community Metrics

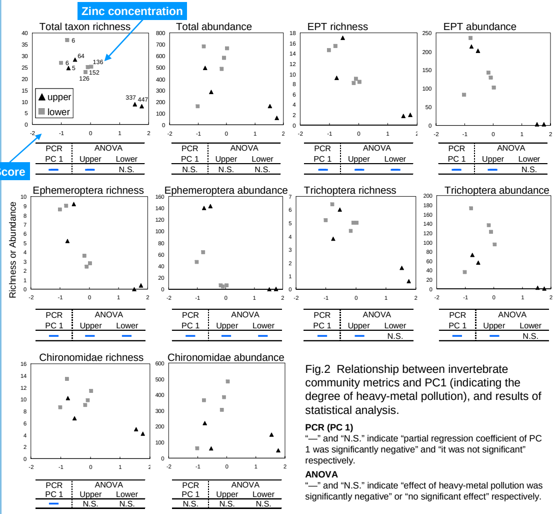


Fig.2 Relationship between invertebrate community metrics and PC1 (indicating the degree of heavy-metal pollution), and results of statistical analysis.

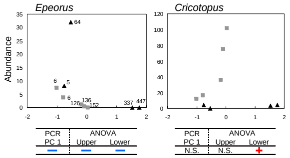
PCR (PC 1)
"—" and "N.S." indicate "partial regression coefficient of PC 1 was significantly negative" and "it was not significant" respectively.

ANOVA
"—" and "N.S." indicate "effect of heavy-metal pollution was significantly negative" or "no significant effect" respectively.

◆80% of the community metrics were significantly decreased as heavy-metal concentrations increased.
◆ The effects on Ephemeroptera diversity and abundance were remarkable even at moderately-polluted sites.

Responses of dominant taxa

examples



Abundance of *Thienemanniella* showed the same tendency

◆Among 16 dominant taxa, 8 were significantly decreased and 2 were increased.

◆While the negative effects of heavy-metal pollution on *Epeorus* (Ephemeroptera) was observed, the abundance of some chironomid taxa at ML sites was significantly larger than those at NL sites.

How much zinc does affect riverine benthic macroinvertebrates at population- and community-levels?

Lower sites;
◆Reduction in Ephemeroptera diversity and abundance at ML sites (Zn: 120-150 μg/L) compared to NL sites (Zn: <10 μg/L)

Upper sites;
◆Reduction in many invertebrate metrics at HU sites (Zn: 350-450 μg/L).
◆Higher Ephemeroptera diversity and abundance at St.6 (Zn: 64 μg/L) compared to St.7 (Zn: <10 μg/L)

>120 μg/L of zinc concentration affects invertebrates negatively?
<60 μg/L of zinc concentration does not?

These results are consistent with Kamo's results (P630). See under paper.

However, some problems remain;
◆We could not separate the effects of zinc from those of other heavy-metals.
◆The number of sampling sites in this study is few.

Conclusions

1. We detected the effects of heavy-metal pollution on riverine benthic macroinvertebrates in Japan.
   i. We observed the negative effects on many of community and population metrics, especially on diversity and abundance of Ephemeroptera.
   ii. Abundance of some chironomid taxa increased by heavy-metal pollutions.
2. We hypothesize that more than 120 μg/L of zinc concentration negatively affects riverine benthic macroinvertebrates at population- and community-level, while less than 60 μg/L of zinc concentration does not.
3. Field surveys can assess the community- and population-level effects directly while laboratory toxicity test cannot. However, they have difficulty assessing the ecological risk of zinc in isolation because other heavy metals usually co-exist in zinc-polluted river water. In order to establish the relationship between zinc concentration and benthic macroinvertebrates, we need extensive researches for rivers that vary in concentrations of heavy metals in water.

References

Seino, S., Abe, T., Fujimaki, H. 2004. Annual Report of Miyagi Prefectural Institute of Public Health and Environment (in Japanese) 22;109-114

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