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CU, CO AND NI CONTAMINATION INDEX FOR RIVER USING RIVER INSECTS AND RIVER PLANTS

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ABSTRACT: Useful species as an index of metal contamination needs a high metal concentration in a contaminated area and low metal concentration in a non-contaminated area. Moreover, it needs a high metal concentration factor. Metal concentrations of moss were high in the Cu mine area (31 to 21,000 and 2 to 200 mg/kg-dry for Cu and Co) and were low in the other areas (2 to 87 and 2 to 33 mg/kg-dry for Cu and Co). Ni concentrations of caddice-worm were high in the serpentinite area (9 to 590 mg/kg-dry) and were low in the other areas (2 to 74 mg/kg-dry). Moss had the highest concentration factor (160,000, 4,600 and 59,000 for Cu, Co and Ni) among river plants. Therefore, it was clarified that moss was useful species for an index of Cu, Co and Ni contamination among river plants based upon its metal concentration and concentration factor. In river insects, metal concentrations of crane fly larva were high in the Cu mine area (50 to 1,400 and 1 to 82 mg/kg-dry for Cu and Co) and were low in the other areas (11 to 130 and 0.7 to 10 mg/kg-dry for Cu and Co). Crane fly larva had the highest concentration factor for Cu (46,000) and also kept high concentration factor for Co (2,700) among river insects. Ni concentrations of caddice-worm were high in the serpentinite area (52 to 220 mg/kg-dry) and were low in the other areas (0.3 to 20 mg/kg-dry). Caddice-worm had the highest Ni concentration factor (22,000) among river insects. Therefore, it was clarified that crane fly larva was useful species for an index of Cu and Co contamination and caddice-worm was useful species for an index of Ni contamination based upon their metal concentrations and concentration factors.

Keywords: Moss, Crane fly larva, Caddice-worm, Heavy Metals, Concentration Factor

1. INTRODUCTION

Even if there is a metal contamination source from metal mines in a catchment, metal concentration of river water in a catchment is not always high because of dilution of rain water [1]. River water metal concentration is changeable depending on rain in a catchment. Therefore, metal concentration of river water is not always useful for evaluating metal contamination in a catchment. Catchment metal concentration is also caused by river sediments. On the other hand, metal concentrations of river insects and river plants are often higher than those of river water because of high bioconcentration factor and their metal concentrations are affected by both river water and river sediments because their metals are derived from both river water and river sediments. Therefore, metal concentrations of river insects and river plants are thought to be useful for evaluating river metal contamination.

Metal concentrations for many river insects and river plants have been studied in metal contamination or non-contamination areas. At past, metal concentrations of river insects, caddice-worm [2]-[3], dobsonfly [4], stonefly [5], mayfly [5], river plants, fern [6], moss [7], and reed [8] have been studied. However, useful species as metal contamination index using river insects and river plants have not been determined because no comparison of contaminated and non-contaminated areas, although some caddice-worm were shown possibility as an index of metal contamination. Therefore, comparing metal concentrations of river insects and river plants sampled at both contaminated and the non-contaminated areas, useful species for an index of metal contamination for river were determined. Useful species as an index of metal contamination needs a high metal concentration in a contaminated area and low metal concentration in a non-contaminated area. Moreover, it needs a high metal concentration factor.

2. STUDY AREA

The Kinokawa River is located in the center of Kinki district and flows into the Kii Channel through the Kii plain as shown in fig.1. The Kinokawa River is classified into A river based on the Ministry of Land, Infrastructure, Transport and Tourism of Japan. The length and total area of the Kinokawa River are 136 km and 1,750 km^2 [9]. The Izumi Group composed of sedimentary rocks, sandstone, mudstone and conglomerate is distributed in the northwest part of the catchment. The Sanbagawa Belt composed of metamorphic rocks, serpentinite and crystalline schist is distributed in the southwest part and the northeast part of the catchment. The Hidakagawa Group

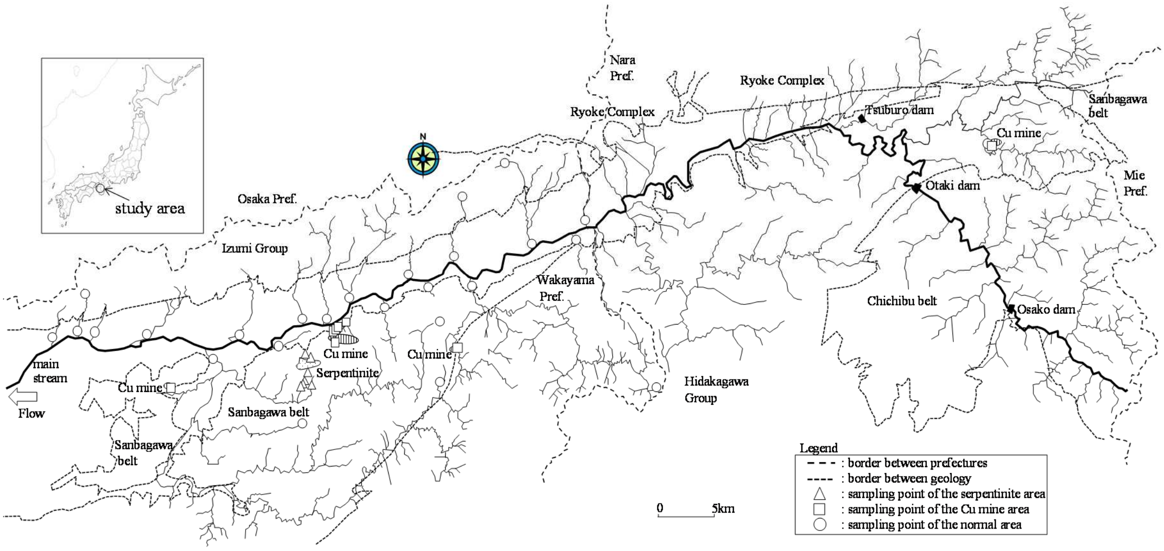

Fig.1 Study area

composed of sedimentary rocks, sandstone and shale is distributed from the southern part to the northeast part of the catchment. The Chichibu Belt composed of sedimentary rocks, sandstone, mudstone, limestone and chert is distributed in the eastern part of the catchment [10]. The Ryoke Complex composed of plutonic rocks, granite and gneiss is distributed in the northeast part of the catchment.

The Kinokawa River catchment has serpentinite and the closed Cu mines. The chemistry of serpentinite is quite different from the other rocks and in particular Mg and Ni concentrations of serpentinite are high. The closed Cu mine produced a lot of Cu and Fe sulfide ore and waste water was low pH and high concentration of sulfate with metal. Then, in this study, catchments were divided into three groups, serpentinite, Cu mine and the normal areas based on geological aspect.

3. STUDY METHOD

River water, river insects and river plants were sampled in the Kinokawa River catchment. Sampling points were shown in fig.1. Sampling and measurement period is September 2013 to May 2015. Cu, Co and Ni concentrations of river water, river insects and river plants were measured. River water samples were filtered with the membrane filter with 0.45 micrometer of pore size on site and it was added concentrated nitric acid before analysis in laboratory. The sampled river insects and river plants were desiccated by dryer at first. After drying, they were dissolved with concentrated nitric acid and it was filtered with the membrane filter with 0.45 micrometer of pore size before analysis. Their Cu, Co and Ni concentrations were measured by ICP-AES. The actual detection limit of ICP-AES is 0.01ppm for Cu, Co and Ni. The species of sampled river insects were Japanese fresh water crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva, crane fly larva, mayfly larva and corixidae. However, crane fly larva and corixidae were not sampled in the serpentinite area. The species of sampled river plants were reed, fern, moss, Japanese knotweed and coix. However, reed and coix were not sampled in the serpentinite area. Moreover, Japanese knotweed was not sampled in the normal area. River plants excluding moss were divided into leaf, upper part stem, middle part stem, lower part stem and root and each part was separately analyzed.

4. RESULTS AND DISCUSSION

4.1 Evaluation for Cu

Fig.2 shows Cu concentrations of river insects and river plants. Cu concentration of a river insect or a river plant was calculated using 0.01 ppm for concentration of sample solution when Cu concentration of sample solution was under the detection limit. Solid mark indicates Cu concentration of river insect and river plant under the detection limit of concentration for sample solution. Cu concentrations of Japanese freshwater crab, dobsonfly larva, dragonfly larva, crane fly larva, mayfly larva and corixidae in the Cu mine area were 114 to 241, 590, 70 to 440, 50 to 1,400, 23 to 180 and 520 mg/kg-dry, respectively. Cu concentrations of Japanese freshwater crab, dobsonfly larva, dragonfly larva, crane fly larva, mayfly larva and corixidae in the other areas were 45 to 72, 16 to 81, 18 to 59, 11 to 130, 10 to 65 and 77 to 190 mg/kg-dry, respectively. Cu concentrations of reed, fern, moss, Japanese knotweed and upper and middle part stem and root

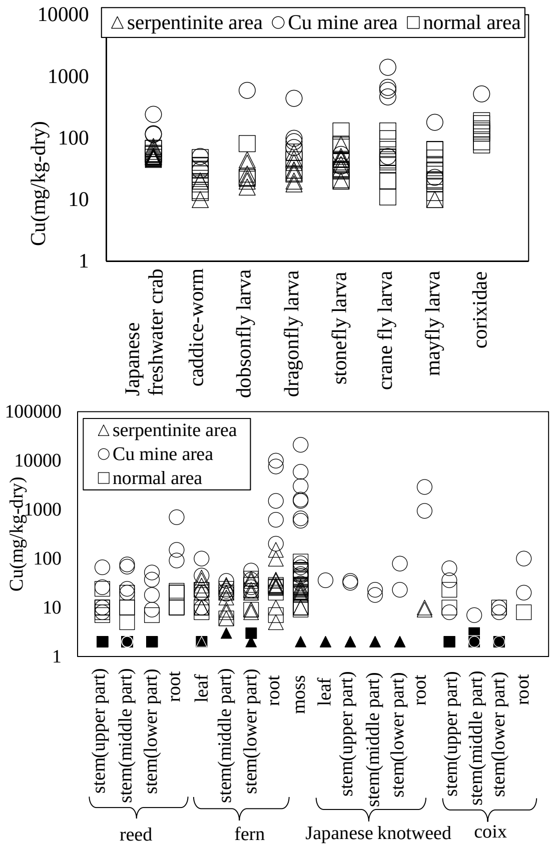

Fig.2 Cu concentrations of river insects and river plants.

of coix in the Cu mine area were 2 to 700, 10 to 10,000, 31 to 21,000, 18 to 2,900 and 2 to 100 mg/kg-dry, respectively. Cu concentrations of reed, fern, moss, Japanese knotweed and upper and middle part stem and root of coix in the other areas were 2 to, 24, 2 to 150, 2 to 87, 2 to 10 and 2 to 23 mg/kg-dry, respectively. Then, their Cu concentrations in the Cu mine area were higher than those in the other areas. In the past study, it was clarified that Cu concentration of river insects and river plants in the Cu mine area in the Kinokawa River catchment was affected by the Cu mine [1]. On the other hand, Cu concentrations of caddice-worm and stonefly larva in the Cu mine area were 30 to 50 and 35 to 54 mg/kg-dry, respectively. Cu concentrations of caddice-worm and stonefly larva in the other areas were 10 to 48 and 20 to 130 mg/kg-dry, respectively. Cu concentrations of lower part stem of coix both in the Cu mine area and the other areas were 2 to 10 mg/kg-dry. Then, their Cu concentrations in the Cu mine area were not higher than those in the other areas. Cu concentration ranges of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva, crane fly larva, mayfly larva and corixidae were 45 to 241, 10 to 50, 16 to 590, 18 to 440, 20 to 130, 11 to 1,400, 10 to 180 and 77 to 520 mg/kg-dry, respectively. Then, crane fly larva had

Table.1 Cu concentration factors of river insects and river plants.

			Cu concentration factor		
			area		
			Cu mine	serpentinite	normal
Japanense freshwater crab			11,000 to 24,000	4,500 to 7,200	4,800 to 6,800
caddice-worm			3,000 to 5,000	1,000 to 2,000	1,300 to 4,800
dobsonfly larva			29,000	1,600 to 4,400	2,300 to 8,100
dragonfly larva			7,000 to 22,000	1,800 to 5,800	2,600 to 5,900
stonefly larva			3,500 to 5,400	2,000 to 7,800	2,000 to 13,000
crane fly larva			5,000 to 46,000		1,100 to 13,000
mayfly larva			2,300 to 18,000	1,000	1,000 to 6,500
corixidae			26,000		7,700 to 19,000
reed	stem	upper part	800 to 6,600		200 to 2,400
		middle part	200 to 7,600		200 to 2,000
		lower part	900 to 5,200		200 to 700
	root		9,100 to 70,000		1,000 to 2,200
fern	leaf		2 to 2,000	200 to 4,100	200 to 2,300
	stem	middle part	630 to 2,200	300 to 2,900	600 to 2,400
		lower part	6 to 1,200	200 to 3,900	300 to 3,900
	root		2,000 to 62,000	500 to 15,000	700 to 2,900
moss			3,100 to 160,000	200 to 2,600	900 to 8,700
Japanese knotweed	leaf		9	200	
	stem	upper part	8 to 1,100	200	
		middle part	4 to 760	200	
		lower part	21 to 760	200	
	root		770 to 31,000	900 to 1,000	
coix	stem	upper part	800 to 6,300		200 to 2,300
		middle part	200 to 700		200 to 300
		lower part	200 to 1,000		200 to 1,000
	root		2,000 to 10,000		800

the highest and a wide range of Cu concentration among river insects. Cu concentration ranges of reed, fern, moss, Japanese Knotweed and coix were 2 to 700, 2 to 10,000, 2 to 21,000, 2 to 2,900 and 2 to 100 mg/kg-dry, respectively. Then, moss had the highest and a wide range of Cu concentration among river plants.

Table.1 shows Cu concentration factors of river insects and river plants. Cu concentration of river water was regarded as 0.01 ppm when a concentration of river water was under the detection limit. Cu concentration factors of Japanese freshwater crab, dobsonfly larva, dragonfly larva, crane fly larva, mayfly larva and corixidae in the Cu mine area were 11,000 to 24,000, 29,000, 7,000 to 22,000, 5,000 to 46,000, 2,300 to 18,000 and 26,000, respectively. Cu concentration factors of Japanese freshwater crab, dobsonfly larva, dragonfly larva, crane fly larva, mayfly larva and corixidae in the other areas were 4,500 to 7,200, 1,600 to 8,100, 1,800 to 5,900, 1,100 to 13,000, 1,000 to 6,500 and 7,700 to 19,000, respectively. Cu concentration factors of reed, fern root, moss, stem and root of Japanese knotweed and upper and middle part stem and root of coix in the Cu mine area were 200 to 70,000, 2,000 to 62,000, 3,100 to 160,000, 4 to 31,000 and 200 to 10,000, respectively. Cu concentration factors of reed, fern root, moss, stem and root of Japanese knotweed and upper and middle part stem and root of coix in the other areas were 200 to 2,400, 500 to 15,000, 200 to 8,700, 200 to 1,000 and 200 to 2,300, respectively. Then, their Cu concentration factors in the Cu mine area were higher than those in the other areas. On the other hand, Cu concentration factors of caddice-worm and stonefly larva in the Cu mine area were 3,000 to 5,000 and 3,500 to 5,400, respectively. Cu concentration factors of caddice-worm and stonefly larva in the other areas were 1,000 to 4,800 and 2,000 to 13,000, respectively. Cu concentration factors of fern leaf, fern stem, Japanese knotweed leaf and lower part stem of coix in the Cu mine area were 2 to 2,000, 6 to 2,200, 9 and 200 to 1,000, respectively. Cu concentration factors of fern leaf, fern stem, Japanese knotweed leaf and lower part stem of coix in the other areas were 200 to 4,100, 200 to 3,900, 200 and 200 to 1,000, respectively. Then, their Cu concentration factors in the Cu mine area were not higher than those in the other areas. The maximum Cu concentration factors of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva, crane fly larva, mayfly larva and corixidae were 24,000, 5,000, 29,000, 22,000, 13,000, 46,000, 18,000 and 26,000, respectively. Then, crane fly larva had the highest Cu concentration factor among river insects. The maximum Cu concentration factors of reed, fern, moss, Japanese knotweed and coix were 70,000, 62,000, 160,000, 31,000 and 10,000, respectively. Then, moss had the highest Cu concentration factor among river plants.

From the above results, Cu concentrations and Cu concentration factors of crane fly larva and moss were high in the Cu mine area and were low in the other areas. Moreover, crane fly larva had the highest and a wide range of Cu concentration and the highest Cu concentration factor among river insects. Moss had the highest and a wide range of Cu concentration and the highest Cu concentration factor among river plants. Therefore, crane fly larva and moss were useful species for an index of Cu contamination.

4.2 Evaluation for Co

Fig.3 shows Co concentrations of river insects and river plants. Co concentration of a river insect or a river plant was calculated using 0.01 ppm for concentration of sample solution when Co concentration of sample solution was under the detection limit. Solid mark indicates Co concentration of river insect and river plant under the detection limit of concentration for sample solution. Co concentrations of dobsonfly larva, dragonfly larva, crane fly larva and corixidae in the Cu mine area were 26, 0.8 to 30, 1 to 82 and 20 mg/kg-dry, respectively. Co concentrations of dobsonfly larva, dragonfly larva, crane fly larva and corixidae in the other areas were 0.9 to 6, 0.6 to 23, 0.7 to 10 and 0.8 to 5 mg/kg-dry, respectively. Co concentrations of reed root, fern root, moss, Japanese knotweed root and coix root in the Cu mine area were 2 to 30, 2 to 21, 2 to 200, 36 to 38 and 2 to 5 mg/kg-dry, respectively. Co concentrations of reed root, fern root, moss, Japanese knotweed root and coix root in the other areas were 2 to 6, 2 to 10, 2 to 33, 13 to 25 and 2 mg/kg-dry, respectively. Then, their Co concentrations in the Cu mine area were higher than those in the other areas. In the past study, it was clarified that Co concentration of river insects and river plants in the Cu mine area in the Kinokawa River catchment was affected by the Cu mine [1]. On the other hand, Co concentrations of Japanese freshwater crab, caddice-worm and stonefly larva in the Cu mine area were 0.1 to 2, 0.9 to 5 and 0.6 to 3 mg/kg-dry, respectively. Co concentrations of Japanese freshwater crab, caddice-worm and stonefly larva in the other areas were 0.2 to 3, 0.3 to 4 and 0.7 to 5 mg/kg-dry, respectively. Co concentrations of reed stem both in the Cu mine area and the other areas were 2 to 3 mg/kg-dry. Co concentrations of fern leaf and fern stem in the Cu mine area were 2 to 3 mg/kg-dry. Co concentrations of fern leaf and fern stem in the other areas were 1 to 3 mg/kg-dry. Co concentrations of Japanese knotweed leaf and stem both in the Cu mine area and the other areas were 2 mg/kg-dry of all. Co concentrations of coix stem in the Cu mine area were 2 mg/kg-dry. Co concentrations of coix stem in the other areas were 2 to 3 mg/kg-dry. Then, their Co concentrations in the Cu mine area were about the same as those in the other areas. Co concentrations of mayfly larva in the Cu mine area were 2 mg/kg-dry. Co concentrations of mayfly larva in the other areas were 1 to 50 mg/kg-dry. Then, Co concentrations of mayfly larva in the Cu mine area were not higher than those in the other areas. Co concentration ranges of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva, crane fly larva, mayfly larva and corixidae were 0.1 to 3, 0.3 to 5, 0.9 to 26, 0.6 to 30, 0.6 to 5, 0.7 to 82, 1 to 50 and 0.8 to 20 mg/kg-dry, respectively. Then, crane fly larva had the highest and a wide range of Co concentration among river insects. Co concentration ranges of reed, fern, moss, Japanese knotweed and coix were 2 to 30, 1 to 21, 2 to 200, 2 to 38 and 2 to 5 mg/kg-dry, respectively. Then, moss had the highest and a wide range of Co concentration among river plants.

Table.2 shows Co concentration factors of river insects and river plants. Co concentration of river water was regarded as 0.01 ppm when a concentration of river water was under the detection limit. Co concentration factors of dobsonfly larva, crane fly larva and corixidae in the Cu mine area

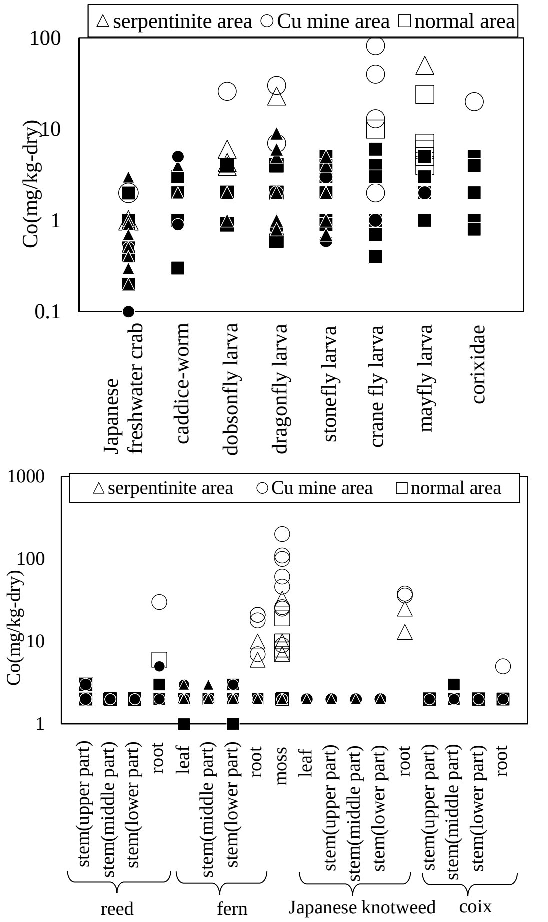

Fig.3 Co concentrations of river insects and river plants.

were 860, 100 to 2,700 and 660, respectively. Co concentration factors of dobsonfly larva, crane fly larva and corixidae in the other areas were 90 to 600, 40 to 1,000 and 80 to 500, respectively. Co concentration factors of reed root, fern root, moss and coix root in the Cu mine area were 200 to 3,000, 43 to 1,800, 200 to 4,600 and 200 to 500, respectively. Co concentration factors of reed root, fern root, moss and coix root in the other areas were 200 to 600, 200 to 1,000, 200 to 3,300 and 200, respectively. Then, their Co concentration factors in the Cu mine area were higher than those in the other areas. On the other hand, Co concentration factors of Japanese freshwater crab, caddice-worm and stonefly larva in the Cu mine area were 10 to 200, 90 to 500 and 60 to 300, respectively. Co concentration factors of Japanese freshwater crab, caddice-worm and stonefly larva in the other areas were 20 to 300, 30 to 400 and 70 to 500, respectively. Co concentration factors of reed stem both in the Cu mine area and the other areas were 200 to 300. Co concentration factors of coix stem in the Cu mine area were 200. Co concentration factors of coix stem in the other areas were 200 to 300. Then, their Co concentration factors in the Cu

Table.2 Co concentration factors of river insects and river plants.

			Co concentration factor		
			area		
			Cu mine	serpentinite	normal
Japanense freshwater crab			10 to 200	20 to 300	20 to 200
caddice-worm			90 to 500	200 to 400	30 to 300
dobsonfly larva			860	100 to 600	90 to 400
dragonfly larva			80 to 1,000	80 to 2,300	60 to 400
stonefly larva			60 to 300	70 to 500	90 to 500
crane fly larva			100 to 2,700		40 to 1,000
mayfly larva			200	5,000	100 to 2,400
corixidae			660		80 to 500
reed	stem	upper part	200 to 300		200 to 300
		middle part	200		200
		lower part	200		200
	root		200 to 3,000		200 to 600
fern	leaf		12 to 200	200 to 300	100 to 200
	stem	middle part	66 to 200	200 to 300	200
		lower part	12 to 200	200	100 to 300
	root		43 to 1,800	200 to 1,000	200
moss			200 to 4,600	200 to 3,300	200 to 1,900
Japanese knotweed	leaf		12	200	
	stem	upper part	12 to 66	200	
		middle part	12 to 66	200	
		lower part	12 to 66	200	
	root		237 to 1,200	1,300 to 2,500	
coix	stem	upper part	200		200
		middle part	200		200 to 300
		lower part	200		200
	root		200 to 500		200

mine area were about the same as those in the other areas. Co concentration factors of dragonfly larva and mayfly larva in the Cu mine area were 80 to 1,000 and 200, respectively. Co concentration factors of dragonfly larva and mayfly larva in the other areas were 60 to 2,300 and 100 to 5,000, respectively. Co concentration factors of fern leaf, fern stem and Japanese knotweed in the Cu mine area were 12 to 200, 12 to 200, 12 to 1,200, respectively. Co concentration factors of fern leaf, fern stem and Japanese knotweed in the other areas were 100 to 300, 100 to 300, 200 to 2,500, respectively. Then, their Co concentration factors in the Cu mine area were not higher than those in the other areas. The maximum Co concentration factors of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva, crane fly larva, mayfly larva and corixidae were 300, 500, 860, 2,300, 500, 2,700, 5,000 and 660, respectively. Then, mayfly larva had the highest Co concentration factor among river insects. Moreover, crane fly larva also kept high Co concentration factor among river insects. The maximum Co concentration factors of reed, fern, moss, Japanese knotweed and coix were 3,000, 1,800, 4,600, 2,500 and 500, respectively. Then, moss had the highest Co concentration factor among river plants.

From the above results, Co concentrations and Co concentration factors of crane fly larva and moss were high in the Cu mine area and were low in the other areas. Crane fly larva had the highest and a wide range of Co concentration among river insects. Mayfly larva had the highest Co concentration factor among river insects. However, Co concentrations of mayfly larva in the Cu mine area were not higher than those in the other areas. Useful species as an index of metal contamination needs a high metal concentration in a contaminated area and low metal concentration in a non-contaminated area. Then, mayfly larva was not useful species for an index of Co contamination. On the other hand, crane fly larva also kept high Co concentration factor among river insects. Moss had the highest and a wide range of Co concentration and the highest Co concentration factor among river plants. Therefore, crane fly larva and moss were useful species for an index of Co contamination.

4.3 Evaluation for Ni

Fig.4 shows Ni concentrations of river insects and river plants. Ni concentration of a river insect or a river plant was calculated using 0.01 ppm for concentration of sample solution when Ni concentration of sample solution was under the detection limit. Solid mark indicates Cu concentration of river insect and river plant under the detection limit of concentration for sample solution. Ni concentrations of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva and mayfly larva in the serpentinite area were 0.2 to 39, 52 to 220, 1 to 83, 9 to 60, 2 to 20 and 80 mg/kg-dry, respectively. Ni concentrations of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva and mayfly larva in the other areas were 0.3 to 2, 0.3 to 20, 0.9 to 4, 0.6 to 10, 0.6 to 5 and 1 to 10 mg/kg-dry, respectively. Ni concentrations of fern, moss and Japanese knotweed in the serpentinite area were 2 to 270, 9 to 590 and 7 to 320 mg/kg-dry, respectively. Ni concentrations of fern, moss and Japanese knotweed in the other areas were 1 to 30, 2 to 74 and 2 to 23 mg/kg-dry, respectively. Then, their Ni concentrations in the serpentinite area were higher than those in the other areas. In the past study, it was clarified that Ni concentration of river insects and river plants in the serpentinite area in the Kinokawa River catchment was affected by serpentinite [1]. On the other hand, Ni concentrations of corixidae in the Cu mine area were 5 mg/kg-dry. Ni concentrations of corixidae in the other areas were 0.8 to 5 mg/kg-dry. Ni concentrations of reed stem both in the Cu mine area and the other areas were 2 to 3 mg/kg-dry. Ni concentrations of coix in the Cu mine area were 2 mg/kg-dry. Ni concentrations of coix in the other areas were 2 to 3 mg/kg-dry. Then, their Ni concentrations in the Cu mine area were about the same as the other areas. Ni concentrations of crane fly larva and reed root in the Cu mine area were 1 to 26 and 5 to 20 mg/kg-dry, respectively. Ni concentrations of crane fly larva and reed root in the other areas were 0.7 to 20 and 2 to 3 mg/kg-dry, respectively. Then, Ni concentrations of crane fly larva and reed root in the Cu mine area were higher than those in the other areas. Ni concentration ranges of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva, crane fly larva, mayfly larva and corixidae were 0.2 to 39, 0.3 to 220, 0.9 to 83, 0.6 to 60, 0.6 to 20, 0.7 to 26, 1 to 80 and 0.8 to 5 mg/kg-dry, respectively. Then, caddice-worm had the highest and a wide range of Ni concentration among river insects. Ni concentration ranges of reed, fern, moss, Japanese Knotweed and coix were 2 to 20, 1 to 270, 2 to 590, 2 to 320 and 2 to 3 mg/kg-dry, respectively. Then, moss had the highest and a wide range of Ni concentration among river plants.

Table.3 shows Ni concentration factors of river insects and river plants. Ni concentration of river water was regarded as 0.01 ppm when a concentration of river water was under the detection limit. Ni concentration factors of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva and mayfly larva in the serpentinite area were 20 to 3,900, 5,200 to 22,000, 100 to 8,300, 900 to 6,000, 200 to 2,000 and 8,000, respectively. Ni concentration factors of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva and mayfly larva in the other areas were 30 to 200, 30 to 2,000, 90 to 400, 60 to 1,000, 60 to 500 and 100 to 1,000, respectively. Ni concentration factors of fern, moss and Japanese knotweed in the serpentinite area were 200 to 27,000, 900 to 59,000 and 700 to 32,000, respectively. Ni concentration factors of fern, moss and Japanese knotweed in the other areas were 100 to 3,000, 200 to 7,400 and 200 to 2,300, respectively. Then, their Ni concentration factors in the serpentinite area were higher than those in the other areas. On the other hand, Ni concentration factors of corixidae in the Cu mine area were 500. Ni concentration factors of corixidae in the other areas were 80 to 500. Ni concentration factors of reed stem both in the Cu mine area and the other areas were 200 to 300. Ni concentration factors of coix in the Cu mine area were 200. Ni concentration factors of coix in the other areas were 200 to 300. Then, their Ni concentration factors in the Cu mine area were about the same as those in the other areas. Ni concentration factors of crane fly larva and reed root in the Cu mine area were 100 to 2600 and 500 to 2,000. Ni concentration factors of crane fly larva and reed root in the other areas were 70 to 2,000 and 200 to 300. Then, their Ni concentration factors in the Cu mine area were higher than those in the other

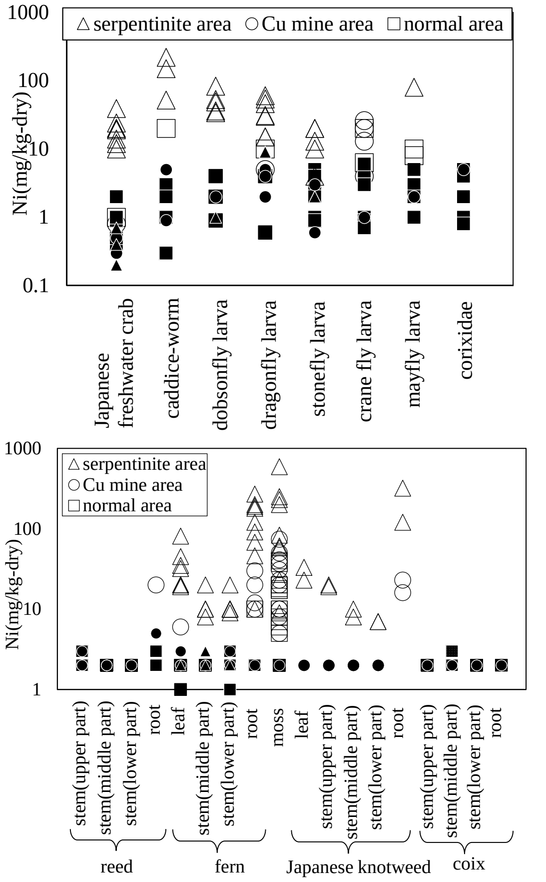

Fig.4 Ni concentrations of river insects and river plants.

areas. The maximum Ni concentration factors of Japanese freshwater crab, caddice-worm, dobsonfly larva, dragonfly larva, stonefly larva, crane fly larva, mayfly larva and corixidae were 3,900, 22,000, 8,300, 6,000, 2,000, 2,600, 8,000 and 500, respectively. Then, caddice-worm had the highest Ni concentration factor among river insects. The maximum Ni concentration factors of reed, fern, moss, Japanese knotweed and coix were 2,000, 27,000, 59,000, 32,000 and 300, respectively. Then, moss had the highest Ni concentration factor among river plants.

From the above results, Ni concentrations and Ni concentration factors of caddice-worm and moss were high in the serpentinite area and were low in the other areas. Moreover, caddice-worm had the highest and a wide range of Ni concentration and the highest Ni concentration factor among river insects. Moss had the highest and a wide range of Ni concentration and the highest Ni concentration factor among river plants. Therefore, caddice-worm and moss were useful species for an index of Ni contamination.

5. CONCLUSION

Table.3 Ni concentration factors of river insects and river plants.

			Ni concentration factor		
			area		
			Cu mine	serpentinite	normal
Japanese freshwater crab			30 to 80	20 to 3,900	40 to 200
caddice-worm			90 to 500	5,200 to 22,000	30 to 2,000
dobsonfly larva			200	100 to 8,300	90 to 400
dragonfly larva			200 to 500	900 to 6,000	60 to 1,000
stonefly larva			60 to 300	200 to 2,000	90 to 500
crane fly larva			100 to 2,600		70 to 2,000
mayfly larva			200	8,000	100 to 1,000
corixidae			500		80 to 500
reed	stem	upper part	200 to 300		200 to 300
		middle part	200		200
		lower part	200		200
	root		500 to 2,000		200 to 300
fern	leaf		200 to 600	200 to 8,100	100 to 200
	stem	middle part	200	200 to 2,000	200
		lower part	200 to 300	200 to 2,000	100 to 300
	root		200 to 3,000	1,000 to 27,000	200 to 1,000
moss			200 to 7,400	900 to 59,000	200 to 4,000
Japanese knotweed	leaf		200	2,300 to 3,300	
	stem	upper part	200	1,900 to 2,000	
		middle part	200	800 to 1,000	
		lower part	200	700	
	root		1,600 to 2,300	12,000 to 32,000	
coix	stem	upper part	200		200
		middle part	200		200 to 300
		lower part	200		200
	root		200		200

In this study, Cu, Co and Ni concentrations of river water, river insects and river plants were investigated in the serpentinite area, the Cu mine area and the normal area of the Kinokawa River catchment in order to find useful species for an index of metal contamination. Useful species as an index of metal contamination needs a high metal concentration in the contaminated area and low metal concentration in the non-contaminated area. Moreover, it needs a high metal concentration factor.

Cu concentrations of moss and crane fly larva in the Cu mine area were 31 to 21,000 and 50 to 1,400 mg/kg-dry, respectively. Cu concentrations of moss and crane fly larva in the other areas were 2 to 87 and 11 to 130 mg/kg-dry, respectively. Cu concentration factors of moss and crane fly larva in the Cu mine area were 3,100 to 160,000 and 5,000 to 46,000, respectively. Cu concentration factors of moss and crane fly larva in the other areas were 200 to 8,700 and 1,100 to 13,000, respectively.

Co concentrations of moss, crane fly larva and mayfly larva in the Cu mine area were 2 to 200, 1 to 82, 2 mg/kg-dry, respectively. Co concentrations of moss, crane fly larva and mayfly larva in the other areas were 2 to 33, 0.7 to 10 and 1 to 50mg/kg-dry, respectively. Co concentration factors of moss, crane fly larva and mayfly larva in the Cu mine area were 200 to 4,600, 100 to 2,700 and 200, respectively. Co concentration factors of moss, crane fly larva and mayfly larva in the other areas were 200 to 3,300, 40 to 1,000 and 100 to 5,000, respectively.

Then, Cu and Co concentrations of moss and crane fly larva in the Cu mine area were higher than those in the other areas and Cu and Co concentration factors of moss and crane fly larva in the Cu mine area were higher than those in the other areas. Moreover, the maximum concentration factors of moss for Cu and Co were highest among river plants. The maximum concentration factor of crane fly larva for Cu was highest among river insects. Therefore, moss in river plants and crane fly larva in river insects were useful species for an index of Cu contamination.

The maximum concentration factor of mayfly larva for Co was highest among river insects. However, Co concentrations of mayfly larva in the Cu mine area were not higher than those in the other areas. Useful species as an index of metal contamination needs a high metal concentration in a contaminated area and low metal concentration in a non-contaminated area. Then, mayfly larva was not useful species for an index of Co contamination. On the other hand, although Co concentration factor of crane fly larva was not the maximum values among the river insects, crane fly larva has a high concentration factor for Co and a wide variation Co concentration with high for the contaminated area and low for the non-contaminated area. Therefore, moss and crane fly larva were useful species for an index of Co contamination.

Ni concentrations of moss and caddice-worm in the serpentinite area were 9 to 590 and 52 to 220 mg/kg-dry, respectively. Ni concentrations of moss and caddice-worm in the other areas were 2 to 74 and 0.3 to 20 mg/kg-dry, respectively. Then, their Ni concentrations in the serpentinite area were higher than those in the other areas. Ni concentration factors of moss and caddice-worm in the serpentinite area were 900 to 59,000 and 5,200 to 22,000, respectively. Ni concentration factors of moss and caddice-worm in the other areas were 200 to 7,400 and 30 to 2,000, respectively. Then, their Ni concentration factors in the serpentinite area were higher than those in the other areas. Moreover, the maximum Ni concentration factor of moss was highest among river plants. The maximum Ni concentration factor of caddice-worm was highest among river insects.

Therefore, it was clarified moss in river plants and caddice-worm in river insects were useful species for an index of Ni contamination.

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