Geochemical risk assessment of highly specified road

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Abstract

In order to determine geochemical safety route for highly specified road in mining area, natural background of arsenic and heavy metals was evaluated, and geochemical risk assessment was performed. The study area, including two candidates of the routes (A route and B route), was divided into 1 km mesh, and one sample from soil layer B was collected from individual mesh. Based on chemical composition of the sample, we carried out multivariate analysis to evaluate geochemical risks of arsenic and heavy metals. Based on distribution of arsenic and heavy metals and principal factor of the multivariate analysis, we could determine the geochemical safety route, here, A route was adequate plan to build the highly specified road. Base on risk assessment and estimation of total amount of excavated rocks, 7.8 % of the total excavated rocks should have high risks of heavy metals, and then 7.4% of excavated rocks was recognized as high risk, which was very good corresponded to estimated value.

Keywords: heavy metal, excavated rocks, geochemistry figure, analysis of surface soil

1. Introduction

In the ground constituting Japan which is a world eminent volcano country, heavy metals supplied from a deep part under the ground is taken after various processes. These heavy metals may spread in what is dug with construction in neighboring environment, and in late years this is taken up as a heavy metals problem derived from nature (Hattori et al., 2003; Hosokawa et al., 2007).

We carried out the route choice of the highly specified road by geochemical technique from a point of view that prevented environmental influence with the natural-origin heavy metals included in the excavated rocks from tunnels.

2. Distribution of the stratum of the road planning routes

Two route plans (A route and B route) were planned in a highly specified road (section of approximately 14km).

The volcanic rock which is main in so-called green tuff, a volcano clastic form rock and a sedimentation rock of the Miocene, are distributed along the plan route. And bench sediment and pyroclastic flow sediment of the Quaternary coat these.

The geological feature of this area receives mineralization over a wide area and includes much heavy metals.

Hydrothermal alteration is weak in the northern part of investigation area including the A route and a vein deposit excels, but is small for the scale in this area. Other than it, a small manganese deposits are distributed. On the other hand, the southern part is a prominent area of the mineralization, and Kuroko deposits and vein deposits are distributed around B route.

3. Heavy metal risk evaluation by the geochemical technique

We evaluated by the geochemical map in a heavy metal risk in this route choice. The geochemical map is an elemental concentration distribution map (Shiikawa et al., 1975). The geochemical map was used by discovering a collection of local body of the heavy metals on the surface of the ground to explore the deposit that there was in the outskirts. Generally, the investigation area is divided by mesh, and the soil or riverbed sediment are gathered from the representative spot in the mesh and the element included in them is analyzed and is plotted according to concentration. It is understood that these analyses level shows the background concentration of element of interest in the mesh.

3.1 Method of sampling and analysis

Mesh of 1km square was set around each route, and a sample was gathered for 79 mesh in total. The representative spot was chosen in each mesh, and the soil of around 1 kg was sampled from there. The soil is divided into the A to C layer towards a deep part by appearance. The soil was sampled by B- layer said that the materials such as inorganic elements were accumulated most. The sampled soil was brought into a room and was dried naturally. The enough dry soil sample was sieved by a 100 mesh sieve (the size of cavity is 0.147mm) and was used for analysis by the absorptiometry. The sample was analyzed about cadmium, lead, arsenic, mercury, copper, manganese, zinc.

3.2 Relative examination between the elements by the multivariate analysis

A multivariate analysis was carried out about each elemental concentration to consider the association (symbiosis) between the elements included in the soil sample. A multivariate analysis included some technique, but we carried out principal component analysis and a factor analysis. We show the contribution ratio of factor loading to express the correlation of principal ingredient and each element, eigenvalue to express the dispersion of the factor which we demanded in principal ingredient analysis and each factor to Table 1. In addition, as for the number of the factors, two were adopted because the accumulation contribution ratio to the 2nd factor became 77.2%.

Then, about the meaning that the first and 2nd factor that had the substantial contribution, we interpreted it based on elemental symbiosis as follows. The 1st factor shows strong correlation with copper, lead, zinc, mercury and arsenic and shows slightly strong correlation with cadmium. These results suggest that each element except manganese is symbiosis. From this, we can estimate that these elemental distribution is regulated by the distribution of the mineralization zone. The 2nd factor shows only manganese and strong correlation. From this, it is guessed that the distribution of manganese is unrelated to other elements.

Then, we show the thing which plotted the factor score of each sample provided by a factor analysis in Fig. 1. In the point colored in the 1st factor score distribution map densely, it is thought with the area where a deposit mainly composed of copper, lead and zinc is distributed over. In that figure, on the east side of the A route, the center and the east side of the B route, the high point of the factor score is recognized. On the other hand, in the point colored in the 2nd factor score distribution map densely, the possibility that a rock including manganese primodial is distributed, or a manganese deposit does existence. In that figure, the high point of the factor score is recognized on the east side of the A route, the center and the east side of the B route. From the above-mentioned result, we understood that the 1st factor score was the area where the area where the mesh indicating the positive price was distributed over was high in content such as the heavy metal. The 1st factor score distribution map shows that only one place of mesh indicating the factor score becomes the positive number on the A route, in other hand, on the B route, such meshes are distributed for the whole of the route.

Table 1 Factor loadings, eigenvalue and contribution of each factor

Principal components		1	2	3	4	5	6	7
Factor loadings	Cd	0.642	- 0.289	0.696	0.033	0.133	0.002	0.034
	Cu	**0.944**	0.034	- 0.114	- 0.109	- 0.228	0.030	0.174
	Pb	**0.948**	0.008	- 0.088	0.074	- 0.027	- 0.290	- 0.047
	Zn	**0.936**	0.041	0.090	- 0.107	- 0.257	0.129	- 0.143
	Hg	**0.809**	- 0.103	- 0.260	- 0.395	0.330	0.051	- 0.013
	As	**0.785**	- 0.017	- 0.215	0.554	0.139	0.106	0.002
	Mn	0.214	**0.955**	0.180	- 0.015	0.098	0.004	0.009
Eigenvalue		4.39	1.01	0.66	0.49	0.27	0.12	0.05
Contribution (%)		62.8	14.4	9.4	7.0	3.9	1.7	0.8
Cumulative contribution (%)		62.8	77.2	86.6	93.6	97.5	99.2	100.0

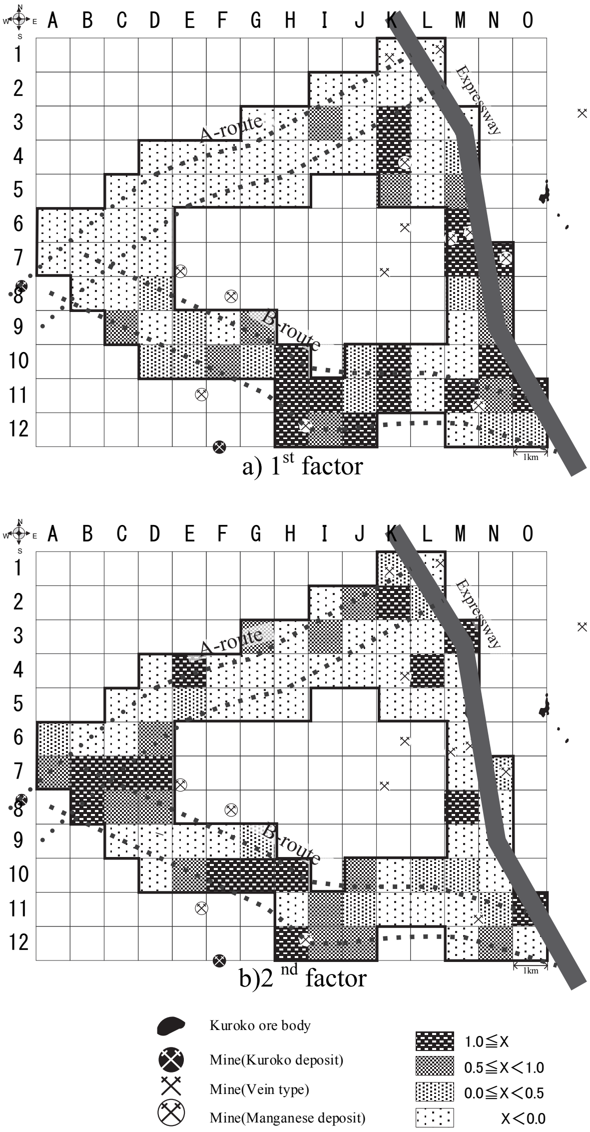

Fig.1 Distribution map of factor score

Then, we evaluated the heavy metal content of the B route by the comparison with the factor score of which nearby the C tunnel located in the neighborhood. Because quantity of elution of copper, lead, iron from a rock targeted for digging exceeded waste water regulations in the C tunnel, treatment of excavated rocks was performed. From this, it is judged when there is the concentration of heavy metal included in the rock around the C tunnel in the level that should be handled. It became clear that the factor score of the B route showed the value that 1 rank was higher in than C tunnel to the whole by comparing the factor score of the B route with the factor score of the neighborhood of this C tunnel. It was expected in the B route by this result that treatment of excavated rocks was necessary for extension more than C tunnel.

Based on the above-mentioned result, all the excavated rocks of the range where the 1st factor score corresponded to the mesh indicating the positive number was considered high in heavy metal content. Then, we found a ratio of quantity of heavy metal high content rocks in the quantity of all excavated rocks and show it in Table 2. A ratio of heavy metal high content rocks quantity in the quantity of all excavated rocks was 7.8% by the A route as we showed it in Table 2. On the other hand, the ratio became 67.0% by the B route. From these results, it became clear that there were few areas where heavy metal treatment needed A route than B route. It was judged this result to have a superiority of the A route in environmental conservation and construction cost than B route. Based on the above-mentioned result, A route was finally chosen.

3.3 Inspection of the validity of the route choice based on the construction results

The A route was finally designed for a route consisting of five tunnels. In these tunnels, classification of the excavated rocks was performed by geologic confirmation by the prior evaluation and face observation of the heavy metal risk by the analysis of the advanced bowling core. As a result, the excavated rocks determined that measures were necessary was 10.2% in the whole. These excavated rocks having a risk of fluorine that was not surveyed at the time of the route choice is included in this. Therefore, the excavated rocks of measures to the exclusion of it required becomes 7.4%.This is a value at the same level as 7.8% which is a ratio of quantity of heavy metal high content rocks estimated based on a multivariate analysis result that was shown in Table-1. The forecast about the quantity of excavated rocks needing measures is judged to have been proper by this result.

Then, we show the area where measures of the excavated rocks were required in Fig. 2.

Fig.2 Area of exceed a standard and distribution of 1st factor score

Table 2 Rate of the heavy metal quantity content rocks in each route

(×10,000m³)

A route					B route				
Mesh No.	Amount of Surplus soil				Mesh No.	Amount of Surplus soil			
	cutting		tunnel			cutting		tunnel	
	total	Including high-concentration heavy metals	total	Including high-concentration heavy metals		total	Including high-concentration heavy metals	total	Including high-concentration heavy metals
A-7	28.0	0.0	—	—	B-8	5.8	0.0	5.0	0.0
B-7	93.2	0.0	—	—	C-8	1.3	1.3	12.6	12.6
B-6	2.0	0.0	—	—	D-8	—	—	1.6	1.6
C-6	—	—	18.2	0.0	D-9	—	—	12.6	12.6
C-5	—	—	1.9	0.0	E-9	—	—	16.0	0.0
D-5	16.9	0.0	—	—	F-9	4.9	0.0	—	—
D-4	1.0	0.0	—	—	F-10	—	—	—	—
E-4	2.3	0.0	15.4	0.0	G-10	1.3	1.3	10.8	10.8
F-4	16.9	0.0	—	—	H-10	—	—	—	—
G-5	—	—	—	—	H-11	2.0	2.0	—	—
G-4	13.1	0.0	—	—	I-11	—	—	—	—
H-4	31.7	0.0	3.8	0.0	I-12	—	—	—	—
H-3	—	—	8.8	8.8	J-11	33.9	33.9	—	—
I-3	—	—	13.6	13.6	K-11	12.7	12.7	—	—
J-3	3.7	0.0	—	—	L-11	8.4	0.0	9.6	0.0
J-2	0.9	0.0	10.2	0.0	M-11	1.9	1.9	4.6	4.6
K-2	3.9	0.0	0.6	0.0	N-11	0.1	0.1	—	—
K-1	—	—	—	—	N-12	4.5	4.5	—	—
					O-12	1.0	1.0	—	—
total	213.6	0.0	72.5	22.4	total	77.8	58.7	72.8	42.2
The rate of the heavy metal quantity content rocks in the amount of whole surplus rocks 7.8%					The rate of the heavy metal quantity content rocks in the amount of whole surplus rocks 67.0%				

The figure shows the fact that measures of the excavated rocks came to need almost near of the area that the 1st factor score is high in except the areas where fluorine which was the outside targeted for an evaluation exceeded a standard at the time of the route choice and the western area where selenium, arsenic exceeded a standard. From this result, it is guessed that the quantity of excavated rocks needing measures largely increased when B route is chosen. In this way, the comparison between analysis result and construction results shows that the technique of this heavy metal risk evaluation was proper.

Acknowledgements

On these investigations, analysis, emeritus at late Professor Makoto Shiikawa gave much advice and instruction to me. In addition, Professor Noriyoshi Tsuchiya gave useful advice to me on making the article. I appreciate that I write it down here. In addition, I thank Ministry of Land, Infrastructure and Transport which is the manager of the highly specified road concerned and people concerned deeply.

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