A study on groundwater flow and chemistry of mine waste dams

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Abstract The groundwater flow and its chemistry were investigated at three closed mine sites to adopt an appropriate remediation method. The contaminated seepage water from a mine waste dam at one site primarily originated from the mine waste itself whereas those at the other two sites were affected by the surrounding ore zones. This indicates that hydrogeological conditions control the chemistry of the seepage water from the waste dam.

Key Words mine waste dam, groundwater flow, groundwater chemistry, remediation

Introduction

In Japan, soil covering on tailings and waste rocks, adit plugging, and construction of surface waterways, and other common techniques have been adopted to restrict the groundwater flow through the mine sites. However, the performance of these measures has not been quantified even after these measures have been taken (Okumura 2009, Alakangas 2010). The objective of this study is to examine the present status of mine waste dam in each abondoned mine based on the hydrogeological and geochemical investigations of the sites in order to newly take futher control measures.

Study sites

Mine waste dams at three closed mines (Y, A, and O mines) were selected. Copper was mined until 1971 at Y mine. The tailing dam of Y mine is located on the valley across the stream near the mine as shown in Fig. 1. The plane view of the tailing dam is shown in Fig. 2. The area of the tailing dam is surrounded by the dotted line in the figure. Gold, silver, copper, and lead were mined until 1972 at A mine. The tailing dam of A mine is located along a stream near the mine as shown in Fig. 3. Hydrogeological investigations were carried out by drilling two wells at A-1 and A-2. Copper, lead, and zinc until 1972 were mined at O mine. The chemical properties of the seepage waters are shown in Table 1. The waste rock dam of O mine is located on the valley near the mine as shown in Fig. 4. Five observation wells were constructed to monitor the groundwater levels and their metal concentrations.

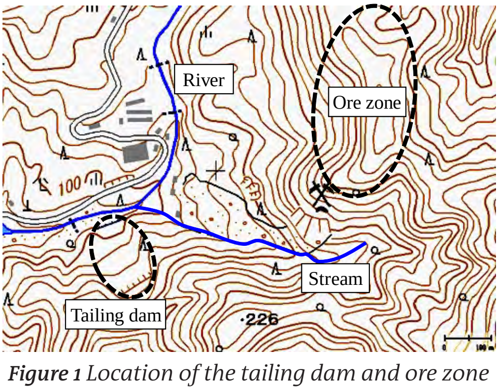

Figure 1 Location of the tailing dam and ore zone of Y mine

Methods

The groundwater level and its quality were monitored using observation wells at the sites. The wells of Y mine (Y-1, Y-2, Y-3, Y-4, and Y-5) are located on the inside of the dam. Two wells of A mine (A-1 and A-2) are located on the inside of the dam, whereas two wells (B-1 and B-2) are on the outside of the dam. The chemical characteristics of the spring point on the mountainside were measured. Three wells of O mine (O-3, O-4 and O-5) are located on the inside of the dam, and two wells (O-1 and O-2) are on the outside of the dam.

Groundwater levels were monitored continuously by inserting pressure transducers into the wells. Groundwater samples were collected at the wells for chemical analysis. The temperature, pH, and electrical conductivity (EC) were measured at each site. Heavy metals and major chemical con-

Table 1 Chemical properties of the seepage waters at Y mine, A mine, and O mine

	pH	T-Fe	Cu	Zn	SO_4
Y mine	4.39	16	15	0.34	230
A mine	2.46	173	19.2	1.10	1,290
O mine	2.98	13.8	3.72	25.9	980

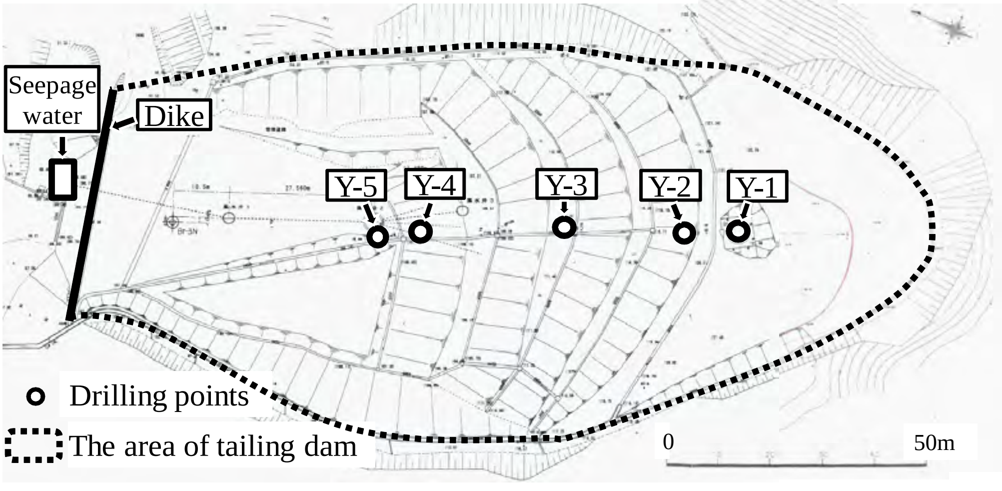

Figure 2 Tailing dam of Y mine

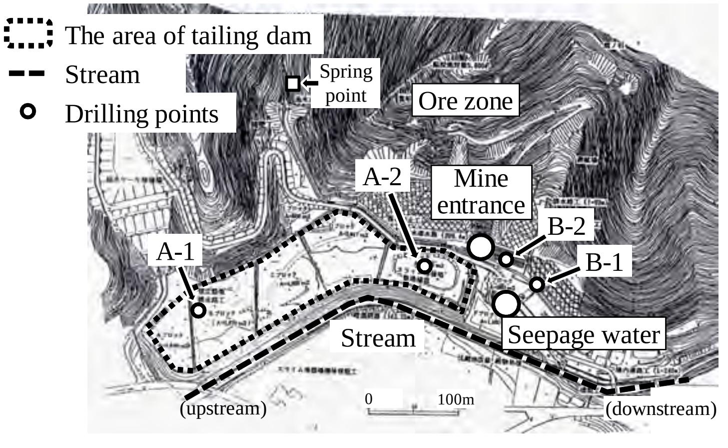

Figure 3 Tailing dam of A mine

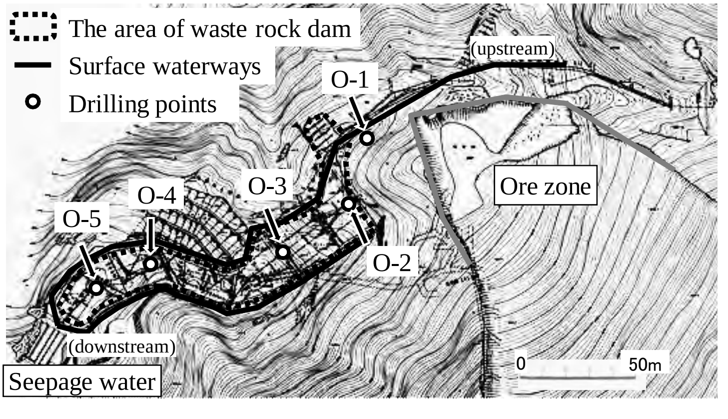

Figure 4 Waste rock dam of O mine

stituents were analyzed by ICP-AES and ion chromatograph, and the metal contents of the tailings or the waste rock were analyzed by ICP-MS or XRF. Dissolution tests using distilled water were also carried out.

Results and Discussion

Table 2 lists metals and sulphur contents of the tailings or the waste rock at each mine, and Table 3 lists the results of dissolution tests. The other results and discussions are described for each mine.

Table 2 Metals and sulphur contents of the tailings or the waste rock [%]

	Fe	Cu	Zn	S
Y mine	0.74	0.22	0.001	0.95
A mine	2.80	0.084	＜0.001	2.24
O mine	13.6	0.09	0.34	7.0

Table 3 The results of dissolution test [mg/L]

	T-Fe	Cu	Zn	SO_4
Y mine	0.11	6.39	0.04	20.3
A mine	0.183	4.73	0.05	157
O mine	47.0	7.61	18.1	1074

Y mine

The geological section of the tailing dam at Y mine is shown in Fig. 5. The width of tailing is approximately 5 m. The groundwater level was in the tailing from Y-3 to Y-5 while it was below the tailing from Y-1 and Y-2. The value of the metal contents and the disolution test at Y mine are less than those of A mine and O mine except for Cu. The dike was broken and the tailing was discharged by an earthquake in those days, and the discharged tailing was replaced with the surrouding soil. That is why the sediment is hetorogeneous and the contents of the heavy metals are relatively lower. Table 5 lists the results of chemical analysis of the groundwater samples at Y-1, Y-2, Y-3, Y-4, and Y-5 and the seepage water. The pH decreased and heavy metals and sulphate concentrations increased along the groundwater flow pathway. Considering this two-dimensional section, this indicates that the tailing is the main source of the contamination of the seepage water.

A mine

Figure 6 shows the geological section of the tailing dam at A mine. The tailing is located from ground level (GL) -3 m to GL -16 m, and the groundwater level was in the tailing. From the result of the metal contents and dissolution tests of the tailing, the contamination potential of groundwater was small at the site. Table 5 shows that the results of chemical analysis of the groundwater samples at A-1, A-2, B-1, and B-2 and the seepage water. The heavy metal concentrations of A-1 and A-2 were lower than that of the seepage water. The pHs of A-1 and A-2 were approximately neutral although those of B-1, B-2, seepage water were acidic. The chemical properties of B-1, B-2, were similar to the seepage water.

Thus, the groundwater was not contaminated at the site, and the flow of the groundwater did not pass through A-1, A-2, and seepage water but passed through the ore zone, B-1, and seepage water. This indicates that the contamination source of the seepage water is not the waste dam but the upward ore zone.

Table 4 Chemical properties of the groundwater at Y mine (the unit is mg/L except pH)

	pH	T-Fe	Cu	Zn	SO_4
Y-1	5.74	1.35	0.14	0.09	55.6
Y-2	4.48	12.17	3.94	0.22	69.8
Y-3	4.84	20.71	5.66	0.55	193.3
Y-4	3.93	9.60	18.67	0.34	220.0
Y-5	3.42	3.35	24.95	0.37	294.0
seepage water	3.94	6.37	16.67	0.37	203.3

Table 5 Chemical properties of the groundwater at A mine (the unit is mg/L except pH)

	pH	T-Fe	Cu	Zn	SO_4
A-1	8.33	0.51	0.02	0.004	101
A-2	6.05	5.14	0.006	0.01	72.5
B-1	2.82	7.14	3.73	0.45	273
B-2	3.55	10.7	4.03	0.75	405
Seepage water	2.46	173	19.2	1.10	1,290

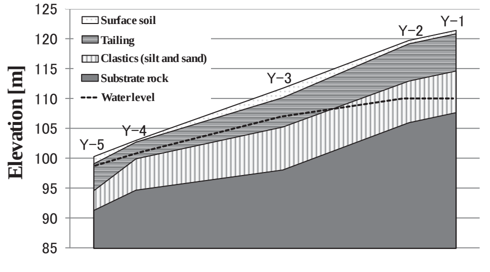

Figure 5 Geological section of the tailing dam at Y mine

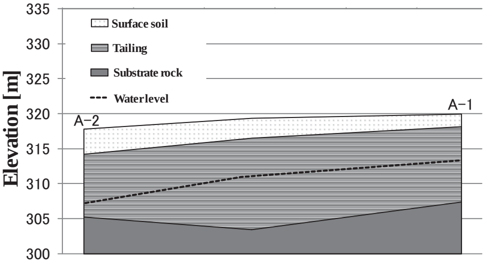

Figure 6 Geological section of the tailing dam at A mine

Table 6 *Chemical properties of the groundwater at O mine (the unit is mg/L except pH)*

	pH	T-Fe	Cu	Zn	SO_4
O-1	3.38	0.62	2.4	3.2	190
O-2	3.55	13	5.8	9.7	310
O-3	2.75	88.2	3.35	38.8	1,090
O-4	2.69	35.9	6.28	32.7	1,370
O-5	2.80	12.2	2.21	4.22	974
seepage water	2.98	13.8	3.72	25.9	980

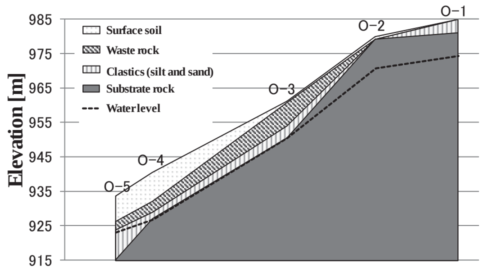

Figure 7 *Geological section of the waste rock dam at O mine*

The pH of the spring point was 5.77, and that of the river next to the dam was 6.83. This indicates that the groundwater of A mine is partially provided from α, and goes to the river without being contaminated by the tailing.

O mine

The waste rock is located from GL -0.5 to -5 m, and the groundwater level in the dam was GL -10m as shown in Fig. 7. Thus, the groundwater level was below the waste rock. Three wells (O-3, O-4, and O-5) are located inside the dam. The results of chemical analysis of the groundwater samples at O-1, O-2, O-3, O-4, and O-5, and the seepage water are shown in Table 6. The groundwaters of O-1 and O-2 located outside the dam were already contaminated. This is due to runoff rain contaminating the groung water by dissolving weathered minerals from an outcrop upstream. The O-3, O-4, O-5, and the seepage water were acidic and contained significant concentrations of heavy metals, and were more contaminated than that of O-1, and O-2.

Meanwhile, because the waste rock has sufficient contamination potential of groundwater from the results of the metal contents and dissolution tests of the waste rock, this means that the contamination of the groundwater results from not only the ore zone outside the dam but also the rainfall which infiltrates the waste dam.

Conclusions

The contamination sources of the seepage waters depend on the hydrogeological conditions of the sites. The waste dam and/or the surrounding ore zones contributed to the contamination of groundwater, and the control measures should be implemented on the outside of the waste dam in order to improve the quality of the seepage water at A mine and O mine. Since the contamination source of Y mine is considered to be the tailing, further investigations are planned to improve the quality of the seepage water.

References

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