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A result of batch test to select effective co-precipitator of zinc containing mine drainage treatment

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Contents

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Outline of Mine Pollution Prevention for Mine Drainage in Japan

Mine Drainage Treatment in Japan

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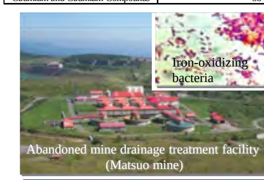
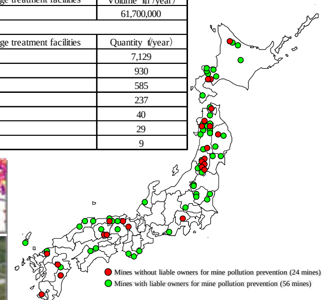
Annual amount of mine drainage and contained heavy metals

	Number of mine drainage treatment facilities	Volume（m^3/year）
Mine drainage	80	61,700,000
	Number of mine drainage treatment facilities	Quantity（t/year）
Soluble Iron	61	7,129
Zinc	74	930
Soluble Manganese	22	585
Copper	63	237
Lead and Lead compounds	50	40
Arsenic and Arsenic compounds	26	29
Cadmium and Cadmium Compounds	58	9



Abandoned mine drainage treatment facility (Matsuo mine)



Abandoned mine drainage treatment facilities in Japan.

- 80 abandoned mine drainage treatment plants are currently in operation.
- The total amount of mine drainage treated is 62 million m^3/year.
- 80% of the total heavy metals is soluble iron, 10% is zinc, and 7% is manganese.

The Budget for Mine Pollution Prevention (1971~2007)

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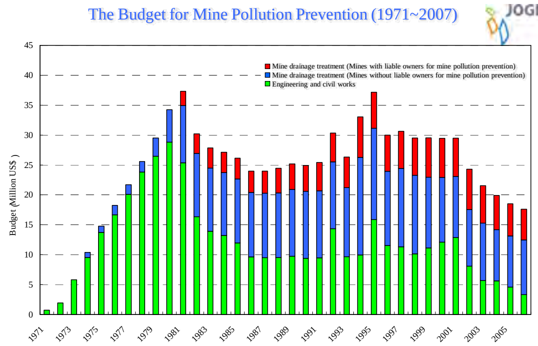

- From 1973 to 1980, the budget increased sharply.
- The total budget of subsidies for mine pollution prevention was US$830 million.
- Approximately 80% of the total budget is spent for the mine drainage treatment.

Effluent Standards in Japan

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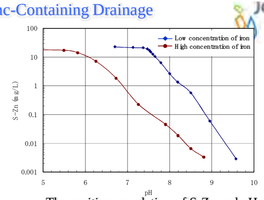
Effluent Standard

	Pollutants		Standards
Items relating to living environment	pH of mine drainage discharged,excluding into open seas		5.8～8.6
	BOD and COD	Maximum	<160mg/L
		Daily average	<120mg/L
	Suspended solids	Maximum	<200mg/L
		Daily average	<150mg/L
	Mineral oil		<5mg/L
	Animal and vegetable oil		<30mg/L
	Phenol		<5mg/L
	Copper		<3mg/L
	Zinc		<2mg/L
	Soluble Iron		<10mg/L
	Soluble Manganese		<10mg/L
	Total Chromium		<2mg/L
	Number of colonies of E.coli		<3,000 units/day

- The Ministry of Environment of Japan revised the effluent standards of the water pollution control law in December 2006.
- The upper limit of zinc content in factory effluence and business activity sites including metal mines was reduced from 5.0 mg/L to 2.0 mg/L.
- The drainage of a few mines have common features, such as relatively higher zinc content than iron content. Thus, the removal of zinc by co-precipitation with iron hydroxide is not sufficient to meet this standard.

Treatment of Zinc-Containing Drainage

Mine drainage which contains ferric iron.



The positive correlation of S-Zn and pH on the neutralization process.

- Zinc ions are removed by "adsorption". The "settlement process" using coagulants and reagents increases the precipitation rate, producing hydroxide.
- In order to precipitate zinc as a hydroxide, it is necessary to increase the pH of drainage to 9.0 or higher.
- However, zinc can be removed at a pH lower than 9.0 if the mine drainage contains iron and other various metals.

In order to remove zinc by the settlement process in mine drainage that contains only zinc without iron, it is necessary to add iron for co-precipitation.

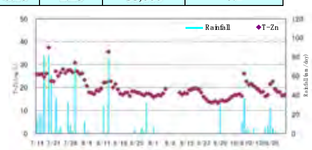
Batch Test to Select the Adsorbent at the Sample Model Mine

The Sample Model Mine

The features of mine drainage of model mine

Quantity (m^3/min)	pH	Drainage (Average) Zn (mg/L)	Drainage (Average) Fe (mg/L)	Treated water Zn (mg/L)	Annual cost for treatment (US$)	Treatment cost per 1 m^3 (US$)
0.3	6.28	22	<0.10	2.28	35,000	0.2

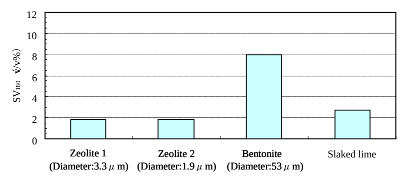
Settlement pond of the model mine



The relationship of the zinc concentration of mine drainage and rainfall.

- Slaked lime is used for neutralization of mine drainage and zinc is removed as hydroxide.
- The quantity of drainage of the sample model mine to be treated is 0.3 m^3/min on an annual mean basis, and the current treatment cost is 0.2 US$/$m^3$
- The zinc concentration of drainage tends to be slightly higher with increased rainfall, resulting in the total concentration of zinc in treated water to exceed 2.0 mg/L.

Comparative Test of Effective Adsorbent



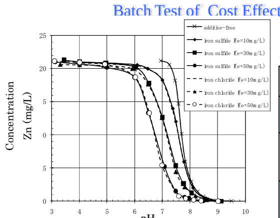
Batch test of the precipitation rate

SV_{180}: The quantity of a precipitate after 180min on neutralizing test

The quantity of precipitate which includeds zeolite, bentonite and slaked lime after the batch test.

- The quantity of a precipitate which is generated by neutralization with slaked lime was compared with a precipitate of zeolite and bentonite.
- Increased consolidation of the precipitate generated with the addition of zeolite resulted in a lower quantity of precipitate than that with only slaked lime.
- However, 500mg/L of zeolite was required to decrease the concentration of zinc in the sample model mine's drainage to 2.0mg/L or less.
- The cost of treatment is 2.2 times the current cost, which exceeds the target of a maximum 20% increase.

Batch Test of Cost Effective Chemical in Iron Sources



The relationship of zinc concentration and pH for iron chloride and iron sulphide.

Cost of iron sulfide and iron chloride

	Iron sulfide	Iron chloride
Reagents	0.3US$/kg	
Cost of adding reagents	0.03US$/$m^3$	0.02US$/$m^3$
An excess ratio comparison with current cost	1.24 times	1.21 times

- A laboratory test for iron sulfide and iron chloride was conducted to identify a more cost-effective chemical in iron sources.
- A significant difference between the zinc-removal effects of both iron sulfide and iron chloride was not confirmed.
- Therefore, iron chloride is a less expensive chemical than iron sulfide. This reagent was used in a laboratory test to determine the amount of iron needed in keeping zinc concentration under 2.0mg/L.
- The result showed that 10mg/L of iron was required to maintain the zinc concentration within the target value of zinc concentration.

On-Site Test at the Sample Model Mine

On-site Test at the Sample Model Mine

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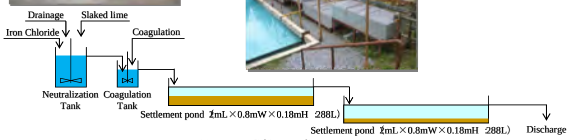

Conceptual figure of on-site test

- Following the batch test, an on-site test was conducted by adding 10mg/L of iron chloride .
- First, the drainage flow rate was kept constant (annual average : 0.3m^3/min) to determine the amount of iron chloride required to meet the new effluent standard.
- Next, the flow rate was increased to evaluate the amount required for an annual maximum flow rate.

Result of On-site Test at the Sample Model Mine

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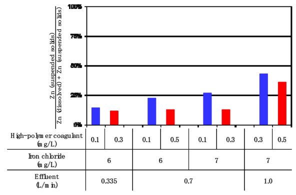
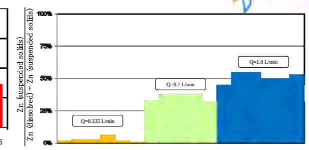


The relationship of effluent volume and concentration of reagent to decrease zinc concentration as suspended solids.



The relationship of effluent volume and the ratio of zinc concentration as suspended solids.

- An additive amount of iron chloride required during ordinary drainage discharge was 6.0 mg/L on an iron basis.
- The concentration of zinc could not be successively reduced by adding more iron chloride during increased drainage discharge. This is because high-concentrated zinc was discharged as a suspended solid.
- The leakage of the suspended solids could be precipitated by increasing of a high-polymer coagulant from 0.1 to 0.5 mg/L.

Additional Cost for Treatment

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	Iron chloride (6mg/L) + Coagulant		
Flow rate of mine drainage (m^3/min)	<0.335	0.335～0.7	0.7<
Iron chloride (mg/L)	6		
Coagulant (mg/L)	0.3	0.5	1.0
Ⅰ. Cost of adding reagent (US$/100m^3)	1.56	1.73	2.17
Ⅱ. Additional cost of slaked lime(US$/100m^3)	0.48		
Ⅲ. Additional cost for dredging work (US$/100m^3)	0.57		
Ⅳ. Cost for depreciation of construction fee (US$/100m^3)	0.53		
Ⅴ. Additional cost for electricity(US$/100m^3)	0.01		
Additional cost (US$/100m^3) Ⅰ+Ⅱ+Ⅲ+Ⅳ+Ⅴ	3.15	3.32	3.76
Current cost for neutralization (US$/m^3)	0.2		
Excess ratio comparison with the current cost	1.16	1.17	1.19

- A confirmed effective method is that the optimal additive amount of iron chloride is 6.0 mg/L on an iron base.
- The additive amount of a high-polymer coagulant changes according to the flow rate.
- The cost for drainage treatment based on this method was up to 1.19 times higher than the current cost (i.e. 1.2 times below the target cost).

Conclusion

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- Though laboratory test and on-site tests a lower-cost treatment method for meeting the new regulations was formulated by the adsorption and settlement process in drainage containing zinc without iron.
- Increased consolidation of the precipitate generated with the addition of zeolite resulted in a lower quantity of precipitate than that with only slaked lime.
- As a result, the addition of iron chloride and the increasing of the high-polymer coagulant reduced the concentration of zinc in treated water to under 2.0 mg/L. Accordingly, the treatment did not exceed the target cost of a maximum 20% increase of the current expense.