Original Paper

Removal of Ferric Ions from Acid Mine Water with Recycled Rock Wool

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Abstract

The removal of ferric ions from acid mine water was investigated with the neutralizer of recycled rock wool (RRW) in this study. The performance on the removal of ferric ions by the neutralizer of RRW was also compared with that in the neutralizer of virgin rock wool (VRW). Some wastes like the materials from rock wool fire-resistant cover of steel-frame buildings, rock wool insulator wastes of thermal power plants and so on were collected in order to make RRW. In the intermediate process, the objectives were separated and other matters were removed. Sample particles were made after adding blast furnace cement and water as a binder to the objectives and mixing together. When the cumulative volume of passing water increased at the average rate of passing water from 3.85 to 3.89 L/day, the removal performance of ferric ions on RRW was inferior to that on VRW. It is considered that since RRW has larger bulk density, that is, smaller specific surface area, the chemical reactivity of RRW is inferior to that of VRW. When the average rate of passing water was changed from 1.81 to 1.91 L/day, the removal performance of ferric ions on RRW was almost equal to that on VRW.

1. Introduction

Rock wool is an artificial mineral fiber made by the slag from blast furnaces and it is produced by the centrifugal at a certain temperature. Rock wool is sometimes confused with asbestos. However, it is non-crystalline and the mean diameter of single fiber is longer by several ten-hundred times than that of asbestos. There is no report about the incidence of lung cancer from those who treated rock wool in Japan. The production amount is about 270,000 tons annually and mainly used for fire-resistant cover materials, ceiling boards, insulators, plant equipment insulators, thermal insulators, acoustic materials, artificial farmland and soil improvement materials as the alternative asbestos.

Since rock wool contains plenty of basic elements like Ca, it has a beneficial function such as

the neutralization for the treatment of acid mine water. Authors We have been investigating the treatment of acid mine water by the neutralizer of with rock wool^{1–3}). In the previous study⁴), the field tests were carried out and the reaction mechanism of the removal of iron with the virgin rock wool was discussed in order to investigate the performance of virgin rock wool neutralizer for the treatment of acid mine water containing ferric ions. It was found that iron removal took place by the neutralization reaction through the elution of the basic component, when the pH of treatment water was kept more than 7. It was also found that the removal life of the neutralization becomes longer because the iron oxidation bacteria in the acid water containing iron ions breed on the surface of the material and iron ions are removed by the bacteria oxidation reaction if the pH of treatment water is below 7. In this study, the experiments on the removal of ferric ions from acid mine water were carried out with the neutralizer of wasted rock wool. The performance on the removal of ferric ions by the neutralizer of wasted rock wool was

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Fig. 1 Production flow of RRW from recycled rock wool.

compared with that in the neutralizer of virgin rock wool.

2. Production flow of the neutralization materials from recycled rock wool

2.1. Neutralization materials from wasted rock wool

Some wastes like the materials from rock wool fire-resistant cover of steel-frame buildings, rock wool insulator wastes of thermal power plants and so on were collected in order to make recycled rock wool. In the intermediate process, the objectives were separated and other matters were removed. Sample particles were made after adding blast furnace cement and water as a binder to the objectives and mixing together. They are called, namely neutralization materials of the wasted rock wool, as RRW. Figure 1 shows the production flow as mentioned above.

2.2. Properties of neutralization materials

RRW is a neutralization material made from recycled rock wool whose main component is fiber-shaped calcium silicate and the particle size is 5–30mm. The addition of this material to the acid mine water containing iron makes it possible for

Fig. 2 Shapes of RRW (a) and VRW (b).

ferric ions to be removed. VRW which was the neutralization material made from virgin rock wool and unsolidificated particles were employed as a comparison material. Table 1 and 2 show the chemical and physical properties of each material and Fig. 2 shows the shapes of RRW and VRW.

3. Procedure

RRW and VRW were spread at the bottom of the containers and acid mine water was poured on them. This is called an artificial damp ground purification method. The containers were put in the greenhouse and the relationship between treatment time and water quality was investigated.

The containers were placed in the flower greenhouse in the Shiraishi Farm (Sango City in Saitama Prefecture) in order to avoid the effect of rain. Figure 4 shows the containers and the cross section of the equipment is shown in Fig. 5. Table 3 and 4 show the experimental conditions of the test bed and the acid mine water quality, respectively.

4. Results and discussion

The colloidal brown-colored precipitation was found in the test beds from the beginning of the experiments. It is considered that the colloidal precipitation takes place because of the deposit of dissolved iron by oxidation reaction. Table 5 shows the quality of treated water in the continuous water passing test.

Table 1 Chemical properties of neutralization materials [wt%].

	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	MnO	SO ₃	Igloss	Total
RRW	32.9	9.5	35.6	2.6	2.2	0.1	1.0	12.0	96.3
VRW	32.9	10.8	48.3	3.0	1.3	0.2	0.7	0.4	98.7

Table 2 Physical properties of neutralization materials.

	Bulk density	Water permeability [cm/sec]	Shape
RRW	0.47	1.3×10^0	Solidificated particle
VRW	0.21	4.3×10^{-1}	Particulate cotton

Fig. 3 Containers for RRW and VRW.

Fig. 4 Cross section of equipment (water depth 2 cm $\times$ container length 43 cm).

Figure 5 shows the relationship between the cumulative volume of passing water through 1 kg of rock wool neutralizer and pH of original acid water and treated water in average rate of passing water from 3.85 to 3.89 L/day. At the beginning of water passing test, the treated water by VRW②-1 showed high pH value because of the elution of basic component from the neutralization material, but the pH value of the treated water by VRW②-1 reached closely to that of the original acid mine water after passing 1,800 L/kg of the cumulative volume. On the other hand, the elution amount of basic component from RRW①-1 is less than that from VRW②-1 because water was added in producing RRW①-1. Thus the pH value of the treated water by RRW①-1 right after passing the original acid mine water was lower than that by VRW②-1. However, the pH value of the treated water by RRW①-1 reached closely to that of the original acid mine water after 1,000 L/kg of the cumulative volume.

Fig. 5 Change in pH value of treated water and original water at the average rate of passing water from 3.85 to 3.89 L/day.

Figure 6 shows the relationship between the cumulative volume of passing water through 1 kg of rock wool neutralizer and pH of original acid water and treated water at the average rate of passing water from 1.81 to 1.91 L/day. The pH values of RRW①-2 and VRW②-2 were almost equal to that of original acid mine water. In this experiment, total Fe concentration in the original water was higher than the Fe concentration used in the experiment shown in Fig. 6. Therefore, it is considered that the OH⁻ produced by the elution of basic component from the neutralizer reacted with ferric ions and it suppressed the increase in pH value of treated water.

Figure 7 shows the changes in the total Fe (described as T-Fe in the figures, hereafter) concentration of the original acid mine water and treated water per 1 kg of the neutralizer. The average rate of passing water was from 3.85 to 3.89 L/day. In case of VRW②-1, most of ferric ions were removed until 3,000 L/kg of the cumulative volume. From the further research results, it is known that the chemical neutralization reaction and coprecipitation take place by the neutralization materials at the beginning of the cumulative volume and then biochemical reaction happens by iron bacteria afterwards⁴⁾. As for RRW①-1, the removal of ferric ions was not performed sufficiently at the be-

Table 3 Experimental condition.

Container No.	Neutralization materials	Weight of neutralization materials [g]	Test bed volume [L]	Passing rate of water [L/d]	Treatment time [H]
①-1	RRW	100	1.3	3.87	8.1
①-2	RRW	100	1.3	1.91	16.3
②-1	VRW	100	1.3	3.85	8.1
②-2	VRW	100	1.3	1.81	17.2

Table 4 Quality of acid mine water [mg/L].

	pH	SO ₄ ²⁻	Ca ²⁺	T-Fe
Average	2.42	303	1.2	115
Highest	3.11	310	1.2	181
Lowest	1.91	300	1.2	45

Fig. 6 Change in pH value of treated water and original water at the average rate of passing water from 1.81 to 1.91 L/day.

gining of passing test. This is due to the fact that pH value of RRW①-1 was not as high as that of VRW②-1 and the chemical neutralization reaction and coprecipitation did not take place sufficiently. On the other hand, the similar removal of ferric ions as in VRW②-1 was observed after the cumulative volume was more than 1,000 L/kg. The reason for the decline of the removal percentage around 2,500 L is considered that the reaction product makes the passage which temporarily retards the reaction due to the small bulk amount of RRW.

Figure 8 shows the changes in the total Fe concentration of the original acid mine water and treated water. The average rate of passing water was from 1.81 to 1.91 L/day. Although bulk density and water permeability of RRW①-2 were different from that of VRW, total Fe concentration treated with RRW and VRW②-2 was almost the same. It was considered that RRW②-2 as the neutralizer had enough time to react with ferric ions because of low average rate of passing water.

Fig. 7 Change in total Fe concentration of treated water and original water at the average rate of passing water from 3.85 to 3.89 L/day. **Fig. 8** Change in total Fe concentration of treated water and original water at the average rate of passing water from 1.81 to 1.91 L/day.

Figure 9 shows the relationship between the cumulative volume of passing water through 1 kg of rock wool neutralizer and the cumulative removal amount of iron at the average rate of passing water from 3.85 to 3.89 L/day. When the cumulative volume increased, the removal performance of ferric ions of RRW①-1 was inferior to that of VRW①-1. It is considered that since RRW①-1 has larger bulk density, that is, smaller specific surface area, the chemical reactivity of RRW①-1 is inferior to that of VRW①-1.

Figure 10 shows the relationship between the cumulative volume of passing water through 1 kg of rock wool neutralizer and cumulative removal amount of iron at the average rate of passing water

Table 5 Quality of treated water.

Container No.	Neutralization materials	pH	Concentration of T-Fe [mg/L]	Removal of iron [%]	Cumulative treated iron [g/kg]	Cumulative treated water [L/kg]
①-1	RRW	2.97	51.7	58.8	438	7191
①-2	RRW	2.84	63.6	64.1	400	1862
②-1	VRW	3.71	28.6	78.7	577	7092
②-2	VRW	2.81	76.2	55.4	341	1761

Fig. 9 Cumulative Fe removal of treated water at the average rate of passing water from 3.85 to 3.89 L/day.

Fig. 10 Cumulative Fe removal of treated water at the average rate of passing water from 1.81 to 1.91 L/day.

from 1.81 to 1.91 L/day. Although RRW①-2 had enough time to react with ferric ions, the cumulative removal amount of iron corresponded mostly to that by VRW②-2 at any cumulative volume of passing water.

5. Conclusion

In this study, the experiments on the removal of ferric ions from acid mine water were carried out with the neutralizer from wasted rock wool. The performance on the removal of ferric ions by the neutralizer of wasted rock wool was compared with that by the neutralizer of virgin rock wool. When the cumulative volume of passing water increased at the average rate of passing water from 3.85 to 3.89 L/day, the removal performance of ferric ions with RRW was inferior to that with VRW. It is considered that the chemical reactivity of RRW is inferior to that of VRW since RRW has larger bulk density, that is, smaller specific surface area. When the average rate of passing water was changed from 1.81 to 1.91 L/day, the removal performance of ferric ions with RRW was almost equal to that with VRW.

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