Pilot-scale Tests of Passive Treatment System for AMD in Japan

Kentaro Hayashi[1], Tsubasa Washio[1], Kazuhiro Kojima[1], Yusei Masaki[2], Akihiro Kanayama[2], Takaya Hamai[2], Mikio Kobayashi[2], Nobuyuki Masuda[2], Masahiro Sowanaka[2], Takeshi Sakata[2]

[1]*Metals Technology Center, Japan Oil, Gas and Metals National Corporation, Furudate 9-3, Kosaka-kouzan, Kosaka, Akita, Japan, hayashi-kentaro@jogmec.go.jp*

[2]*Metals Environment Management Department, Japan Oil, Gas and Metals National Corporation, Toranomon 2-10-1, Minato-ku, Tokyo, Japan*

Abstract

A biological passive mine water treatment system, which is environment-friendly and energy saving, has been developed by JOGMEC. In this "JOGMEC process", contaminated mine water is treated in a vertical-flow anaerobic bioreactor that utilizes SRB. It is necessary to introduce compact passive treatment system with a higher flow rate (shorter HRT).

Keywords: AMD, Passive Treatment, Sulfate Reducing Bacteria

Introduction

Japan Oil, Gas and Metals National Corporation (JOGMEC) has been researching on passive treatment system since 2007 and has focused on treatment methods to remove metal ions contained in acid mine drainage, AMD, as sulfide by utilizing sulfate reducing bacteria (SRB). Field tests have been conducted with anaerobic reactors filled with "rice bran" and "rice husk" for AMD since 2014. Continuous removal of metal ions for more than 300 days has been confirmed with hydraulic retention time (HRT) of 50 hours even under the conditions close to natural environment that the ambient temperature dropped to around -15°C in the winter. Besides, continuous removal for more than one year has been confirmed with the HRT of 25 hours. As described above, it has been confirmed that AMD can be treated for a long period under HRT of 12.5 to 50 hours by "JOGMEC process" which removes metal ions as sulfide using an anaerobic reactor filled with agricultural wastes such as rice husk and rice bran. Then, since November 2016, the pilot-scale demonstration tests for AMD containing iron, zinc, copper, and cadmium ions was started.

Methods

The pilot-scale demonstration tests had been carried out at an abandoned mine site in Japan. In these tests, the AMD (Table 1 shows the concentration of each metal ion) was treated with two-step passive treatment systems. The first step was Iron oxidation reactor, in which ferrous ions in AMD were oxidized to ferric ions and precipitated as oxides utilizing the function of iron oxidizing bacteria. The second step is Anaerobic reactor. In this reactor various metal ions were precipitated as sulfides resulting from the reaction with hydrosulfide ion generated by SRB. The appearance and treatment flow of facility for these tests are shown in Fig.1.

The iron oxidation reactor is a PVC tank (W 1.6 m × D 1.3 m × H 1.0 m). For the activation of aerobic iron-oxidizing bacteria utilized in the iron oxidation reactor, raw AMD water was introduced into the reactor like a shower to raise the dissolved oxygen concentration. The iron oxidation reactor was filled with rice husk as carrier of iron-oxidizing bacteria and capturing material of precipitated iron oxides. Rice husk was filled with the thickness of about 0.5 m in

***Table 1** Mine Water Quality (average)*

pH	T-Fe	Zn	Cu	Cd	SO_4^{2-}
[-]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
3.5	38	15.4	4.9	0.06	310

the reactor. The volume was about 1 m^3 and was half of reactor. AMD was introduced into the iron oxidation reactor at a flow rate of approximately 5.2 L/min, and under this condition the HRT was 2.5 hours.

In the anaerobic reactor, sulfate ions were reduced by SRB and then hydrosulfide ions were generated. They reacted with metal ions contained in AMD and resultantly the products were precipitated mainly as sulfides. The reactor was made of concrete and its dimensions were W 3 m × D 2 m × H 2.5 m, and was buried in the semi-underground, 1.8 m out of 2.5 m in height is installed in the ground. AMD was treated at a flow rate of about 2.6 L / min. and the HRT in the anaerobic reactor was 30 hours.

As the contents, at the bottom of the reactor, limestone (particle size 20 to 40 mm) was filled to a thickness of about 0.15 m to prevent clogging of the perforated drain pipes. At the middle area of reactor rice husk layer existed for SRB reaction site and capturing precipitates. Three materials were mixed in this layer, 750 kg of rice husk for substrate, 3,000 kg of limestone (particle size 20 to 40 mm) for pH buffering, 75 kg of soil for resource of bacteria. Furthermore, rice bran as organic matter was filled in the upper layer. In order to keep a good permeability inside the reactor, rice bran was divided into mesh bags and filled in consideration of maintainability such as additional filling and removing. Four ports were set at 4 ports in the depth direction (1st port: 0.50 m from the top of the rice husk layer, 0.75 m at the 2nd port, 1.00 m at the 3rd, 4th port: 1.25 m) of the anaerobic reactor and then samples can be obtained using those ports.

The AMD before and after treatment were periodically sampled and analyzed. Items for monitoring were temperature, pH, Oxidation-Reduction Potential (ORP), metal concentrations (such as iron, copper, zinc, and cadmium), sulfate ion concentration, total sulfide ion concentration that hydrogen sulfide, hydrogen sulfide ion, and other sulfide ion were fixed as sulfide ion under strong alkaline condition, and analyzed with a spectrophotometric method using methylene blue, and chemical oxygen demand (COD).

Results

(1) Iron oxidation reactor

Fig.2 shows ferrous ion (Fe2+) and total iron concentrations of treated water. Most of

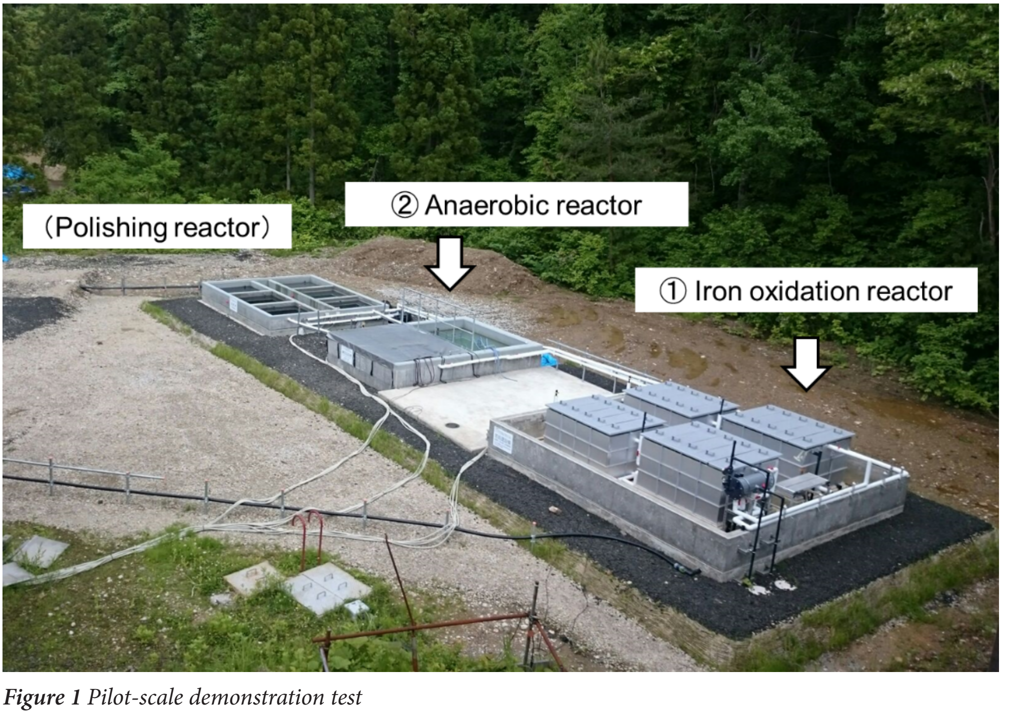

Figure 1 *Pilot-scale demonstration test*

ferrous ion was oxidized to ferric ion (Fe^{3+}) with iron oxidation reactor, and total iron was decreased from 30 - 40 mg/L to less than 10 mg/L (Domestic effluent standards of total iron concentration is 10 mg/L). The performance of iron ion removal has been stably maintained throughout the year. Especially in summer season, in the area of 300 - 400 days in Fig.2, the performance was better and the concentration of total iron was 2 - 5 mg/L.

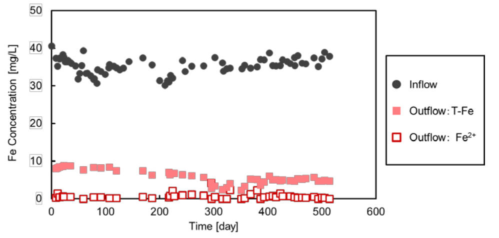

Figure 2 Changes in iron concentration of treated water

(2) Anaerobic reactor

Since May 2017, the test was carried out under the conditions of 25 hours of HRT and 1.0 m of thickness of the rice husk layer (middle of the anaerobic reactor). Although dissolved zinc ion concentration after filtration was low, zinc content in particulate compounds in the effluent gradually increased. These phenomena were probably caused by inadequate trapping of particulate zinc sulfides in the reactor. And then, the thickness of rice husk layer was thickened to 1.25 m to capture particulate zinc in April 2018.

Fig.3 shows the ORP transition of each depth of the anaerobic reactor and outflow, and Fig.4 shows the performance of zinc removal. According to Fig.3, Outflow was stably under the reductive atmosphere and the ORP were -200 – -300 mV. The ORP of each depth of anaerobic reactor was less than 0 mV, under the 2nd port (at 75 cm from the top of the rice husk layer) was less than -200 mV. According to Fig.4, zinc concentration decreased from 16 mg/L to less than 2 mg/L, and zinc ion concentration in filtered water with the 0.45 μm syringe filter was nearly 0 mg/L. Total zinc concentration in outflow decreased to less than 2 mg/L (Fig.4) with 125 cm as the thickness of the rice husk layer, whereas it was found to be 10 mg/L with the thickness of 120 cm. This implies that the particle products were efficiently captured owing to the thicker rice husk layer.

Since July 2018, the flow rate of anaerobic reactor was increased from 2.6 L/min to 3.2 L/min, it means that HRT was same as before April 2018.

Fig.5 shows the transition of ORP in the anaerobic reactor. ORP of each depth were all negative values, and were also -200 – -300 mV for outflow after the HRT was shortened.

Fig.6 shows the performance of zinc removal. Zinc was not detected from filtered samples, and most of zinc ion was removed. However, zinc was detected from unfiltered samples, and the particulate zinc was found to be approximately 6 mg/L.

Discussion

After the rice husk layer of anaerobic reactor was thickened for promotion to capture the particulate containing zinc, zinc concentration was resultantly almost 0 mg/L

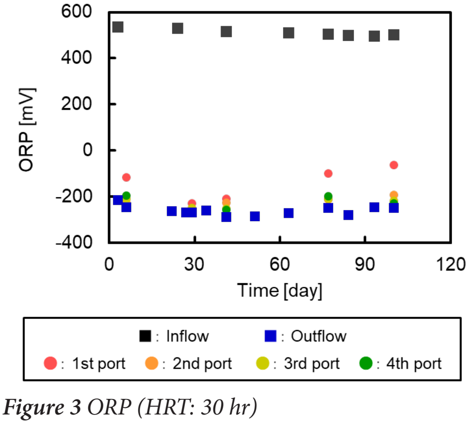

Figure 3 ORP (HRT: 30 hr)

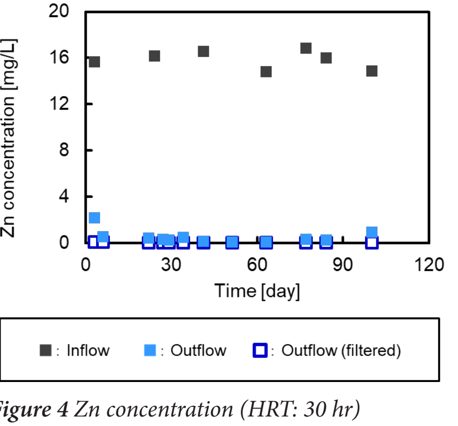

Figure 4 Zn concentration (HRT: 30 hr)

in nonfiltered samples. It was presumed that the area of negative ORP and sulfate reduction reaction of SRB were also thickened and the efficiency to capture particulate products was promoted. However, in the case that the flow rate of anaerobic reactor increased and HRT was shortened in the same condition as before thickening the rice husk layer, the particulate containing zinc was detected again from the anaerobic reactor outflow.

Then, the zinc concentration of each depth of the anaerobic layer was less than outflow. From this result, particulate containg zinc was detected in outflow, not because the sulfate reduction reaction of SRB or the ability to capture sulfide metal were insufficient, but because the flow in the rice husk layer was not homogeneous. In other words, it is considered that precipitation reaction of zinc occurred when treated water and untreated water mixed at the bottom of the anaerobic reactor after passing the rice husk layer. It was suggested that it is important to maintain the homogeneiety of the flow in the anaerobic reactor to a ceratin extent in order to make the processing more stable. On the other hand, although the particulate containing zinc was detected in the outflow under the condition of a shortend HRT (25 hours), the throughput in the same area was increased compared to before thickening the rice husk layer (1.0 m), that is, it is thought that the processing could become efficient and the equipment could be made compact by making the reactor deep.

References

Furuya et al. (2012) Research on the applicability of anaerobic passive bioreactor for mine water treatment in Japan. IMWA2012 proceedings, Bunbury

Hamai et al. (2013) Research on the applicability of anaerobic passive bioreactor to acid mine drainage treatment in Japan. IMWA2013 proceedings, Colorado

Hamai et al. (2015) The sequential experiments of passive treatment system using bioreactor for acid mine drainage in Japan. ICARD2015 proceedings, Santiago

Hamai et al. (2014) The metal removal performance of anaerobic bioreactor in passive treatment for mine drainage. The Mining and Materials Processing Institute of Japan

Hamai et al. (2015). The metal removal performance of anaerobic bioreactor in passive treatment for mine drainage. The Mining and Materials Processing Institute of Japan

Hamai et al. (2015) The bench scale field tests of passive treatment for acid mine drainage. The Mining and Materials Processing Institute of Japan

Hamai et al. (2015) The bench scale field tests of passive treatment for acid mine drainage (process compactification). The Mining and Materials Processing Institute of Japan

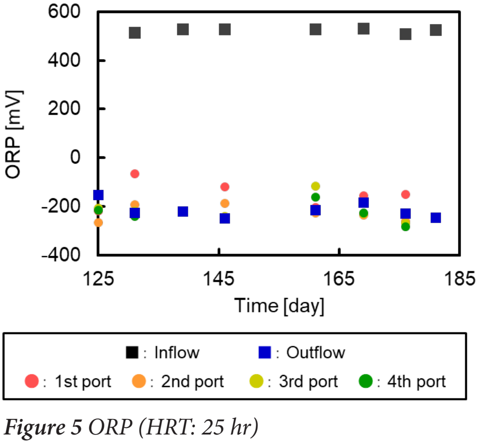

Figure 5 ORP (HRT: 25 hr)

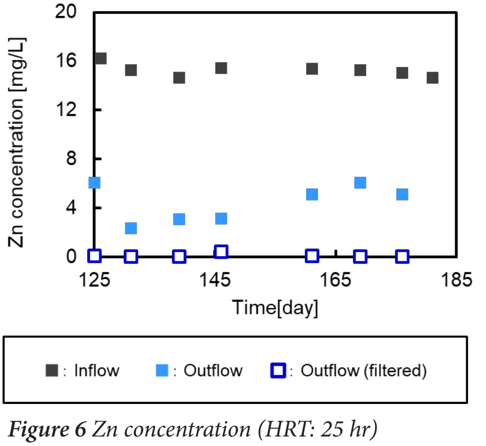

Figure 6 Zn concentration (HRT: 25 hr)