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A study on removal and recovery of heavy metals from industrial wastewater by precipitation and foam separation

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Abstract

In this study, recovery of heavy metals from artificial wastewater containing Cr, Cu, Cd, Pb and Mo by precipitation and foam separation using lime and milk casein was investigated. In addition, to demonstrate the effectiveness of the proposed precipitation and foam separation method, it was applied to mining tailing water collected from an ore-mining facility in Mongolia. Lime was used as an alkaline agent for heavy-metal precipitation. Milk casein functioned as both a collector and a frother for foam separation. The removal efficiencies of heavy metals were determined by inductively plasma spectrometry. As results, the casein enabled the collection and recovery of the precipitation components of heavy metals within a total processing time of 10 min. Precipitation and foam separation using lime and casein is an effective and adaptable method for treating industrial effluents that contain heavy metals.

Keywords: Heavy metals, casein, precipitation, foam separation, mining tailing water

1. INTRODUCTION

Even today, there is a high need for removal of heavy metals from industrial wastewater with easily and quickly at low-cost. In addition, it is desirable to recover the heavy metals which become the valuable materials. As prior studies, foam separation has received considerable interest due to its simplicity, rapidity, high efficiency and cost-effective for the solid-liquid separation [1]–[3].

The role of surface active substance is the most important in the foam separation process. Besides, milk casein, one of the eco-friendly surface-active proteins, has unique characteristics such as high foaming capacity and adsorbed to ferric and aluminum hydroxides as collector for removal of suspended substances [1]. However, there is no study about attachment of casein for the removal of heavy metals by the foam separation.

In this study, the removal and recovery of heavy metals from artificial wastewater using dispersed bubbles and milk casein were tested with pre-precipitation. In addition, to prove the effectiveness for the actual condition, precipitation and foam separation was applied to the mining tailing water collected from the mining industry in Mongolia.

2. MATERIALS AND METHODS

2.1 Artificial wastewater preparation and sampling of the mining tailing water

Artificial wastewater containing heavy metals (Cr, Cu, Cd, Pb, and Mo) in each concentration of 10 mg/L was prepared with moderately hard water.

A sample of mining tailing water was collected from the tailing processing plant of the Erdenet Mining in Mongolia during summer season in 2017.

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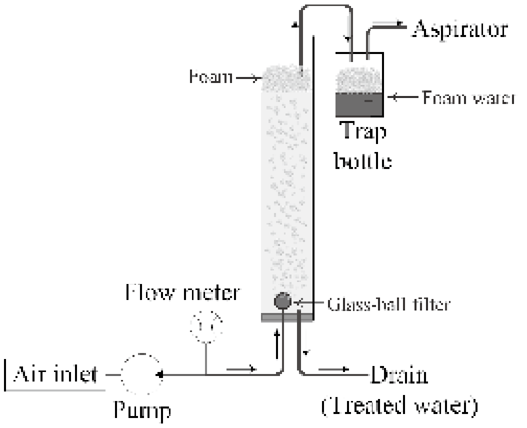

Fig. 1. Foam separation batch equipment system

2.2 Precipitation and sedimentation

To simulate the optimum pH, the effect of coagulant, and the comparison of alkali chemicals such as sodium hydroxide (NaOH) and calcium hydroxide ($Ca(OH)_2$), jar test was performed by using a conventional jar tester (MJS-8, Miyamoto, Japan) under the different condition. As a coagulant, ferric coagulant (39% iron (III) chloride, Takasugi Seiyaku, Japan) was used. The supernatant water was sampled after sedimentation into a new vial and the concentrations of heavy metals were determined.

2.3 Precipitation and foam separation

After precipitation process, a proper amount of the milk casein (5, 10, 15 mg/L) as a surface-active substance was added into the precipitated wastewater. Jar testing procedure was done for the precipitated water in order to enhance interaction between heavy metals components and casein with mixing speed at 150 rpm. Subsequently, foam separation process was carried out by transferring precipitated raw water into the cylindrical column of the batch flotation equipment **(Fig. 1).**

The dispersed air was provided from the bottom of the column with a glass-ball filter (Kinoshita Rika, Japan) which has 1.5 cm of diameter and 5-10 μm of pore size. Foam generated on the water surface was recovered in a trap bottle by an aspirator. The processing time for foam separation was 2 min and 4 min; the flow rate of the air supply was 0.3 L-air/min. The treated water was sampled from the drain. In order to recover Mo selectively, the treated water was acidified to the pH 5-6. After acidification, foam separation process was done again as described above with addition of casein.

2.4 Analytical methods

The concentration of all heavy metals in the raw water and treated water was determined by inductively coupled plasma spectrometry (ICPS 8100, Shimadzu, Japan). The pH, total dissolved solids, and electron conductivity were measured by a benchtop pH/water quality analyzer (LAQUA, Horiba, Japan). The turbidity was determined by a turbidimeter (SEP-PT-706D, Mitsubishi Chemical Analytech, Japan).

3. RESULTS AND DISCUSSION

As shown in **Fig. 2**, the removal of all heavy metals except Mo was gradually increased at pH 6 to pH 9 by the treatment of precipitation and foam separation from artificial wastewater. The removal efficiencies of the Cr, Cu, Cd, and Pb were more than 96% at the pH about 9. According to solubility diagrams [4], negatively charged components of the heavy metals dominate at the higher alkaline condition as above pH 10 which is illustrating it was difficult for the negatively charged casein to function to these components by electrostatic interaction.

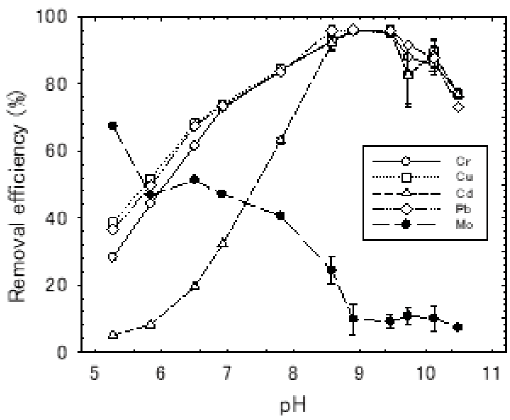

Fig. 2. Removal efficiency of the heavy metals by precipitation and foam separation from artificial wastewater.

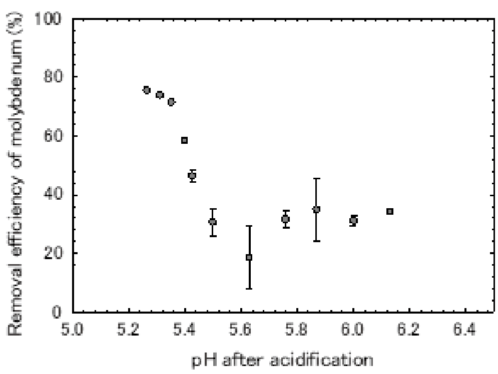

Fig. 3. Selective removal of the Mo by foam separation after acidification.

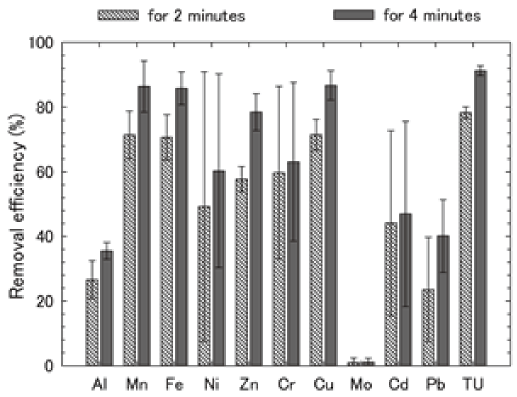

Fig. 4. Removal of the detected metals and turbidity (TU) by the foam separation from mining tailing water.

Although the heavy metals were sufficiently removed under optimum condition at pH 9 with adding lime and casein dosage of 15 mg/L, the only Mo was remained in the water.

Therefore, the treated water remained Mo was acidified and retreated to remove Mo selectively. The removal efficiency of Mo increased to more than 76% by foam separation after acidification at the pH about 5.3 from alkaline treated water (**Fig.3**).

In the mining tailing water, Al, Mn, Fe, Ni, Zn, Cr, Cu, Mo, Cd, and Pb were detected. Since the raw water used for this study treated already by flocculation, the metal concentration was low similar to previous report [5].

The high removal efficiencies were obtained for Mn, Fe, and Cu and were more than 85% (**Fig. 4**). A noteworthy fact was that the more than 90% of suspended solids contained in the mining tailing water were removed together with the heavy metals. However, the Mo removal was extremely low due to the very low initial concentration.

4. CONCLUSION

Precipitation and foam separation using lime and casein was demonstrated as effectively and adaptable method for treating industrial effluents included heavy metals within 10 min of total processing. Casein functioned sufficiently as surface active substance to collect the heavy metal components from artificial wastewater. Furthermore, the precipitation and foam separation was applied to the actual industrial wastewater such as mining tailing water.

5. REFERENCES

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