

Bioleaching of Marine Manganese Nodules by Acidophilic Sulfur-Oxidizing Bacteria

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ABSTRACT

A unique bioprocess is proposed for extracting metals from marine manganese nodules. In this bioleaching, sulfurous acid and sulfuric acid are biologically produced from elemental sulfur and simultaneously used as leaching agents to manganese nodules. In the leachability aspect of nodules, the thermophile *Acidianus brierleyi* growing on elemental sulfur at 65°C is more effective than the mesophile *Thiobacillus* species at 30°C. Leaching experiments with *A. brierleyi* were undertaken to optimize the conditions under which valuable metals in nodules are solubilized during the bacterial growth on elemental sulfur.

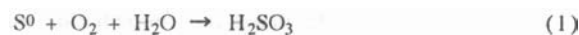
KEY WORDS: Manganese nodules, metals recovery, bioleaching, sulfur-oxidizing bacteria, *Acidianus brierleyi*, *Thiobacillus ferrooxidans*, *Thiobacillus thiooxidans*

INTRODUCTION

There have been many investigations into the recovery of valuable metals from marine manganese nodules because of their potential importance for mineral resources in future (Fuerstenau and Han, 1983). Although physical and chemical processes have been extensively developed for extracting the metals from manganese nodules, another possible process is the leaching of nodules by microbial means. In the area of hydrometallurgy, a large amount of work has been conducted in the application of microorganisms to the recovery of base and precious metals from various sulfide mineral resources, but little attention has been given to the microbial treatment of manganese nodules.

The primary microorganisms in sulfide leachings is acidophilic mesophile *Thiobacillus thiooxidans* and *Thiobacillus ferrooxidans*, which grow optimally at 30°C and low pH 1-2. Moreover, the acidophilic thermophile *Acidianus brierleyi*, which has a temperature optimum for activity at 65°C, is a candidate microbe for sulfide leachings. Although these acidophilic sulfur-oxidizing bacteria obtain their growth energy from the oxidation of inorganic sulfur compounds, they have no ability to attack directly manganese nodules

which are comprised mainly of oxides of manganese and iron. Alternatively, there is a unique treatment of manganese nodules with the sulfur-oxidizing bacteria growing on elemental sulfur. The microbial treatment is induced in a combined process. In the first stage chemical leaching agents, in this case, sulfurous acid and sulfuric acid, are biologically produced from elemental sulfur added in the medium :



The bacterially produced acids are then used to solubilize metals in manganese nodules. This bioleaching appears to be a technically possible method because leaching techniques with sulfurous acid or sulfuric acid have been proposed for hydrometallurgical treatment of manganese nodules.

The purpose of this work is to obtain rate data on the leaching of raw manganese nodules by the thermophilic and mesophilic bacteria growing on elemental sulfur, to compare the nodule leachability between the thermophile *A. brierleyi* and the mesophile *T. thiooxidans* and *T. ferrooxidans*, and to optimize the conditions under which valuable metals in nodules are dissolved during the bacterial growth.

EXPERIMENTAL SECTION

Mineral

The manganese nodules used in this study were collected in the western part of Central Pacific Basin and were provided by the National Institute for Resources and Environments, Japan. The nodules were ground and then sieved to obtain the size fraction -330+500 mesh (25-45 μm). To determine the chemical composition, sample of the sieved nodule particles was completely dissolved in HCl and HNO₃, and the solution generated by this procedure was analyzed for transition metals by ion chromatography. The initial contents of each metal in the sieved nodule particles was 22.9 wt% Mn, 13.0 wt% Fe, 1.37 wt% Cu, 0.591 wt% Ni, 0.385 wt% Co and 0.421 wt% Zn, respectively.