Bioresource Technology 130 (2013) 673–680

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Bioleaching of spent hydrotreating catalyst by acidophilic thermophile *Acidianus brierleyi*: Leaching mechanism and effect of decoking

Abhilasha Bharadwaj, Yen-Peng Ting *

Department of Chemical and Biomolecular Engineering, National University of Singapore, 4 Engineering Drive 4, Singapore 117576, Singapore

HIGHLIGHTS

- ▶ Decoking removed impurities from spent catalyst and affected bioleaching.
- ▶ Ni concentration in leachate was reduced to below regulated level after bioleaching.
- ▶ Spent medium leaching showed higher efficiency than two-step leaching.
- ▶ Bioleaching efficiency was higher than chemical leaching for most metals.

ARTICLE INFO

Article history:
Received 3 October 2012
Received in revised form 7 December 2012
Accepted 8 December 2012
Available online 22 December 2012

Keywords:
Bioleaching
Spent catalyst
Thermophile
Acidianus brierleyi
Decoking

ABSTRACT

Bioleaching of spent hydrotreating catalyst by thermophillic archae *Acidianus brierleyi* was investigated. The spent catalyst (containing Al, Fe, Ni and Mo as major elements) was characterized, and the effect of pretreatment (decoking) on two-step and spent medium leaching was examined at 1% w/v pulp density. Decoking resulted in removal of carbonaceous deposits and volatile impurities, and affected the solubility of metal compounds through oxidization of the metal sulfides. Nearly 100% extraction was achieved using spent medium leaching for Fe, Ni and Mo, and 67% for Al. Bioleaching reduced nickel concentration in the leachate below the regulated levels for safe waste disposal. Chemical (i.e. abiotic) leaching using equimolar concentration of sulfuric acid produced by the bacteria during two-step process achieved a lower leaching efficiency (by up to 30%). Results indicated that *A. brierleyi* successfully leached heavy metals from spent catalyst.

1. Introduction

The use of hydrotreating catalysts has increased significantly over the years due to stringent environmental regulations on the production of cleaner fuels with ultra-low sulfur levels. Hydrotreating catalysts are used for the removal of undesirable impurities such as sulfur and nitrogen, and toxic metals such as vanadium present in crude petroleum (Furimsky, 1996). During the use of these catalysts, deactivation occurs due to deposition of metal sulfides, oxides and other contaminants which results in the generation of large quantities of spent catalysts as solid wastes every year. Hydrotreating catalysts are often used to produce ultra-low sulfur diesel with sulfur levels <10 ppm. The need to comply with an EU legislation which requires non-road diesel to meet 10 ppm sulfur standards by 1st January 2011 necessitated an increase in hydrotreating capacity by five times. As a result, 150,000–170,000 tons of spent hydrotreating catalysts per year are generated worldwide, a statistic bound to only increase with rapid industrialization and increased processing of heavier feedstock (Dufresne, 2007).

Spent hydrotreating catalysts are classified as hazardous wastes and come under the controlling terms of EPA, Basel Convention and OECD rules and cannot be exported to third world countries (Marafi and Stanislaus, 2008). The petroleum industry uses methods such as chemical recovery, regeneration or landfilling for spent catalyst management which pose serious threat to the environment by producing large amounts of toxic gases or by leaching harmful metal ions and other contaminants into the environment. In addition to these negative environmental impacts, the cost for landfilling (which amounts up to 200 US $/ton of spent catalyst) has put pressure on refiners to look for environmentally safe and economic options for their disposal (Marafi and Stanislaus, 2008).

Bioleaching offers many attractive features, being cost efficient, and more environmentally benign compared to their chemical counterparts, which require the use of strong chemicals under high temperature and pressure conditions (Das et al., 2011). Bioleaching has been investigated for the extraction of metals from various solid industrial wastes for well over a decade. These wastes include fly ash, sewage sludge, spent batteries and electronic scrap

* Corresponding author.
E-mail address: chetyp@nus.edu.sg (Y.-P. Ting).

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http://dx.doi.org/10.1016/j.biortech.2012.12.047