Resources, Conservation & Recycling 196 (2023) 107035

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

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

A novel membrane-integrated sustainable technology for downstream recovery of molybdenum from industrial wastewater

Ramesh Kumar [a], Chengjia Liu [a], Geon-Soo Ha [b], Kwang Ho Kim [b], Sankha Chakrabortty [c], Suraj K. Tripathy [c], Young-Kwon Park [d], Moonis Ali Khan [e], Krishna Kumar Yadav [f,g], Marina M.S. Cabral-Pinto [h], Byong-Hun Jeon [a,*]

[a] Department of Earth Resources & Environmental Engineering, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Republic of Korea
[b] Clean Energy Research Center, Korea Institute of Science and Technology, Seoul 02792, Republic of Korea
[c] School of Chemical Technology, Kalinga Institute of Industrial Technology, Bhubaneswar 751024, India
[d] School of Environmental Engineering, University of Seoul, Seoul 02504, Republic of Korea
[e] Chemistry Department, College of Science, King Saud University, Riyadh 11451, Saudi Arabia
[f] Faculty of Science and Technology, Madhyanchal Professional University, Ratibad, Bhopal 462044, India
[g] Environmental and Atmospheric Sciences Research Group, Scientific Research Center, Al-Ayen University, Thi-Qar, Nasiriyah, 64001, Iraq
[h] Geobiotec Research Centre, Department of Geoscience, University of Aveiro, Aveiro 3810-193, Portugal

ARTICLE INFO

Keywords:
Industrial wastewater
Resource recovery
Nanofiltration
Molybdenum trioxide
Sustainable technology
Circular economy

ABSTRACT

An experimental investigation was conducted to recover and recycle a precious metal (molybdenum) while treating industrial wastewater using a novel membrane-integrated hybrid technology. Hollow-fiber crossflow modules containing ultrafiltration and nanofiltration membranes in the recirculation mode successfully separated 96.5% of the molybdenum from industrial wastewater. The volume of feed wastewater (250 L) was reduced by ~94%, and the molybdenum concentration was increased from 1.32 to 10.2 g/L using a VNF-1 membrane for its smooth recovery (98.7%) as ammonium molybdate by chemical precipitation under response-surface-optimized conditions of critical parameters of NH_4^+/Mo ratio (1.32), pH (1.7), temperature (62 °C), and time (15.7 h). Further, ammonium molybdate was converted into MoO_3 of high purity (99.4%) using thermal decomposition at 500 °C for 30 min. This is the first proof-of-concept demonstrating the use of a membrane system to recover molybdenum from industrial wastewater to promote a circular economy for recycling and regenerating valuable resources.

1. Introduction

The depletion of primary resources and growing demand for raw materials in developed and developing countries due to rapid industrialization have necessitated technological advancement for recovering and recycling valuable byproducts from secondary sources (Liu et al., 2022). Various petroleum refining, electroplating, chemical, and mineral refining industries generate wastewater that contains molybdenum and other organic and inorganic contaminants (Cai et al., 2022; Sun and Lee, 2011). Direct discarding of molybdenum-containing wastewater is not permitted because it contains rare, precious, and saleable industrial elements (Henckens et al., 2018). However, hazardous end-of-life catalyst-containing waste effluents are disposed of annually (~170 kt); this causes serious environmental issues and enhances post-handling costs (Abidli et al., 2022). The maximum permissible limit for the disposal of molybdenum is 40 mg/L (U.S. Department of Health and Human Services, 1978) because of the possible risk to aquatic and terrestrial life upon prolonged exposure (Swinkels et al., 2004).

Molybdenum trioxide (MoO_3) is an essential part of electronics, electro- and photochromic devices, lithium-ion batteries, photocatalytic processes, and gas sensors because of its thermodynamically stable and tunable properties (Pradeesh et al., 2018). The recovery of molybdenum from wastewater in a saleable form, viz., molybdenum trioxide, is an attractive option for closing the cycle of molybdenum utilization. Various conventional methods, such as biosorption, electrodialysis, chemical coagulation, ion exchange, solvent extraction, adsorption, and flocculation, have been used to remove toxic metals from wastewater (Bădescu et al., 2018; Moradi et al., 2018; Parhi and Misra, 2022; Tran

* Corresponding author.
E-mail address: bhjeon@hanyang.ac.kr (B.-H. Jeon).

https://doi.org/10.1016/j.resconrec.2023.107035
Received 19 January 2023; Received in revised form 7 April 2023; Accepted 5 May 2023
Available online 10 May 2023