Separation and Purification Technology 382 (2026) 135739

Contents lists available at ScienceDirect

Separation and Purification Technology

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

Development of metal–organic framework–like La–methanoate@OMS nanohybrid for the efficient adsorption of arsenate

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ARTICLE INFO

Keywords:
Lanthanum–methanoate nanohybrid
Metal–organic frameworks
Adsorption
Arsenate

ABSTRACT

The presence of arsenate ions (As^{5+}) in water at concentrations exceeding the World Health Organization's recommended limit poses serious risks to humans, animals, and the environment, necessitating efficient removal methods. In this research, a metal–organic framework–like lanthanum–methanoate (LaMe) nanohybrid was synthesized through a solvothermal synthetic process using three different organic linkers with La moieties for As^{5+} removal. To enhance the stability and adsorption capacity of pristine LaMe, oxygen-incorporated molybdenum disulfide (OMS) was incorporated to form a nanohybrid structure (LaMe@OMS). Among the tested linkers, La–NBDC@OMS exhibited the highest adsorption capacity, whereas La–H_4TCPP@OMS demonstrated superior structural stability. The LaMe@OMS nanohybrid exhibited a maximum adsorption capacity of 2.855 mmol/g at 25°C and exhibited pH-dependent performance, peaking at pH 5.0–7.0. The nanohybrid demonstrated high selectivity in the presence of common coexisting anions, except PO_4^{3-} and F^-. Adsorption behavior followed the Langmuir isotherm and pseudo-second-order kinetic models, while spectroscopic and thermal analyses confirmed surface interactions with As^{5+} and robust stability. The primary adsorption mechanism was chemisorption involving ligand exchange and electrostatic interactions. Moreover, the nanohybrid retained high efficiency over multiple adsorption–desorption cycles, confirming excellent reusability. These results highlight the LaMe@OMS nanohybrid as a promising and reusable adsorbent for efficient As^{5+} removal from aqueous environments.

1. Introduction

Global water pollution is primarily driven by agricultural and industrial activities, which release a wide range of contaminants into the environment [1]. Many of these pollutants resist biodegradation, persist in ecosystems, and eventually accumulate in the food chain, posing serious threats to human and ecological health [2]. Among these, arsenic is of particular concern because it is a well-known carcinogen, and the World Health Organization has set a maximum permissible limit of 0.01 mg/L in drinking water [3]. Arsenite (As^{3+}) is generally recognized as more mobile and toxic than arsenate (As^{5+}). While As^{3+} tends to exist in neutral molecular forms near circumneutral pH, As^{5+} predominantly occurs as anionic species ($H_2AsO_4^-$ and $HAsO_4^{2-}$), which make it more amenable to removal by adsorption.

Research on water treatment technologies to remove aqueous contaminants has progressed through multiple approaches, each with distinct strengths and weaknesses. Oxidation processes can rapidly degrade pollutants, yet their scalability and cost remain challenging [4].

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https://doi.org/10.1016/j.seppur.2025.135739
Received 26 June 2025; Received in revised form 7 October 2025; Accepted 16 October 2025
Available online 17 October 2025