ACS OMEGA

Open Access

http://pubs.acs.org/journal/acsodf

Article

A Novel Approach for Nanosponge: Wool Waste as a Building Block for the Synthesis of Keratin-Based Nanosponge and Perspective Application in Wastewater Treatment

Gjylije Hoti, Fabrizio Caldera, Francesco Trotta, Marina Zoccola, Alessia Patrucco, and Anastasia Anceschi*

Cite This: *ACS Omega* 2024, 9, 43319−43330

Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information

ABSTRACT: Wool waste is a huge environmental problem that needs to be addressed in order to avoid the continuous accumulation of biohazardous waste in landfills. In recent years, wool has proven to be an excellent source of keratin that can be used for various purposes. But never before has keratin from wool waste been used as a building block to synthesize a well-known class of biopolymers called nanosponges. Typically, nanosponges are produced by the reaction of cyclodextrins with an appropriate cross-linker to obtain an insoluble hyper-cross-linked polymer, which has applications in various fields. For this reason, a novel, affordable approach for the synthesis of a novel class of nanosponge using wool keratin as the building block has been presented. The keratin nanosponge was synthesized by reacting keratin with pyromellitic dianhydride as a cross-linking agent. The formation of a cross-linked polymer was successfully confirmed by CHNS-elemental analysis, TGA, DSC, FTIR-ATR, SEM, and water absorption capacity measurements. Surprisingly, the keratin-based nanosponge showed ~50% uptake of heavy metals after only 24 h of contact time. The adsorption kinetics was also evaluated, indicating a pseudo-second-order model fit and the mechanism is predominantly the intraparticle diffusion process. The novel synthesized nanosponge proved to be a possible alternative for wastewater treatment.

■ INTRODUCTION

Natural fiber processing has the highest environmental impact, particularly wool.[1] Furthermore, water pollution caused by mainly anthropogenic activities is an extremely serious environmental problem that has emerged in recent years.[2] Thus, the time has come for a transition by proposing a new system with a vision aligned with the circular economy principle.

Industrial waste often contains a wide range of toxic dissolved inorganic chemicals that have been discharged into the environment, leading to severe water pollution. These pollutants include heavy metal ions, colorants, phenols, organic compounds, and inorganic ions.[3,4] Heavy metals have become increasingly prevalent in aquatic systems due to excessive discharges from various industries, such as metallurgical and chemical fertilizer production.[5,6] As a result, many aquatic environments now have metal concentrations in excess of water quality criteria, and there is a need to develop measures to protect ecosystems, fauna, and flora, as well as human health. Studies conducted during the past few years have shown that even low concentrations of heavy metals can cause acute lethal toxicity because of their ability to accumulate and nonbiodegradable nature.[7]

Based on that, the removal of heavy metals in water has attracted significant attention, and various methods have been applied. Various techniques are commonly used to treat heavy metal pollution in wastewater, including chemical precipitation,[8] membrane filtration,[9] electrochemical treatment,[10] solvent extraction,[11] ion exchange,[12] and adsorption.[13] Chemical precipitation and electrochemical treatment are commonly used, but they produce a large quantity of sludge that is difficult to be treated.[14] Membrane filtration, solvent extraction, and ion exchange are expensive and difficult to be applied at a large scale.[15] Thus, these techniques have some shortcomings, such as complex processing, being expensive, and being energy-consuming. An ideal alternative is considered adsorption. Adsorption is currently used for industrial applications and it is considered ideal for wastewater treatment because of its simplicity and cost-effectiveness.[16] Over the last

Received: November 16, 2023
Revised: September 2, 2024
Accepted: September 5, 2024
Published: October 16, 2024

https://doi.org/10.1021/acsomega.3c09133
ACS Omega 2024, 9, 43319−43330