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3D Printed Functionalized Nanocellulose as an Adsorbent in Batch and Fixed-Bed Systems

Mohd Shaiful Sajab [1,2,*], Wan Nazihah Liyana Wan Jusoh [1,2], Denesh Mohan [1,2], Hatika Kaco [3] and Rubiyah Baini [4]

[1] Research Center for Sustainable Process Technology (CESPRO), Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia
[2] Department of Chemical and Process Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia
[3] Kolej GENIUS Insan, Universiti Sains Islam Malaysia, Bandar Baru Nilai, Nilai 71800, Negeri Sembilan, Malaysia
[4] Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), Kota Samarahan 94300, Sarawak, Malaysia
* Correspondence: mohdshaiful@ukm.edu.my

Abstract: Nanocellulose, a refined form of cellulose, can be further functionalized on surface-active sites, with a catalyst as a regenerative agent. Newly developed adsorbents are expected to have the characteristics of good and rapid adsorption performance and regeneration properties with flexible structure using 3D printing technology. In this work, the adsorption performance of 3D printed functionalized nanocellulose was investigated using batch and fixed-bed column adsorption. Kinetics adsorption studies were divided into different adsorption models, with the pseudo-second order model showing a better correlation coefficient than the pseudo-first order and intraparticle diffusion models. The Langmuir and Thomas models were used to calculate the adsorption performance of batch and fixed-bed columns. Given the catalytic activity of Fenton oxidation, the fixed-bed column was regenerated up to five adsorption-desorption cycles, suggesting satisfactory performance of the column, with a slightly reduced adsorption capacity.

Keywords: 3D printing; additive manufacturing; cellulose; water remediation

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1. Introduction

Every year, a large quantity of synthetic dyes, approximately 8×10^5 tons, are produced. However, they exhibit significant losses, with 15% of the production discharged during application [1]. Dyes can have harmful effects on humans, including causing dermatitis, affecting the central nervous system, and leading to long-term genotoxicity and cancer. Additionally, dyes and pigments can indirectly impact human health by flowing through the food chain, ultimately being consumed by humans. Research has shown that their toxicity is magnified by a factor of 1000 when detected in humans compared to the actual concentration in the food chain [2,3].

To mitigate these impacts, proper treatment for decolorization is necessary, as traditional sewage treatment methods are inadequate for removing dyes to the extent required for meeting minimum color standards. Currently, there are several techniques for treating wastewater, which can be broadly divided into two categories: physicochemical and biological treatments. Treating dyes can be expensive and can involve long and complicated processes, which can also generate secondary hazardous materials [3,4]. Each treatment method has its own advantages and disadvantages, and its limitations depend on the specific conditions of the effluent. A more effective, sustainable, and environmentally friendly alternative method is desired for the treatment process.

To address this challenge, low-cost alternative adsorbents have been developed, such as those made from clays, siliceous minerals, agricultural waste, biosorbents, and other materials. These have been shown to be as effective as commercially available adsorbents.