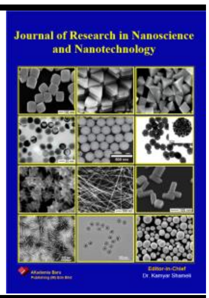
Journal of Research in Nanoscience and Nanotechnology 10, Issue 1 (2024) 1-6

Penerbit Akademia Baru

Journal of Research in Nanoscience and Nanotechnology

Journal homepage:
http://akademiabaru.com/submit/index.php/jrnn/index
ISSN: 2773-6180



Effect of Cu(II) Concentration on Pandan Leaf (Pandanus amaryllifolius) Nanocellulose's Adsorption Efficiency

Haziqatulhanis Ibrahim [1], Norazlianie Sazali [2,*], Wan Norharyati Wan Salleh [3], Afdhal Junaidi [4], Triyanda Gunawan [4], Nurul Widiastuti [4] and Nurasyikin Misdan [5]

[1] Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
[2] Faculty of Manufacturing and Mechatronic Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
[3] Advanced Membrane Technology Research Centre (AMTEC), Universiti Teknologi Malaysia, 81310 Skudai, Johor Darul Takzim, Malaysia
[4] Institut Teknologi Sepuluh Nopember, 60111 Sukolilo, Surabaya, Indonesia
[5] Department of Mechanical Engineering Technology, Faculty of Engineering Technology, Univesiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor Malaysia
* Correspondence: azlianie@umpsa.edu.my
https://doi.org/10.37934/jrnn.10.1.16

ABSTRACT

Heavy metals pose a significant environmental threat due to their toxic nature and long-lasting presence in ecosystems. Adsorption is a notable method for reducing low-concentration heavy metals in wastewater due to its simplicity, cost-effectiveness, and high efficiency. Nanocellulose-based adsorbents are gaining significant attention due to their environmentally friendly characteristics and unique properties. They are particularly effective in addressing heavy metal ion contamination, such as Cu(II). Malaysia possesses a significant quantity of pandan leaves, which show potential for applications in wastewater treatment and as a valuable source of nanocellulose for polymer composites. Various techniques, including chemical pretreatments and the sulfuric acid hydrolysis method, are employed to extract nanocellulose from pandan leaves. Acrylamide, a vinyl monomer, is subsequently employed for grafting. In addition, AAS was used to monitor the removal of Cu(II) ions. This study investigates the binding characteristics of nanocellulose derived from pandan leaves with varying concentrations of Cu(II) using a series of batch adsorption experiments. Our study reveals that a concentration of 30 ppm Cu(II) has a significant effect on the adsorption efficiency of pandan leaf nanocellulose.

Keywords:
Pandan leaf, Cu(II) adsorption,
Nanocellulose

Received: 19 Oct. 2023	Revised: 1 Dec. 2023	Accepted: 1 Jan. 2024	Published: 29 Feb. 2024

1. Introduction

The issue of heavy metal pollution in the environment has become a matter of great importance due to the inherent toxicity and long-lasting persistence of these contaminants in ecosystems [1]. The presence of these pollutants presents a substantial risk to both the integrity of the environment and the well-being of humans. The resolution of this problem necessitates the use of efficient and enduring remedial strategies [2]. Adsorption has emerged as a prominent method for the effective removal of low-concentration heavy metals from wastewater, owing to its varied range of techniques [3]. This approach is highly regarded due to its straightforwardness, cost-efficiency, and notable efficacy [4].

The investigation of nanocellulose-based materials has been driven by the pursuit of environmentally sustainable and high-performance adsorbents in recent years. Nanocellulose, which is obtained from diverse sources such as plant fibers, demonstrates distinctive characteristics and notable compatibility with the environment [5]. Significantly, this approach has exhibited remarkable potential in addressing the issue of heavy metal ion pollution, specifically emphasizing ions such as Cu(II) [6].

Malaysia, well-known for its diverse range of flora and fauna, possesses a significant and adaptable natural asset: pandan leaves (Pandanus amaryllifolius) [7]. Pandan leaves have historically been utilized for the purpose of enhancing culinary experiences, extracting natural dyes, and adding taste to various dishes [8]. In addition to their conventional applications, pandan leaves have recently attracted interest in the field of environmental science [9,10]. They are being explored for their potential contributions to wastewater treatment and as a source of nanocellulose, a material that shows promising potential in polymer composites and adsorption technologies [11].

The process of extracting nanocellulose from pandan leaves requires a methodical approach that involves chemical pretreatments and the utilization of the sulfuric acid hydrolysis technique, followed by grafting with acrylamide, a vinyl monome. In the field of accurate monitoring of Cu(II) ion elimination, atomic absorption spectrometry (AAS) is often regarded as the preferred method.

The present study undertakes a thorough investigation of the binding properties demonstrated by nanocellulose generated from pandan leaves when subjected to different concentrations of Cu(II). Our objective is to get a comprehensive understanding of the complex interaction between pandan leaf nanocellulose and Cu (II) ions by conducting a series of carefully planned batch adsorption studies. Our primary objective is to comprehend the substantial impact of a copper(II) concentration 15, 30, and 45 ppm. on the effectiveness of pandan leaf nanocellulose adsorption. By undertaking this research, the study not only makes a valuable contribution to the progress of sustainable methods for eliminating heavy metals, but also highlights the capacity of utilizing natural resources to tackle urgent environmental issues.

2. Methodology

Pandan leaves were collected in Johor, Malaysia, from a neighborhood as a source of cellulose. Nitric acid (HNO_3), sodium chlorite ($NaClO_2$), and sulfuric acid (H_2SO_4) from the Merck company Sigma-Aldrich are the three chemicals that are utilized to extract cellulose. Pellets of sodium hydroxide (NaOH) were bought from QReC. Dimethylformamide (DMF) and ceric ammonium nitrate $(NH_4)_2Ce(NO_3)_6$ from Merck, were utilized for graft copolymerization. For adsorption investigations, a Cu(II) nitrate trihydrate $Cu(NO_3)_2.3H_2O$ stock solution containing 1000 ppm was generated. Distilled water was utilized throughout the experiment.

The pandan leaves are cleaned, chopped into small bits, and dried before the nanocellulose extraction process begins. The ground-up dried pandan leaves were then put into a mixture of 5%

NaOH by weight and $NaClO_2$ at 125 °C for two hours. After the sample was neutralized, the hydrolysis procedure was carried out by adding 60% H_2SO_4 at a ratio of 5:100 (weight percent) for 1 hour at a temperature of 125 °C. Up until a pH of zero was reached, cold distilled water was added to the solution. By combining 10 g/L of the newly-produced nanocellulose with ceric ammonium nitrate for 10 minutes, the grafting procedure for the obtained nanocellulose was continued. The acrylamide solution was then added, and everything was agitated for an hour at 60 °C. After filtering and washing with deionized water, the resultant mixture was dried at 40 °C until the mass remained constant. The remaining homopolymer was then removed by further washing with dimethylformamide, and the solid was dried for 48 hours.

The adsorption experiment was conducted under ambient conditions, utilizing a solution with a pH of 6. Various concentrations of Cu(II) metal, namely 15 ppm, 30 ppm, 45 ppm, were introduced at the beginning of the test. The calculation of adsorption capacity is determined by employing the following formula.

Adsorption capacity, qe (mg/g):

$$q_e = \frac{(C_o - C_e)V}{m} \tag{1}$$

The concentrations at beginning and equilibrium, denoted as C_0 (ppm) and C_e (ppm) respectively, are related to the solution volume V (L) and the mass of the adsorbent utilized, m (g).

3. Results and Discussion

One important aspect that affects nanocellulose's capacity to absorb is the initial concentration of metal ions. It significantly affects how effectively the adsorption process operates [3]. The initial concentration of the metal ion solution and the adsorption capacity are found to be directly correlated [12]. This connection develops as a result of concentration differences that make the adsorption process easier to perform at greater metal ion concentrations [13]. However, an optimum is reached when the maximum metal ion capture efficiency of the adsorbent is achieved. Adsorption loses effectiveness when the balance between the quantity of metal ions and the quantity of adsorption sites is disrupted beyond this threshold [14]. As a result, the amount of metal ions that may be efficiently adsorbed is reduced, leading to a reduction in adsorption capacity.

This occurrence is supported by Table 1 and Figure 1, which show that the maximum adsorption capacity is reached at a concentration of 30 ppm. This crucial finding leads us to the conclusion that nanocellulose's adsorption properties are best matched at a concentration of 30 ppm. However, a decrease in adsorption capacity is shown when the concentration deviates from this equilibrium point, such as at higher (45 ppm) and lower (15 ppm) concentrations. The imbalanced link between the number of accessible adsorption sites and the concentration of metal ions is to blame for this reduction. Our findings further demonstrate the unique influence of grafting treatment on adsorption capacity. The efficacy of adsorption is specifically increased by the addition of functional groups obtained from acrylamide monomers, highlighting the possibility of specific alterations to enhance nanocellulose-based adsorbents. This phenomenon was also explained by previous research [15].

Table 1
Cu(II) adsorption capacity of different initial concentrations with and without grafting

Cu(II) concentration (ppm)	Adsorption capacity (mg/g)	
	Ungrafted	Grafted
15	10.30	11.61
30	26.61	27.42
45	15.66	20.67

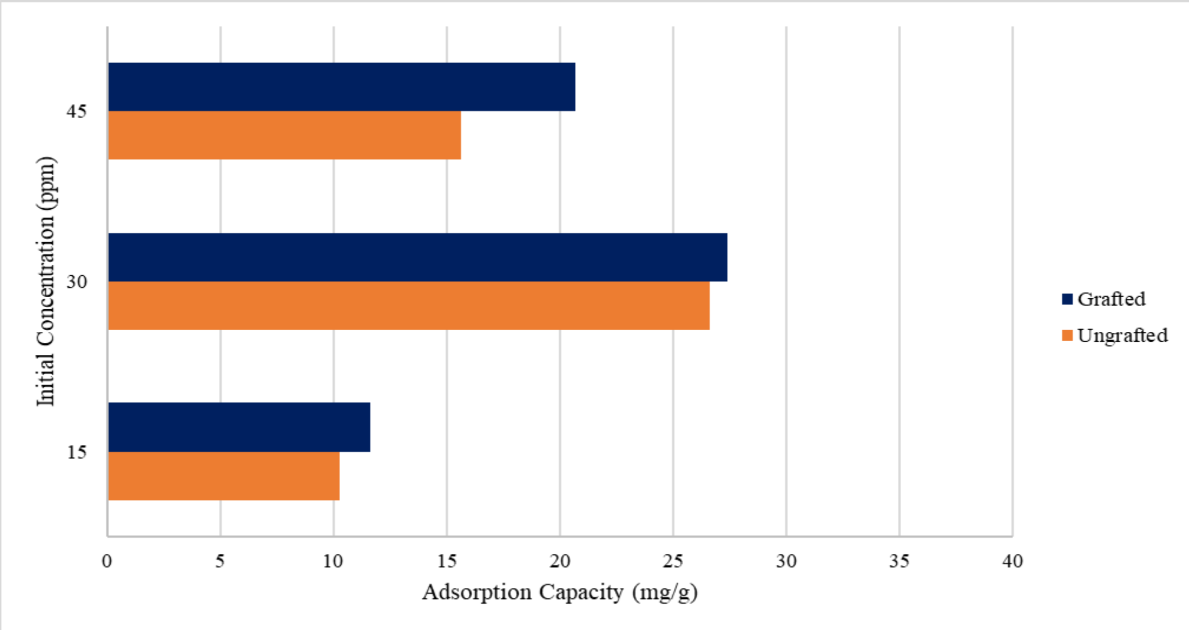


Fig. 1. The effect of treatment on increasing fruit mass for (a) 8 weeks and (b) 12 weeks

4. Conclusions

In conclusion, our investigation reveals that nanocellulose derived from pandan leaves exhibits a commendable adsorption capacity for Cu(II) ion solutions. Notably, we observe a direct correlation between the initial concentration of Cu (II) and the adsorption capacity of the nanocellulose. Within the scope of this study, we pinpoint the optimal Cu(II) concentration for adsorption at 30 ppm, where the nanocellulose demonstrates its highest adsorption capacity, reaching 26.61 ppm.Furthermore, our findings highlight the transformative impact of grafting nanocellulose with acrylamide monomers. This modification substantially enhances the adsorption capacity, with an impressive peak capacity of 27.42 ppm. This result underscores the potential for tailoring nanocellulose-based adsorbents to achieve even greater efficiency in heavy metal ion removal applications.In summary, nanocellulose from pandan leaves not only displays intrinsic adsorption capabilities but also exhibits the adaptability to be further enhanced through chemical modification. These findings contribute to the growing body of knowledge in sustainable adsorption technologies and open doors to innovative approaches to addressing environmental challenges posed by heavy metal ion contamination.

Acknowledgement

This research was funded by Universiti Malaysia Pahang, Grant number PDU223204.

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