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Lithium Chloride-Mediated Enhancement of Dye Removal Capacity in Borneo derived Nanocellulose-based Nanocomposite Membranes (NCMs)

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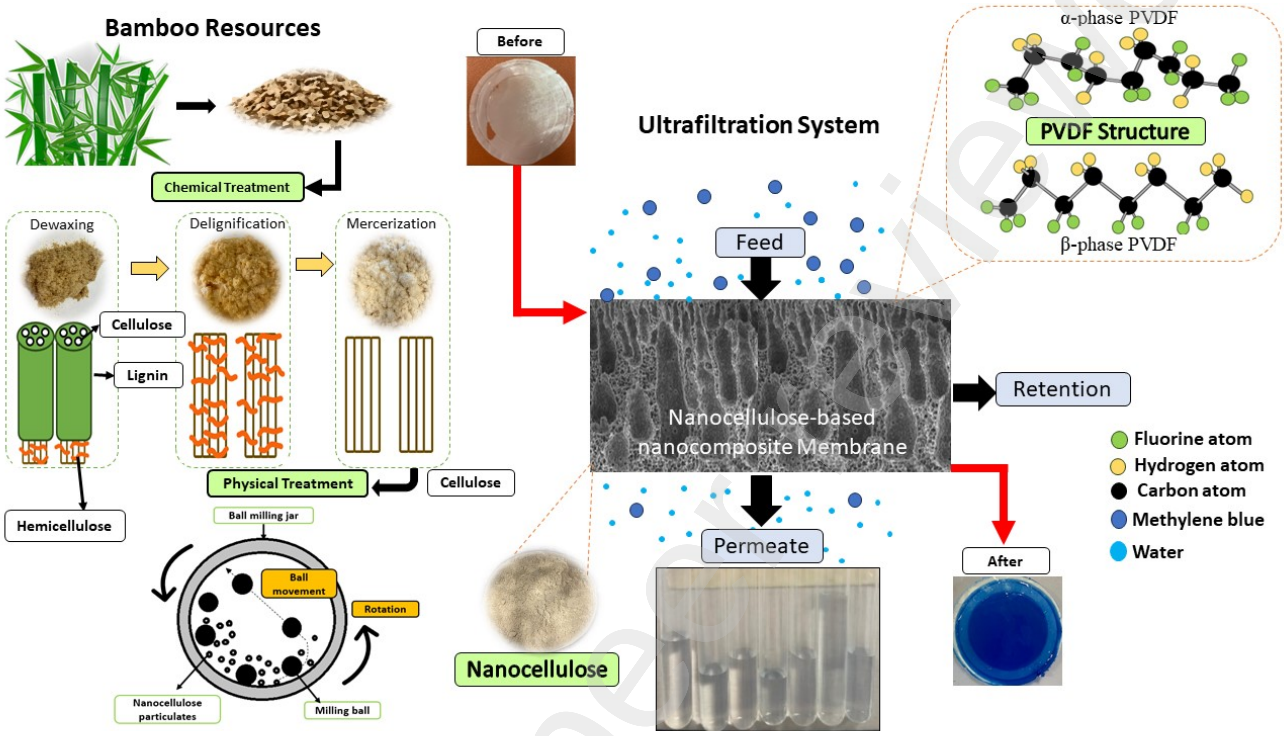
ABSTRACT

Demand for sustainable materials for membrane fabrication is rapidly increasing, particularly in Sarawak coastal areas. nanocellulose emerges as a promising alternative for membrane development due to its availability, intrinsic biodegradability, and high strength. However, the hydrophobicity of nanocellulose limits its applicability in water treatment operations. hence necessitating the need for innovative solutions. Herein, we examine the potential of bamboo-derived nanocellulose to enhance nanocomposite membrane-based water treatment systems by incorporating lithium chloride as a pore-forming additive. Nanocomposite membranes (NCMs) were synthesised using a LiCl-doped solution of nanocellulose and polyvinylidene fluoride (PVDF) through phase inversion and controlled solidification methods. The results show that nanocellulose incorporation induces structural alterations in NCMs, with reduced size in cellulose microfibrils. The crystallinity of nanocellulose was enhanced through interactions between PVDF and nanocellulose. The integration of nanocellulose along with lithium chloride was observed to have a significant impact on water permeation flux, attaining 104 L/m2h due to improved hydrophobicity and reduced fouling. In addition, the developed NCMs recorded 93% methylene blue (MB) removal within 10 minutes. Revealing high potential of NCMs as an alternative and sustainable material for the development of nanocomposite membranes to mitigate contemporary challenges of water scarcity.

Keywords: Bamboo, nanocellulose, Lithium chloride, LiCl, Extraction, water treatment

Graphical Abstract



1. Introduction

The World Water Council projection for 2030 warns of a remarkable issue, which is reporting an anticipated 3.9 billion individuals residing in regions that could be associated with water scarcity issues [1]. This challenge extends beyond relying solely on technology owing to an intricately interrelated sustainability factors, thus necessitating a comprehensive global response [2]. In Sarawak, the water scarcity issues, especially in coastal rural areas, demand a subtle approach [3], [4]. Because the region is endowed with vast availability of natural water sources, which are currently being underutilized by the local communities [5]. Realizing this issue, the implementation of advanced water treatment technology should be considered of paramount importance by ensuring not only a clean water supply but also for environmental preservation [6]. Compared to chemical coagulation treatment, membrane filtration systems could produce clean water for domestic consumption and are preferable for diverse filtration applications [7]. This is since membranes play an imperative role in selectively permeating specific components. The advancement of membrane application in water treatment signifies a commitment to sustainable water technologies which align with green engineering principles and mitigate global demand for clean water [8]. A study reported that membrane-based desalination has emerged as an alternative solution to address water scarcity issues in Sarawak remote areas [9]. The utilization of membrane-based technology could effectively remove impurities and produce high-quality water, which aligns with Sarawak's increasing demand for water resources [10]. Nanocellulose-incorporated membranes offer a distinctive edge in desalination applications owing to their inherent hydrophilic nature, biodegradability, and resistance to fouling, which present advantages in comparison to conventional petroleum-based polymeric substances [11], [12].Since membranes employed in water treatment applications conventionally derive from non-cellulose organic polymers, namely polypropylene, polysulfide, polyvinylidene fluoride, and polyether sulfone [13]. To improve the physicochemical properties of nanocellulose membranes, recent advancements have leveraged various nanomaterials [14]. Nanocellulose could be derived from renewable and sustainable sources which offer a hydrophilic, non-toxic, and environmentally benign alternative [15]. Bamboo nanocellulose, a low-cost lignocellulosic species exhibits excellent wicking capabilities and has antimicrobial properties even after several repeated washing cycles which makes it a potential candidate for sustainable material development [16]. It exhibits high strength characteristics and has a shorter growth cycle. The preference for nanocellulose over micro-sized materials in desalination, adsorption, and pollutant removal is attributed to their unique characteristics which are high surface areas, nano dimension, robust strength, and environmentally friendly [17]. This development could meet the growing demand for renewable materials as well as ensure highly efficient treatment of waste streams while minimizing the occurrence of secondary pollution [6]. Despite this advancement, it was reported that the production of nanocellulose membranes depends on suitable solvent systems for nanocellulose dissolution and regeneration [18]. This indicates the ongoing challenge of solvent selection and highlights the importance of further study to refine nanocellulose membrane manufacturing processes for an effective implementation in desalination systems. According to the literature, the application of an ionic liquid that is characterized by a composition of solely ions with a melting point being less than 100^{o}C [19]–[21]. However, the performance of lab-made nanocellulose-incorporated membranes is found to be less effective in comparison to lab-made-petroleum based polymeric membranes [22]. Hence, addressing this research gap requires new investigation to ensure the efficacy of nanocellulose-incorporated