UNIVERSITI TEKNOLOGI MARA

SURFACE FUNCTIONALIZATION OF POLYMER MEMBRANE IN ENHANCING BIOCATALYTIC REMOVAL OF WATER MICROPOLLUTANTS

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ABSTRACT

Membrane technology plays a crucial role in removing micropollutants such as methylene blue (MB) and Bisphenol-A (BPA). However, secondary waste will be generated as the polymer membrane could not degrade MB and BPA. It can only be degraded to its non-phenolic compound with the help of an enzyme. A polymer membrane needs to be slightly hydrophilic to guarantee the stability of an enzyme. Polymer membranes are well known as hydrophobic membranes, demonstrating high trans-membrane pressure and fouling, limiting their applicability. Thus, polymer membranes demand additional efforts to improve their performance. Metal-chelated biocatalytic membranes (MCBM) were synthesized in this study using a commercial polymer membrane, polyvinylidene fluoride (PVDF), and procedural coatings to overcome these issues. Chemicals that have hydrophilic characteristics, such as dopamine (DA) and polyethyleneimine (PEI), were used. DA also helps in providing more absorption sites for metal ion chelation. Iminodiacetic acid (IDA) was coated on the modified membrane as a metal chelator for metal ion (Zn^{2+}, Mn^{2+}, Ni^{2+}, and Cu^{2+}). Fourier-transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy with Energy Dispersive X-ray (SEM-EDX) results found different peaks and surface morphologies on the metal-chelated membranes (MCMs), proving the successful modifications. Laccase (EC 1.10.3.2) was immobilized on the MCMs to form MCBM to improve its stability and aid the degradation of MB and BPA. Due to the great affinity of copper in Laccase, the Cu-chelated biocatalytic membrane (2h) has the highest enzyme loading (88%). The enzyme kinetics were also studied, where the K_m for immobilized Laccase is lower (range of 0.22 mM–0.79 mM) than the free Laccase (0.83 mM), showing a better substrate affinity towards the immobilized Laccase. The value of V_{max} for the free Laccase (0.0039 mM/s) is lower than immobilized Laccase. The degradation of MB and BPA by MCBMs are more than 80%. The MCBMs was projected could be used up to 20 and 10 cycles to remove MB and BPA, respectively. The stability of the immobilized Laccase was compared to that of free Laccase in 28 days and the relative activity of immobilized Laccase is doubled compared to free Laccase, proving that immobilization had improved the stability of Laccase.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Freshwater supplies that are clean, safe, and dependable are human rights. It is critical for public health regardless of whether it is utilized for drinking, food production, home usage, or industrial use. The present world water demand is around 4600 km^3 per year, and it is expected to increase by 20% to 30% by 2050, reaching 5500 to 6000 km^3 per year [1]. Water availability diminishes as a result of decreasing sources mainly caused by pollution. According to the United Nations World Water Development Report, 1.8 billion people would live in countries with acute water shortages by 2025, since freshwater is frequently contaminated with micropollutants such as Bisphenol-A (BPA) [1]. BPA removal from water is critical because it has a detrimental impact on abnormalities, altered behaviour, disturbing the circulatory systems of aquatic animals, development, growth, and survival [2–5]. Various water treatment processes, such as coagulation-flocculation (iron and alum), activated carbon adsorption, advanced oxidation processes (permanganate, ozone, and chlorine), membrane filtration, and biological (enzymatic) treatment, have been widely used to overcome the problem over the years. These traditional therapies must be modified since they have substantial downsides such as high operational cost, large sludge volume and low efficiency.

Previous studies found BPA in 93% of Langat River samples, with levels ranging from 1.3 to 215 ng/L in surface water and 3.5 to 59.8 ng L^{-1} in tap water. Similarly, other study reported BPA in all collected samples in Langat River with a registered maximum concentration of 8.24 ng/L. BPA level in Salut River, Sabah was reported to be 7.4–10.8 ng/L [6]. In addition, BPA levels in drinking water had previously been found to be as high as 0.42 g/L [7]. The current tolerated daily intake for BPA has been assessed by the European Food Safety Agency to be 50 g/kg (body weight)/day [8].

One previous study found out that membrane filtration by multifunctional polymer membrane, NF90, NF270 and NF103 removed BPA by 97.04%, 84.27% and 78.21, respectively [9]. The membrane filtration technique is popular because it uses