UNIVERSITI TEKNOLOGI MARA

INTEGRATION OF POLYVINYL ALCOHOL (PVA) THIN FILM WITH ZINC-CYCLEN CASTED OVER POLYETHERSULFONE (PES) SUPPORT MEMBRANE FOR CARBON DIOXIDE SEPARATION PERFORMANCE

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ABSTRACT

Carbon dioxide (CO_2) release from fossil fuel industries into the atmosphere has contribute to the global warming effect and climate change. Therefore, the development of CO_2 separation process technologies such as membrane technology had been introduced to capture CO_2 from the flue gas. In a previous study, membrane technology had come together with the biological approach using Carbonic anhydrase (CA) enzyme to enhance this carbon capture technology. However, because of the pH and temperature changes, the long-term stability of the CA enzyme has reduced to 6 months lifetime and causes the enzyme activity to be a permanently loss. Thus, this present study chose a combination of membrane separation technique with biological approach with the used of mimic enzyme-Zn-cyclen for CO_2 separation and focused on polyethersulfone (PES) membrane as support materials. Zn-cyclen as mimic enzyme was used to resemble the active site of CA enzymes and mimic the bio-catalytic process of CA. PVA thin film act as a receive layer so that the membrane could operate in high water swollen in order to achieve the best separation performance. This study was conducted to develop and characterize the polyvinyl alcohol (PVA) thin film integrated with Zn-cyclen and cast over PES membrane for CO_2 separation performance. The catalytic activity and stability of Zn-cyclen on the different pH (6, 7, 8, 9, 10, 11) and temperature (30 ºC, 40 ºC, 50 ºC, 60 ºC, 70 ºC, 80 ºC, 90 ºC) were determined. The optimum pH for Zn-cyclen to perform higher catalytic stability was at pH 9, while, the optimum temperature for higher Zn-cyclen activity was at 70 ºC. However, as the Zn-cyclen integrated onto the PES membrane, the Zn-cyclen pH and temperature stability had shifted at higher range which were at pH 10 and temperature 80 ºC due to indirect contact of pH and temperature on the Zn-cyclen. The pH and temperature stability of CA were at pH 7.5 and temperature 37 ºC. From the kinetics study, the kinetics parameters of K_m, V_{max}, and K_{cat} value for Zn-cyclen was 1.5491 mmol/L, 2.088 µmol/min, and 0.348 min^{-1} respectively. Meanwhile, the kinetics parameters of K_m, V_{max}, and K_{cat} value for CA enzyme was 1.594 mmol/L, 1.307 µmol/min, and 0.330 min^{-1} respectively. In comparison with CA, the Zn-cyclen had possess higher pH and temperature stability, and better value of enzyme kinetics parameters. Therefore, Zn-cyclen can be used to replace CA for better achievement in CO_2 hydration reaction and separation performance. The integrated PES+PVA+Zn-cyclen membrane was developed through dip-coating method. The integrated PVA+Zn-cyclen thin film had improved the swelling behaviour and hydrophilicity of the PES membrane. Higher swelling percentage contributed into faster CO_2 hydration rate. In the separation reaction of CO_2 using integrated Zn-cyclen based membrane, the time taken for a complete carbonation reaction was 9.75 min, which was longer compared to free Zn-cyclen with 2.58 min at enzyme optimum temperature and flowrate of 80 ˚C, and 200 mL/min respectively. For CO_2 separation experiment, CO_2 feed flowrate was conducted by manipulating at (200, 500, 800, 1000 mL/min) and temperature at (30 ºC - 90 ºC). This finding showed that the integrated PES+PVA+Zn-cyclen membrane had better CO_2 separation performance because the longer the carbonation reaction time, the higher the amount of CO_2 adsorbed onto the membrane. In conclusion, Zn-cyclen is suitable to replace CA enzyme because it gives a better value of kinetics parameter and catalytic stability, and the use of integrated Zn-cyclen membrane is recommend due to better performances of CO_2 separation.

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TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Research Background

The deterioration of the world's environment due to global warming desires to draw the eye of the world. This global warming issue is happening due to the emission of carbon dioxide (CO_2) into the atmosphere. Figure 1.1 shows that the CO_2 concentration in atmosphere is rapidly increasing over the year which represent the increase of CO_2 emissions. The International Panel on Climate Change (IPCC) also predicted that by 2100, CO_2 levels in the atmosphere could reach 570 parts per million, sea levels could rise by 3.8 metres, and global mean temperatures would rise by about 21 ^{o}C, all of which would have a significant impact on the environment [1].

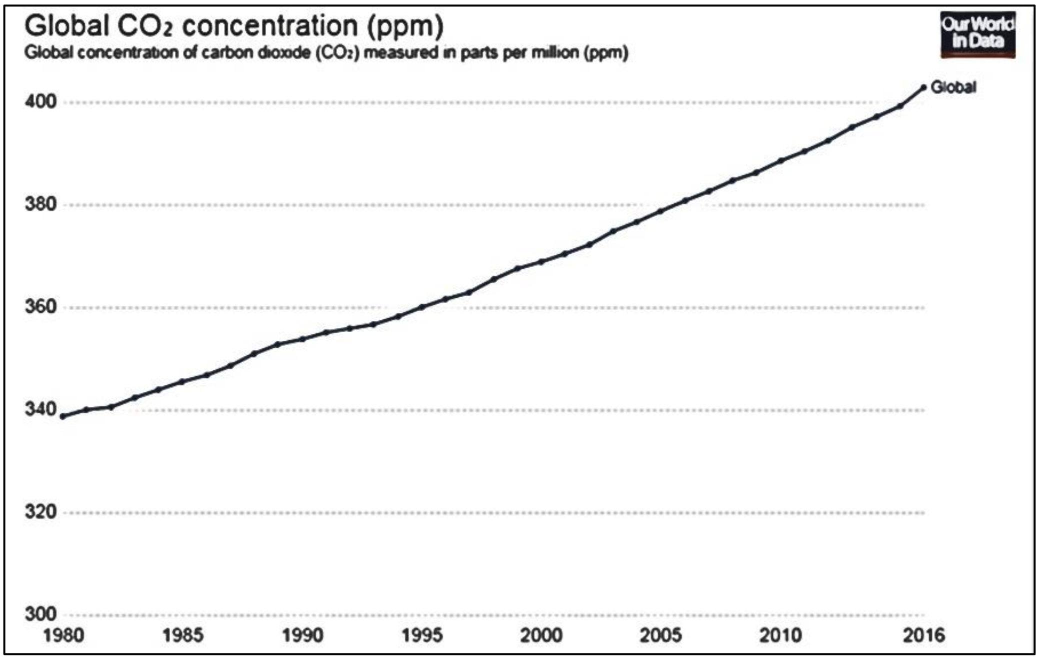

Figure 1.1 Global CO_2 Concentration in Atmosphere (Sources from National Oceanic and Atmospheric Administration (NOAA))

The IPCC, on the other hand, estimates that with carbon capture and storage technologies, CO_2 emissions into the atmosphere might be reduced by 80-90 % [2]. As a result, Carbon Capture and Storage (CCS) technology were explored as the ultimate solution to the global warming problem.