# DEVELOPMENT OF THERMO-RESPONSIVE IONIC LIQUID AS DRAW SOLUTION AND ITS PERFORMANCE IN FORWARD OSMOSIS

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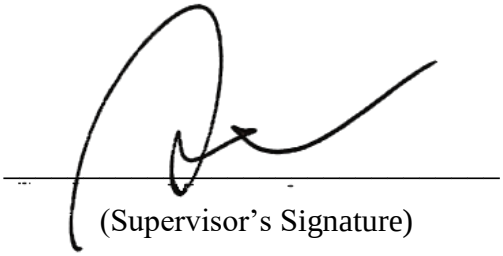

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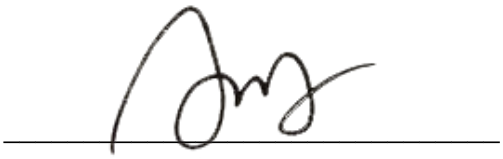

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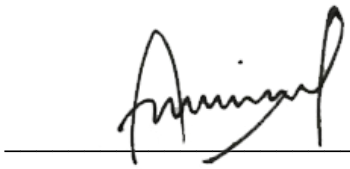

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# ABSTRAK

Penyahgaraman berasaskan teknologi membran adalah salah satu pendekatan yang telah banyak diterokai untuk menangani cabaran bagi meningkatkan keperluan air yang bersih. Walaupun proses osmosis berbalik (RO) telah digunakan dahulu, namun teknologi penyahgaraman membran osmosis kehadapan (FO) menjanjikan proses cekap tenaga yang berpotensi serta berdaya maju. Tetapi, masalah utama dalam proses FO adalah kekurangan larutan penarik yang bersesuaian untuk dijana semula. Satu kelebihan yang berbeza menggunakan cecair ionik tindakbalas haba (TRILs) adalah keberkesanan dalam menjana semula larutan penarik melalui rangsangan haba. Dalam kajian ini, 10 kation dan dua anion telah dipilih daripada pangkalan data COSMO-RS dan menerusi kaedah ramalan faktor van't Hoff. 11 jenis ILs telah berjaya disintesis melalui kaedah metatesis dan peneutralan. ILs yang telah disintesis akan dicampur dengan air dan telah disejukkan kepada 0 °C dan kemudian dipanaskan secara beransur-ansur kepada 70 °C untuk menyaring suhu kritikal. Apabila larutan didapati telah terpisah di atas suhu kritikal, campuran ini menjalani fasa peralihan jenis LCST dan yang sebaliknya untuk UCST. Mekanisme interaksi antara molekul TRILs dengan air telah dianalisa menggunakan simulasi COSMO-RS dan H NMR bagi ILs yang terpilih. TRILs telah diuji dalam proses osmosis kehadapan sebagai larutan penarik dan mencapai fluks air yang tinggi, 1-butil-3-metilimidazolium tetrafloroborat ([Bmim] [$BF_4$]) (0.71 LMH) dan tetrabutilfosfanium trifloroasetat ([$P_{4444}$][TFA]) (0.44 LMH ) berbanding NaCl (0.33 LMH). [Bmim] [$BF_4$] dipilih sebagai larutan penarik dimana Aquaporin membran dengan mod PRO telah digunakan untuk menguji kesan parameter dan keadaan optimum untuk proses FO. Eksperimen 2-tahap faktor telah digunakan untuk mengkaji kesan parameter seperti kadar aliran larutan bekalan dan larutan penarik, kepekatan larutan penarik, suhu dan jenis aliran dengan kepekatan larutan bekalan menggunakan air laut tiruan (0.6 M NaCl). Kepekatan larutan penarik dan interaksi antara larutan penarik dan kadar aliran larutan bekalan adalah faktor yang paling penting untuk mencapai fluks air yang tinggi 5.1 LMH. Selain itu, kadar aliran larutan penarik dan interaksi kadar aliran larutan penarik dan bekalan memberi kesan negatif yang ketara untuk mendapatkan fluks garam berbalik rendah 1.3 gMH. Fungsi kebolehinginan (DF) telah digunakan, untuk mendapatkan fluks air tertinggi 5.04 LMH dan garam berbalik terendah 1.71 gMH dengan kadar kebolehinginan 0.95. Keadaan optimum untuk prestasi FO adalah kadar aliran larutan penarik dan bekalan 300 ml/min dengan kepakatan larutan penarik 3.0 M pada suhu 25 °C dan aliran sehala. Dalam kajian ini, fasa pemisahan cecair-cecair melalui ransangan haba boleh dicapai. Jumlah [Bmim][$BF_4$] yang dikesan dalam fasa air menggunakan spektroskopi UV-Vis dan air ditulenkan menggunakan kaedah penurasan-nano (NF). Tumbuhan kangkung telah dipilih untuk mengkaji kesan kehadiran ILs di dalam air pada pertumbuhan pokok dan jumlah [Bmim][$BF_4$] yang dikesan boleh diterima pada kadar kepekatan dibawah 500 ppm. Berdasarkan kepada dapatan kajian ini, dapat disimpulkan bahawa, [Bmim][BF4] adalah alternatif yang sesuai untuk digunakan sebagai larutan penarik dalam proses FO.

## ABSTRACT

Desalination based on membrane technology is one of the approaches which has been extensively explored to tackle the challenge in increasing demand of clean water. Although reverse osmosis (RO) process has been applied for a long time, the promising forward osmosis (FO) membrane desalination is viewed as a potentially viable energy efficient performance technology. But, the main problem in FO process is the lack of suitable draw solutes that can be efficiently regenerated. A distinct advantage using thermo-responsive ionic liquids (TRILs) is the efficient in regenerating the draw solute via thermally stimulation. In this study, 10 cations and two anions were selected from COSMO-RS database and van't Hoff factor prediction. 11 type of ILs was successfully synthesized via metathesis and neutralization method. The synthesized ILs were mixed with water and were cooled to 0 °C and then gradually heated to 70 °C to screen critical temperature. When a solution was found to be phase-separated above its critical temperature, this mixture underwent the lower critical solution temperature (LCST) type phase transition and which contrary with upper critical solution temperature (UCST) behavioral. The interactions mechanism of TRILs with water were examined using COSMO-RS simulation and H NMR for selected ILs. The TRILs were tested in FO process as draw solution and achieved high water flux 1-butyl-3-methylimidazolium tetrafluoroborate ([Bmim][$BF_4$]) (0.71 LMH) and tetrabutylphosphonium trifluoroacetate ([$P_{4444}$][TFA]) (0.44 LMH) compared to NaCl (0.33 LMH). The [Bmim][$BF_4$] was selected as draw solution and aquaporin membrane with pressure retarded osmosis (PRO) mode was used to evaluate the effect of parameter and optimal condition for FO process. The 2-Level factorial experiment design was used to study the effect of parameters such as feed and draw flowrate, draw solution concentration, temperature and type of flow with feed concentration using artificial seawater (0.6 M NaCl). The draw solution concentration and the interactions between draw and feed flowrate was the most significant factors to achieve high water flux 5.1 LMH. Besides that, the draw flowrate and the interaction of draw flowrate and feed flowrate give high significant negative effect which is good to obtain low reverse salt 1.3 gMH. The desirability function (DF) was used, in order to obtain the highest water flux 5.04 LMH and the lowest reverse salt flux 1.71 gMH with 0.95 desirability. The optimal condition for FO performance is 300 ml/min feed and draw flowrate with 3.0 M draw solution at 25 °C and co-current flow. In this research, the phase separation via thermally stimulated liquid-liquid phase separation was achievable. The traceable amount of [Bmim][$BF_4$] in water rich phase was detected using UV-Vis spectroscopy and purified using nanofiltration (NF). The water spinach was selected to study the effect of traceable amount of ILs in water on plant growth and acceptable traceable amount of [Bmim][$BF_4$] is below 500 ppm. Based on the findings, it can be concluded that, [Bmim][$BF_4$] is alternatively suitable to be use as draw solution in FO process.

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