DEVELOPMENT OF NOVEL HIGH PERFORMANCE ASYMMETRIC ULTRA LOW PRESSURE NANOFILTRATION (AULP-NF) MEMBRANE FOR CHARGED SOLUTES REMOVAL

ABDUL RAHMAN BIN HASSAN

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Allah the Almighty says in the ***Holy Quran, Chapter 55: versus 19 – 21:***

He has lat free
The two seas
Meeting together:

Between them is a barrier
Which they do not transgress:

Then which of the favors
Of your lord will ye deny?

And in Chapter 25: versus 53:

It is He Who has
Let free the two bodies
Of flowing water
One palatable and sweet
And the other salt
And bitter; yet has He
Made a barrier between them
A partition that is not
To be passed

(Translation by Abdullah Yusof Ali)

To my beloved mother (Maisamah Binti Ahmad) and my late father (Hassan Bin Abdullah), thanks for all your love and support, this thesis is the symbol of your success in educating me. Especially to my dearly loved wife (Maizatul Arnie Binti Zakaria) you are my inspiration, your encouragement and endless support are truly appreciated. To my lovely daughters (Nur Salsabila, Nur Najahah & Nur Afiqah), may this thesis be an inspiration, guidance and motivation for you in the future. To my understanding father/mother in law, a million thanks for your infinite helpfulness and advices.

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Chairperson : **Nora'aini Binti Ali, Ph.D.**

Member : **Associate Professor Ir. Ahmad Bin Jusoh, M.Sc.**
Asmadi Bin Ali@Mahmud, M. Sc.

Faculty : **Science and Technology**

Nanofiltration is the most recently developed pressure-driven membrane process for the liquid-phase separations. As continuous developed of new membranes materials, special features likes nanometer ranges of pore radius, high retention of charged particles, inherent charges and lower operating pressure, its applications are rapidly increased especially in the field of process water, drinking water or wastewater treatment.

In this study, a multi-component dope solutions consisting of polyethersulfone, 1-methyl-2-pyrrolidone and water has been formulated from 11 wt% to 19 wt% of polymer concentration. Based on a dry/wet phase inversion technique, Asymmetric Ultra Low Pressure-Nanofiltration (AULP-NF) membranes were prepared by using an electrically controlled casting machine. At low operating pressures from 100 kPa to 500 kPa, membranes performances in terms of pure water permeability, salt water permeation and salts rejection membrane separation performances have been evaluated by using of multivalences salts. For the membranes separation improvement, the effect of rheological factor that is shear rates between 93.33 s^{-1} to

466.67 s^{-1} has been deduced during the casting process. Meanwhile, the addition of polymeric additive (PVP) in the ranges of 1 wt% to 9 wt% was found to enhance the separation performances. In addition, the optimum conditions of polymer concentration, shear rates and additive concentration were identified. From this study, the best polymer concentration was found to be of about 13.56 wt% and high water flux obtained ranging from 1.01 x $10^{-4}m^3/m^2.s$ to 3.81 x 10^{-4} $m^3/m^2.s$ are so surprisingly. Besides, experimental data demonstrated of an excellent salt water permeation and rejection data of about 1232 $L/m^2.h$ and 99.94%, respectively. Meanwhile, at the optimum shear rates (155.55 s^{-1}) and additive concentration (3 wt%), the experimental results revealed that the ions separation performances have been improved. Thus, this was indicated that the novel high performances AULP-NF membranes was developed.

The newly fabricated AULP-NF membranes produced have an integral skinned membranes, thinner skin layer and narrow pore sizes which ranges from 0.37 nm to 0.44 nm pore radius. AULP-NF was found to be comparable to the available commercial membranes that are in ranges of 0.39 nm to 1.59 nm. In addition, further consideration on ions separation mechanism found that the ions transport through AULP-NF membranes is dominated by a convection factor. In combination with the separation properties, AULP-NF membranes provides an excellent technical potentials towards membranes development and a great platform for the production of locally novel high performances ultra low pressure membranes for various applications in the future.

Abstrak tesis yang dikemukan kepada Senat Universiti Malaysia Terengganu sebagai memenuhi keperluan untuk ijazah Sarjana Sains.

PEMBANGUNAN TERBARU MEMBRAN ASIMETRIK TEKANAN ULTRA RENDAH- NANOTURASAN (AULP-NF) BERPRESTASI TINGGI BAGI PENYINGKIRAN BAHAN-BAHAN LARUT BERCAS

ABDUL RAHMAN BIN HASSAN

March 2007

Pengerusi : **Nora'aini Binti Ali, Ph.D.**

Ahli : **Associate Professor Ir. Ahmad Bin Jusoh, M. Sc.**
Asmadi Bin Ali@Mahmud, M. Sc.

Fakulti : **Sains dan Teknologi**

Nanoturasan adalah proses membran pacuan tekanan terkini yang dibangunkan bagi pemisahan fasa cecair. Sebagai bahan membran terbaru yang dibangunkan berterusan, ciri-ciri istimewa seperti jejari liang berjulat nanometer, penyingkiran tinggi partikel-partikel bercas, cas tersedia and tekanan operasi yang rendah, aplikasinya berkembang pesat terutama dalam bidang proses air, air minuman dan rawatan air sisa.

Dalam kajian ini, larutan polimer berbilang komponen yang terdiri daripada polietersulfona, 1-metil-2-pirolidona dan air telah dirumuskan daripada kepekatan polimer sebanyak 11 % berat hingga 19 % berat. Barpandukan teknik fasa balikan kering/basah, membran Asimetrik Tekanan Ultra Rendah-Nanoturasan (AULP-NF) telah disediakan menggunakan mesin penuangan kawalan elektrik. Pada tekanan operasi rendah daripada 100 kPa hingga 500 kPa, prestasi membran dari segi penelapan air tulen, kebolehtelapan garam dan penolakan garam telah dinilaikan melalui pengunaan garam-garam berbilang valensi. Bagi meningkatkan penyingkiran membran, kesan faktor reologikal iaitu kadar ricihan di antara 93.33 s^{-1} hingga

466.67 s^{-1} telah dikenakan semasa proses penuangan. Sementara itu, penambahan bahan tambah polimerik (PVP) dalam julat 1 % berat hingga 9 % berat telah berupaya meningkatkan prestasi penyingkiran. Di samping itu, keadaan optimum bagi kepekatan polimer, kadar ricih dan kepekatan bahan tambah telah dikenalpasti. Daripada kajian ini, kepekatan polimer terbaik telah dijumpai pada 13.46 % berat dan fluks air tinggi yang diperolehi dari julat 1.01 x $10^{-4}m^3/m^2.s$ to 3.81 x 10^{-4} $m^3/m^2.s$ adalah amat memberansangkan. Selain itu, data eksperimen menunjukkan penelapan dan penolakan garam yang sangat baikl dengan nilai masing-masing kira-kira 1232 $L/m^2.h$ and 99.94%. Sementara itu pula, pada nilai optimum bagi kadar ricih (155.55 s^{-1}) dan kepekatan bahan tambah (3 wt%), keputusan eksperimen telah menunjukkan bahawa prestasi penyingkiran garam telah pun ditingkatkan. Oleh yang demikian, ini menunjukkan bahawa membran AULP-NF berprestasi tinggi terbaru telah pun berjaya dibangunkan.

Membran AULP-NF terbaru yang dihasilkan itu menghasilkan membran berlapisan sempurna, lapisan kulit nipis dan saiz liang yang kecil iaitu dari julat 0.37 nm hingga 0.44 nm jejari liang. AULP-NF juga didapati setanding dengan membran komersial yang sedia ada deangan jejari liang dalam julat 39 nm hingga 1.59 nm Disamping itu, kajian terhadap mekanisma pemisahan ion-ion mendapati bahawa pengangkutan ion-ion melalui membran AULP-NF di dominasi oleh faktor perolakan. Melalui kombinasi dengan sifat-sifat pemisahan, membran AULP-NF menyediakan suatu potensi teknikal yang baik ke arah pembangunan membran dan platform terbaik untuk penghasilan membran tekanan ultra rendah berprestasi tinggi tempatan bagi pelbagai kegunaan pada masa depan.