DEVELOPMENT OF POLYETHER BLOCK AMIDE (PEBAX) NANOCOMPOSITE MEMBRANES USING NANOADSORBENT FROM AGRICULTURAL WASTES AS FILLERS FOR GAS SEPARATION

ALIA AQILAH BINTI GHAZALI

MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science in Chemical Engineering.

_____

(Supervisor's Signature)

Full Name : ASSOC. PROF. TS. DR. SUNARTI BINTI ABD RAHMAN

Position : SENIOR LECTURER

Date :

_____

(Co-supervisor's Signature)

Full Name : DR. ROZAIMI BIN ABU SAMAH

Position : SENIOR LECTURER

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

_____

(Student's Signature)

Full Name : ALIA AQILAH BINTI GHAZALI

ID Number : MKC 18016

Date :

DEVELOPMENT OF POLYETHER BLOCK AMIDE (PEBAX) NANOCOMPOSITE MEMBRANES USING NANOADSORBENT FROM AGRICULTURAL WASTES AS FILLERS FOR GAS SEPARATION

ALIA AQILAH BINTI GHAZALI

Thesis submitted in fulfilment of the requirements
for the award of the degree of
Master of Science

College of Engineering

UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2020

ACKNOWLEDGEMENTS

First and foremost, I would like to express my greatest gratitude to my main supervisor, Associate Professor Ts. Dr. Sunarti binti Abd Rahman for giving me the opportunity to do the Master study. I wish to thank her for her continuous guidance, suggestions, sharing, encouragement and patience in my experiments, articles and thesis for the last one and half years. I would also like to thank my co-supervisor, Dr Rozaimi bin Abu Samah for his excellent guidance and advice.

I am also indebted to the Malaysian Ministry of Higher Education and Universiti Malaysia Pahang for financially supporting my study. Additionally, I would also like to thank the academic, research and support staffs from Faculty of Chemical & Process Engineering Technology for lending me their helping hands throughout my study.

I would like to express my appreciation to all my lab mates and friends. Unfortunately, I could not list out all the names but you know who you are.

I wish to thank my dear husband, Mohamad Wafiq bin Taufik for his unshakeable trust and understanding. Finally, I would also take this opportunity to express my heartfelt gratitude to my parents, Ghazali bin Ismail and Nur Sarina Wong binti Abdullah as well as other family members for their unconditional love and support throughout my life. This accomplishment would not have been possible without them. Thank you.

ABSTRAK

Sepanjang dekad yang lalu, proses membran untuk pemisahan gas semakin mendapat penerimaan dalam industri dan pasaran dan mereka bersaing dengan operasi sedia ada seperti tekanan ayunan penyerapan dan penyulingan kriogenik. Baru-baru ini, terdapat usaha yang intensif dalam pembangunan bahan membran yang lebih baik dan lebih kuat yang dipanggil membran nanokomposit yang melibatkan penambahan nanoadsorben seperti zeolit dan silika dalam polimer matriks. Minat yang mendalam telah diberikan kepada nanoadsorben yang disediakan daripada sisa pertanian kerana jumlahnya yang amat tinggi, ciri-ciri yang menjanjikan, dan prestasi penjerapan yang munasabah berbanding dengan nanoadsorben konvensional. Oleh itu, tujuan kajian ini adalah untuk membina, mencirikan, menilai dan mengoptimumkan membran nanokomposit yang terdiri daripada polyether block amide (Pebax) bergabung dengan dua jenis nanoadsorben yang berlainan (kulit nanas dan pelepah kelapa sawit) disalut atas polyvinylidene fluoride (PVDF) komersil bagi menyokong membran. 2^4 Full Factorial Design (FFD) telah digunakan dalam kajian ini untuk meminimumkan faktor-faktor yang mempengaruhi semasa penyediaan membran nanokomposit. Sebanyak empat faktor telah dipilih untuk dijalankan secara serentak dan respons adalah berdasarkan kebolehtelapan gas (CO_2, CH_4, N_2) dan selektiviti (CO_2/CH_4, CO_2/N_2). Dalam penyediaan membran, faktor-faktor yang terlibat adalah kepekatan Pebax (3 dan 6 wt%), jenis nanoadsorben (kulit nanas dan OPF), kepekatan nanoadsorben (0.5 dan 5 wt% berdasarkan berat Pebax) dan masa sonikasi (15 dan 30 minit). Dua faktor yang paling berpengaruh terhadap kecekapan pemisahan gas akan dijalankan kajian lanjut untuk pengoptimuman menggunakan Central Composite Design (CCD). Molekul permukaan membran nanokomposit yang baru disintesis dianalisis dengan menggunakan Field Emission Scanning Electron Microscope (FESEM), kewujudan kumpulan fungsi menggunakan Fourier Transform Infrared Spectroscopy (FTIR), pengukuran kuasa dan pengimejan menggunakan kaedah Atomic Force Microscopy (AFM), dan kristaliti menggunakan instrumen X-Ray Diffraction (XRD). Penemuan dari pemeriksaan tersebut mencadangkan bahawa faktor yang paling mempengaruhi kebolehtelapan dan selektiviti adalah kepekatan Pebax dan jenis nanoadsorben. Keadaan terbaik diketahui memaksimumkan kebolehtelapan dan selektiviti. Keadaan yang dikenalpasti adalah kepekatan Pebax pada 5.5 wt% menggunakan 4.5 wt% nano nanas karbon aktif dan 15 minit sonikasi yang memberikan ketelapan CO_2, selektiviti CO_2/CH_4 dan selektiviti CO_2/N_2 1537.08 Barrer, 40.21 dan 41.39. Hasil kajian menunjukkan bahawa FFD sesuai untuk meminimumkan faktor-faktor dengan mempertimbangkan interaksi antara faktor-faktor yang terlibat dalam sintesis filem membran untuk prestasi pemisahan gas yang sangat baik. Selain itu, penggabungan nanoadsorben kos rendah ini dilaporkan mengubah struktur membran polimer dan sifat-sifat kimia yang membawa kepada penambahbaikan prestasi membran yang secara signifikan berada hampir dan melepasi garisan limit Robeson, serta menunjukkan nilai yang tinggi buat kedua-dua kebolehtelapan gas dan selektiviti.

ABSTRACT

Over the past decade, membrane processes for gas separation are gaining a larger acceptance in the industry and the markets are competing with consolidated operations such as pressure swing absorption and cryogenic distillation. There have been intensive efforts in the development of better and more robust membrane material called nanocomposite membranes which involved the incorporation of nanoadsorbents such as zeolite and silica in the polymer matrix. Recently, interest has been given to nanoadsorbents derived from agricultural wastes due to their abundance, promising features, and reasonable adsorption performances compared to the conventional nanoadsorbents. Therefore, the purpose of this study is to develop, characterise, evaluate and optimise the nanocomposite membranes comprised of the coated polyether block amide (Pebax) filled with two different types of nanoadsorbent (pineapple peel and oil palm frond) on the commercial polyvinylidene fluoride (PVDF) support membrane. A 2^4 full factorial design (FFD) was utilized in this study to minimize the influenced factors during nanocomposite membrane preparation. A total of four factors were chose to run simultaneously and the responses were based on permeability (CO_2, CH_4, N_2) and ideal selectivity (CO_2/CH_4, CO_2/N_2). For the preparation of flat sheet membrane, the factors include Pebax concentration (3 and 6 wt%), types of nanoadsorbent (pineapple peel and OPF), nanoadsorbent concentration (0.5 and 5 wt% based on Pebax weight) and sonication time (15 and 30 min). Two most influenced factors towards the final separation efficiency were further study for optimisation using central composite design (CCD). The surface morphologies of the newly synthesized nanocomposite membranes were analysed using Field Emission Scanning Electron Microscope (FESEM), functional groups using Fourier Transform Infrared Spectroscopy (FTIR), force measurement and imaging using Atomic force microscopy (AFM), and crystallinity using X-Ray Diffraction instrument (XRD). The findings from the screening suggested that the most influential factors that affect the permeability and selectivity are Pebax concentration and types of nanoadsorbent. The best condition was known to maximize the permeability and selectivity. The identified conditions were Pebax concentration at 5.5 wt% using 4.5 wt% nano-pineapple peel activated carbon and sonication time of 15 min which gave CO_2 permeability, CO_2/CH_4 selectivity and CO_2/N_2 selectivity of 1537.08 Barrer, 40.21 and 41.39, respectively. The outcome of this study indicates that FFD was suitable to minimize and eliminate factors by considering the interaction among the factors involves in membrane film synthesis for excellent gas separation performance. Besides, the incorporation of this nanoadsorbents were reported to alter the polymer membrane structure and chemical properties which led to an improvement of the membrane's performance that lie significantly near and above the Robeson upper bound limit, which satisfies both high selectivity as well as high permeability.

TABLE OF CONTENT

REFERENCES

Abd Rahman, S., & Ahmad, A. L. (2013). Optimization studies on TFC membrane for Membrane Gas Absorption (MGA) application. IOP Conf. Series: Materials Science and Engineering, 46, 012002. doi:10.1088/1757-899X/46/1/012002

Abdul Wahab, M. S., & Abdul Rahman, S. (2015). Development of PEBAX Based Membrane for Gas Separation: A Review. International Journal of Membrane Science and Technology, 2(2), 78-84.

Abedini, R., Mousavi, S. M., & Aminzadeh, R. (2011). A novel cellulose acetate (CA) membrane using TiO_2 nanoparticles: Preparation, characterization and permeation study. Desalination, 277(1-3), 40-45. doi:10.1016/j.desal.2011.03.089

Adeleke, O. A., Latiff, A. A. A., Saphira, M. R., Daud, Z., Ismail, N., Ahsan, A., . . . Hijab, M. (2019). Locally Derived Activated Carbon From Domestic, Agricultural and Industrial Wastes for the Treatment of Palm Oil Mill Effluent. In Nanotechnology in Water and Wastewater Treatment (pp. 35-62).

Afshoun, H. R., Chenar, M. P., & Ismail, A. F. (2018). Effect of Coating Method and Feed Pressure and Temperature on CO_2/CH_4 Pebax/PES Composite Membranes. Journal of Gas Technology, 3(1).

Agarry, S. E., & Ogunleye, O. O. (2015). Bioadsorption of 2,6-Dichlorophenol from Aqueous Solution onto Plantain and Pineapple Peels Mixture Used as Adsorbent: Optimization Studies Based on Taguchi Method, Batch Equilibrium, and Kinetic Modelling. Chemistry and Materials Research, 7(3).

Aghaei, Z., Naji, L., Hadadi Asl, V., Khanbabaei, G., & Dezhagah, F. (2018). The influence of fumed silica content and particle size in poly (amide 6-b-ethylene oxide) mixed matrix membranes for gas separation. Separation and Purification Technology, 199, 47-56. doi:10.1016/j.seppur.2018.01.035

Ahmad, J., & Hagg, M.-B. (2013). Preparation and characterization of polyvinyl acetate/zeolite 4A mixed matrix membrane for gas separation. Journal of Membrane Science and Research, 427, 73–84. doi:10.1016/j.memsci.2012.09.036

Ahmad, M. N., Mokhtar, M. N., Baharuddin, A. S., Hock, L. S., Ali, S. R. A., Abd-Aziz, S., . . . Hassan, M. A. (2011). Changes in Physicochemical and Microbial Community During Co-Composting of Oil Palm Frond With Palm Oil Mill Effluent Anaerobic Sludge. Bioresources, 6, 4762–4780.

Ahmadpour, E., Sarfaraz, M. V., Behbahani, R. M., Shamsabadi, A. A., & Aghajani, M. (2016). Fabrication of mixed matrix membranes containing TiO_2 nanoparticles in Pebax 1657 as a copolymer on an ultra-porous PVC support. Journal of Natural Gas Science and Engineering, 35, 33-41. doi:10.1016/j.jngse.2016.08.042

Ahmed, M. B., Hasan Johir, M. A., Zhou, J. L., Ngo, H. H., Nghiem, L. D., Richardson, C., . . . Bryant, M. R. (2019). Activated carbon preparation from biomass feedstock: Clean production and carbon dioxide adsorption. Journal of Cleaner Production, 225, 405-413. doi:10.1016/j.jclepro.2019.03.342

Al Aani, S., Haroutounian, A., Wright, C. J., & Hilal, N. (2018). Thin Film Nanocomposite (TFN) membranes modified with polydopamine coated metals/carbon-nanostructures for desalination applications. Desalination, 427, 60-74. doi:10.1016/j.desal.2017.10.011

Ali, R. M., Hamad, H. A., Hussein, M. M., & Malash, G. F. (2016). Potential of using green adsorbent of heavy metal removal from aqueous solutions: Adsorption kinetics, isotherm, thermodynamic, mechanism and economic analysis. Ecological Engineering, 91, 317-332. doi:10.1016/j.ecoleng.2016.03.015

An, X., Xu, G., Xie, B., & Hu, Y. (2019). Structural tailoring of hierarchical fibrous composite membranes to balance mass transfer and heat transfer for state-of-the-art desalination performance in membrane distillation. Journal of Materials Chemistry A, 7(5), 2376-2384. doi:10.1039/c8ta10850a

Antony, J. (2014). Full Factorial Designs. In Design of Experiments for Engineers and Scientists (pp. 63-85).

Ayodele, B. V., Ghazali, A. A., Mohd Yassin, M. Y., & Abdullah, S. (2019). Optimization of hydrogen production by photocatalytic steam methane reforming over lanthanum modified Titanium (IV) oxide using response surface methodology. International Journal of Hydrogen Energy, 44(37), 20700-20710. doi:10.1016/j.ijhydene.2018.06.185

Azizi, N., Mohammadi, T., & Behbahani, R. M. (2016). Synthesis of a PEBAX-1074/ZnO nanocomposite membrane with improved CO_2 separation performance. Journal of Energy Chemistry, 26(3), 454-465. doi:10.1016/j.jechem.2016.11.018

Azizi, N., Mohammadi, T., & Behbahani, R. M. (2017). Synthesis of a new nanocomposite membrane (PEBAX-1074/PEG-400/TiO_2) in order to separate CO_2 from CH_4. Journal of Natural Gas Science and Engineering, 37, 39-51. doi:10.1016/j.jngse.2016.11.038

Azizi, N., Mohammadi, T., & Mosayebi Behbahani, R. (2017). Comparison of permeability performance of PEBAX-1074/TiO_2, PEBAX-1074/SiO_2 and PEBAX-1074/Al_2O_3 nanocomposite membranes for CO_2/CH_4 separation. Chemical Engineering Research and Design, 117, 177-189. doi:10.1016/j.cherd.2016.10.018

Azizi, S., Azizi, N., & Homayoon, R. (2018). Experimental Study of CO_2 and CH_4 Permeability Values Through Pebax®-1074/Silica Mixed Matrix Membranes. Silicon, 11(4), 2045-2057. doi:10.1007/s12633-018-0021-z

Bastani, D., Esmaeili, N., & Asadollahi, M. (2013). Polymeric mixed matrix membranes containing zeolites as a filler for gas separation applications: A review. Journal of Industrial and Engineering Chemistry, 19(2), 375-393. doi:10.1016/j.jiec.2012.09.019

Bergna, D., Varila, T., Romar, H., & Lassi, U. (2018). Comparison of the Properties of Activated Carbons Produced in One-Stage and Two-Stage Processes. C, 4(3). doi:10.3390/c4030041

Bernardo, P., Drioli, E., & Golemme, G. (2009). Membrane Gas Separation: A Review/State of the Art. Industrial & Engineering Chemistry Research, 48, 4638–4663. doi:10.1021/ie8019032

Bhattacharya, M., & Mandal, M. K. (2018). Synthesis of rice straw extracted nano-silica-composite membrane for CO_2 separation. Journal of Cleaner Production, 186, 241-252. doi:10.1016/j.jclepro.2018.03.099

Boujibar, O., Souikny, A., Ghamouss, F., Achak, O., Dahbi, M., & Chafik, T. (2018). CO_2 capture using N-containing nanoporous activated carbon obtained from argan fruit shells. Journal of Environmental Chemical Engineering, 6(2), 1995-2002. doi:10.1016/j.jece.2018.03.005

Bulan, R., Mandang, T., Hermawan, W., & Desrial. (2015). Physical and Mechanical Properties of Palm Frond for the Development of Palm Oil Waste Chopper and Pressing Machine Design. International Journal of Scientific & Engineering Research, 6(2).

Buonomenna, M. G., Yave, W., & Golemme, G. (2012). Some approaches for high performance polymer based membranes for gas separation: block copolymers, carbon molecular sieves and mixed matrix membranes. RSC Advances, 2(29). doi:10.1039/c2ra20748f

Casari, C. S., Li Bassi, A., Baserga, A., Ravagnan, L., Piseri, P., Lenardi, C., . . . Milani, P. (2008). Low-frequency modes in the Raman spectrum of sp−sp^2 nanostructured carbon. Physical Review B, 77(19). doi:10.1103/PhysRevB.77.195444

Chen, H. Z., Thong, Z., Li, P., & Chung, T.-S. (2014). High performance composite hollow fiber membranes for CO_2/H_2 and CO_2/N_2 separation. International Journal of Hydrogen Energy, 39(10), 5043-5053. doi:10.1016/j.ijhydene.2014.01.047

Chen, X. Y., Vinh-Thang, H., Ramirez, A. A., Rodrigue, D., & Kaliaguine, S. (2015). Membrane gas separation technologies for biogas upgrading. RSC Advances, 5(31), 24399-24448. doi:10.1039/c5ra00666j

Chen, X. Y., Vinh-Thang, H., Rodrigue, D., & Kaliaguine, S. (2014). Effect of macrovoids in nano-silica/polyimide mixed matrix membranes for high flux CO_2/CH_4 gas separation. RSC Advances, 4(24). doi:10.1039/c3ra47208f

Chen, Y., Zou, C., Mastalerz, M., Hu, S., Gasaway, C., & Tao, X. (2015). Applications of Micro-Fourier Transform Infrared Spectroscopy (FTIR) in the Geological Sciences--A Review. Int J Mol Sci, 16(12), 30223-30250. doi:10.3390/ijms161226227

Cheshomi, N., Pakizeh, M., & Namvar‐Mahboub, M. (2018). Preparation and characterization of TiO_2/Pebax/(PSf‐PES) thin film nanocomposite membrane for humic acid removal from water. Polymers Advanced Technologies, 1-10. doi:10.1002/pat.4242

Cho, I.-H., & Zoh, K.-D. (2007). Photocatalytic degradation of azo dye (Reactive Red 120) in TiO_2/UV system: Optimization and modeling using a response surface methodology (RSM) based on the central composite design. Dyes and Pigments, 75(3), 533-543. doi:10.1016/j.dyepig.2006.06.041

Chun, W. K., Sean, G. P., & Ismail, A. F. (2016). Effect of PMMA-MWNTS Loading on CO_2 Separation Performance of Thin Film Nanocomposite Membrane. Jurnal Teknologi, 78(12), 39-45.

Chung, T.-S., Jiang, L. Y., Li, Y., & Kulprathipanja, S. (2007). Mixed matrix membranes (MMMs) comprising organic polymers with dispersed inorganic fillers for gas separation. Progress in Polymer Science, 32(4), 483-507. doi:10.1016/j.progpolymsci.2007.01.008

Dai, H., & Huang, H. (2016). Modified pineapple peel cellulose hydrogels embedded with sepia ink for effective removal of methylene blue. Carbohydr Polym, 148, 1-10. doi:10.1016/j.carbpol.2016.04.040

Dai, Y., Sun, Q., Wang, W., Lu, L., Liu, M., Li, J., . . . Zhang, Y. (2018). Utilizations of agricultural waste as adsorbent for the removal of contaminants: A review. Chemosphere, 211, 235-253. doi:10.1016/j.chemosphere.2018.06.179

Dai, Z., Ansaloni, L., & Deng, L. (2016). Recent advances in multi-layer composite polymeric membranes for CO_2 separation: A review. Green Energy & Environment, 1(2), 102-128. doi:10.1016/j.gee.2016.08.001

Das, A. K., & Dewanjee, S. (2018). Optimization of Extraction Using Mathematical Models and Computation. In Computational Phytochemistry (pp. 75-106).

Deka, B. J., Guo, J., Khanzada, N. K., & An, A. K. (2019). Omniphobic re-entrant PVDF membrane with ZnO nanoparticles composite for desalination of low surface tension oily seawater. Water Res, 165, 114982. doi:10.1016/j.watres.2019.114982

Duan, J., Pan, Y., Pacheco, F., Litwiller, E., Lai, Z., & Pinnau, I. (2015). High-performance polyamide thin-film-nanocomposite reverse osmosis membranes containing hydrophobic zeolitic imidazolate framework-8. Journal of Membrane Science, 476, 303-310. doi:10.1016/j.memsci.2014.11.038

Ebadi Amooghin, A., Omidkhah, M., & Kargari, A. (2015a). The effects of aminosilane grafting on NaY zeolite–Matrimid®5218 mixed matrix membranes for CO_2/CH_4 separation. Journal of Membrane Science, 490, 364-379. doi:10.1016/j.memsci.2015.04.070

Ebadi Amooghin, A., Omidkhah, M., & Kargari, A. (2015b). Enhanced CO_2 transport properties of membranes by embedding nano-porous zeolite particles into Matrimid®5218 matrix. RSC Advances, 5(12), 8552-8565. doi:10.1039/c4ra14903c

Efome, J. E., Baghbanzadeh, M., Rana, D., Matsuura, T., & Lan, C. Q. (2015). Effects of superhydrophobic SiO_2 nanoparticles on the performance of PVDF flat sheet membranes for vacuum membrane distillation. Desalination, 373, 47-57. doi:10.1016/j.desal.2015.07.002

El-Gendy, N., Madian, H. R., & Amr, S. S. (2013). Design and Optimization of a Process for Sugarcane Molasses Fermentation by Saccharomyces cerevisiae Using Response Surface Methodology. Int J Microbiol, 2013, 815631. doi:10.1155/2013/815631

Erto, A., Tsyntsarski, B., Balsamo, M., Budinova, T., Lancia, A., Petrova, B., & Petrov, N. (2016). Synthesis of Activated Carbons by Thermal Treatments of Agricultural Wastes for CO_2 Capture from Flue Gas. Combustion Science and Technology, 188(4-5), 581-593. doi:10.1080/00102202.2016.1138809

Ervina, J., Mariatti, M., & Hamdan, S. (2016). Effect of Filler Loading on the Tensile Properties of Multi-walled Carbon Nanotube and Graphene Nanopowder filled Epoxy Composites. Procedia Chemistry, 19, 897-905. doi:10.1016/j.proche.2016.03.132

Esposito, E., Clarizia, G., Bernardo, P., Jansen, J. C., Sedláková, Z., Izák, P., . . . Tasselli, F. (2015). Pebax®/PAN hollow fiber membranes for CO_2/CH_4 separation. Chemical Engineering and Processing - Process Intensification, 94, 53-61. doi:10.1016/j.cep.2015.03.016

Farnam, M., Mukhtar, H., & Shariff, A. M. (2016). An investigation of blended polymeric membranes and their gas separation performance. RSC Advances, 6(104), 102671-102679. doi:10.1039/c6ra21574b

Feijani, E. A., Mahdavi, H., & Tavassoli, A. (2018). Synthesis and gas permselectivity of CuBTC–GO–PVDF mixed matrix membranes. New Journal of Chemistry, 42(14), 12013-12023. doi:10.1039/c8nj00796a

Fu, B., Ge, C., Yue, L., Luo, J., Feng, D., Deng, H., & Yu, H. (2016). Characterization of Biochar Derived from Pineapple Peel Waste and Its Application for Sorption of Oxytetracycline from Aqueous Solution. Bioresources, 11(4), 9017-9035.

Galizia, M., Chi, W. S., Smith, Z. P., Merkel, T. C., Baker, R. W., & Freeman, B. D. (2017). 50th Anniversary Perspective: Polymers and Mixed Matrix Membranes for Gas and Vapor Separation: A Review and Prospective Opportunities. Macromolecules, 50(20), 7809-7843. doi:10.1021/acs.macromol.7b01718

García-Rosales, G., Longoria-Gándara, L. C., Avila-Pérez, P., Flores-Cruz, D. O., & López-Reyes, C. (2019). Biogenic Material With Iron Nanoparticles for As(V) Removal. In Plant Nanobionics (pp. 55-75).

Ghaee, A., Zerafat, M. M., Askari, P., Sabbaghi, S., & Sadatnia, B. (2017). Fabrication of polyamide thin-film nanocomposite membranes with enhanced surface charge for nitrate ion removal from water resources. Environ Technol, 38(6), 772-781. doi:10.1080/09593330.2016.1231223

Ghazali, A. A., Roshan, R. K., Rahman, S. A., Wahab, M. S. A., Hazleen, N. S., & Mandayar, N. (2019). 2^3 fractional factorial design for polymer based thin film composite (TFC) membrane synthesis for CO_2/CH_4 separation. 702, 012049.

Girgis, B. S., Temerk, Y. M., Gadelrab, M. M., & Abdullah, I. D. (2007). X-ray Diffraction Patterns of Activated Carbons Prepared under Various Conditions. Carbon Science, 8, 95-100.

Gnanasekaran, D., & Reddy, B. S. R. (2012). Cost effective poly(urethane-imide)-POSS membranes for environmental and energy-related processes. Clean Technologies and Environmental Policy, 15(2), 383-389. doi:10.1007/s10098-012-0500-7

Gutha, Y., Munagapati, V. S., Alla, S. R., & Abburi, K. (2011). Biosorptive Removal of Ni(II) from Aqueous Solution by Caesalpinia bonducella Seed Powder. Separation Science and Technology, 46(14), 2291-2297. doi:10.1080/01496395.2011.590390

Habibiannejad, S. A., Aroujalian, A., & Raisi, A. (2016). Pebax-1657 mixed matrix membrane containing surface modified multi-walled carbon nanotubes for gas separation. RSC Advances, 6(83), 79563-79577. doi:10.1039/c6ra14141b

Harun, Z., Jamalludin, M. R., Yunos, M. Z., Shohur, M. F., & Ismail, A. F. (2013). The Effect of Amorphous Rice Husk Silica to the Polysulfone Membrane Separation Process. Advanced Materials Research, 701, 319-322. doi:10.4028/www.scientific.net/AMR.701.319

Hou, J., Li, X., Guo, R., Zhang, J., & Wang, Z. (2018). Mixed matrix membranes with fast and selective transport pathways for efficient CO_2 separation. Nanotechnology, 29(12), 125706. doi:10.1088/1361-6528/aaa80c

Hussin, M. H., Pohan, N. A., Garba, Z. N., Kassim, M. J., Rahim, A. A., Brosse, N., . . . Haafiz, M. K. (2016). Physicochemical of microcrystalline cellulose from oil palm fronds as potential methylene blue adsorbents. Int J Biol Macromol, 92, 11-19. doi:10.1016/j.ijbiomac.2016.06.094

Isawi, H., El-Sayed, M. H., Feng, X., Shawky, H., & Abdel Mottaleb, M. S. (2016). Surface nanostructuring of thin film composite membranes via grafting polymerization and incorporation of ZnO nanoparticles. Applied Surface Science, 385, 268-281. doi:10.1016/j.apsusc.2016.05.141

Ismail, A. F., Khulbe, K. C., & Matsuura, T. (2015). Fundamentals of Gas Permeation Through Membranes. In Gas Separation Membranes (pp. 11-35).

Ismail, A. F., Norida, R., Rahman, W. A. W. A., Matsuura, T., & Hashemifard, S. A. (2011). Preparation and characterization of hyperthin-skinned and high performances asymmetric polyethersulfone membrane for gas separation. Desalination, 273(1), 93-104. doi:10.1016/j.desal.2010.10.015

Ismail, N. M., Jakariah, N. R., Bolong, N., Anissuzaman, S. M., Nordin, N. A. H. M., & Razali, A. R. (2017). Effect of Polymer Concentration on the Morphology and Mechanical Properties of Asymmetric Polysulfone (PSf) Membrane. Journal of Applied Membrane Science & Technology, 21(1). doi:10.11113/amst.v21i1.107

Jamalludin, M. R., Harun, Z., Hubadillah, S. K., Basri, H., Ismail, A. F., Othman, M. H. D., . . . Yunos, M. Z. (2016). Antifouling polysulfone membranes blended with green SiO_2 from rice husk ash (RHA) for humic acid separation. Chemical Engineering Research and Design, 114, 268-279. doi:10.1016/j.cherd.2016.08.023

Jamshidnezhad, M. (2015). Experimental design in reservoir engineering. In Experimental Design in Petroleum Reservoir Studies (pp. 57-98).

Jomekian, A., Behbahani, R. M., Mohammadi, T., & Kargari, A. (2016). CO_2/CH_4 separation by high performance co-casted ZIF-8/Pebax 1657/PES mixed matrix membrane. Journal of Natural Gas Science and Engineering, 31, 562-574. doi:10.1016/j.jngse.2016.03.067

Kacem, M., Pellerano, M., & Delebarre, A. (2015). Pressure swing adsorption for CO_2/N_2 and CO_2/CH_4 separation: Comparison between activated carbons and zeolites performances. Fuel Processing Technology, 138, 271-283. doi:10.1016/j.fuproc.2015.04.032

Kadhom, M., Yin, J., & Deng, B. (2016). A Thin Film Nanocomposite Membrane with MCM-41 Silica Nanoparticles for Brackish Water Purification. Membranes (Basel), 6(4). doi:10.3390/membranes6040050

Karimi, M. B., Khanbabaei, G., & Sadeghi, G. M. M. (2017). Vegetable oil-based polyurethane membrane for gas separation. Journal of Membrane Science, 527, 198-206. doi:10.1016/j.memsci.2016.12.008

Kazemimoghadam, M. (2017). Synthesis, Evaluation, Modeling and Simulation of Nano-Pore NAA Zeolite Membranes. Advanced Nanoscience and Technology : An International Journal, 3(3/4), 01-20. doi:10.5121/antj.2017.3401

Khan, M. M., Shishatskiy, S., & Filiz, V. (2018). Mixed Matrix Membranes of Boron Icosahedron and Polymers of Intrinsic Microporosity (PIM-1) for Gas Separation. Membranes (Basel), 8(1). doi:10.3390/membranes8010001

Khorshidi, B., Biswas, I., Ghosh, T., Thundat, T., & Sadrzadeh, M. (2018). Robust fabrication of thin film polyamide-TiO_2 nanocomposite membranes with enhanced thermal stability and anti-biofouling propensity. Sci Rep, 8(1), 784. doi:10.1038/s41598-017-18724-w

Khosravihaftkhany, S., Morad, N., Abdullah, A. Z., Teng, T. T., & Ismail, N. (2015). Biosorption of Pb(ii) and Fe(iii) from aqueous co-solutions using chemically pretreated oil palm fronds. RSC Advances, 5(129), 106498-106508. doi:10.1039/c5ra15325e

Khosravihaftkhany, S., Morad, N., Teng, T. T., Abdullah, A. Z., & Norli, I. (2013). Biosorption of Pb(II) and Fe(III) from Aqueous Solutions Using Oil Palm Biomasses as Adsorbents. Water, Air, & Soil Pollution, 224(3). doi:10.1007/s11270-013-1455-y

Kim, J., & Van der Bruggen, B. (2010). The use of nanoparticles in polymeric and ceramic membrane structures: review of manufacturing procedures and performance improvement for water treatment. Environ Pollut, 158(7), 2335-2349. doi:10.1016/j.envpol.2010.03.024

Kim, W.-g., & Nair, S. (2013). Membranes from nanoporous 1D and 2D materials: A review of opportunities, developments, and challenges. Chemical Engineering Science, 104, 908-924. doi:10.1016/j.ces.2013.09.047

Kim, Y., Bae, J., Park, H., Suh, J. K., You, Y. W., & Choi, H. (2016). Adsorption dynamics of methyl violet onto granulated mesoporous carbon: Facile synthesis and adsorption kinetics. Water Res, 101, 187-194. doi:10.1016/j.watres.2016.04.077

Klingberg, P., Wilkner, K., Schluter, M., Grunauer, J., & Shishatskiy, S. (2019). Separation of Carbon Dioxide from Real Power Plant Flue Gases by Gas Permeation Using a Supported Ionic Liquid Membrane: An Investigation of Membrane Stability. Membranes (Basel), 9(3). doi:10.3390/membranes9030035

Kosinov, N., Gascon, J., Kapteijn, F., & Hensen, E. J. M. (2016). Recent developments in zeolite membranes for gas separation. Journal of Membrane Science, 499, 65-79. doi:10.1016/j.memsci.2015.10.049

Kramer, V., Hülagü, D., Kraume, M., & Lyagin, E. (2012). Development of a Mechanistic Model for Mass Transfer in Sorption Selective Mixed-Matrix Membranes for Gas Separation. Procedia Engineering, 44, 1867-1869. doi:10.1016/j.proeng.2012.08.981

Krishni, R. R., Foob, K. Y., & Hameed, B. H. (2014). Food cannery effluent, pineapple peel as an effective low-cost biosorbent for removing cationic dye from aqueous solutions. Desalination and Water Treatment, 52, 6096-6103. doi:10.1080/19443994.2013.815686

Kumar, A., & Jena, H. M. (2016). Preparation and characterization of high surface area activated carbon from Fox nut (Euryale ferox) shell by chemical activation with H_3PO_4. Results in Physics, 6, 651-658. doi:10.1016/j.rinp.2016.09.012

Kumoro, A. C., Hendriansyah, R., Prakoso, T., Widiatmoko, P., Nurdin, I., Devianto, H., . . . Nam, P. T. S. (2018). Manufacturing Carbon Material by Carbonization of Cellulosic Palm Oil Waste for Supercapacitor Material. MATEC Web of Conferences, 156. doi:10.1051/matecconf/201815603018

Kusworo, T. D., Ismail, A. F., & Mustafa, A. (2015). Experimental Design and Response Surface Modeling Of PI/PES-Zeolite 4A Mixed Matrix Membrane For CO_2 Separation. Journal of Engineering Science and Technology, 10(9), 1116 - 1130.

Lau, W. J., Gray, S., Matsuura, T., Emadzadeh, D., Chen, J. P., & Ismail, A. F. (2015). A review on polyamide thin film nanocomposite (TFN) membranes: History, applications, challenges and approaches. Water Res, 80, 306-324. doi:10.1016/j.watres.2015.04.037

Lau, W. J., Ismail, A. F., Misdan, N., & Kassim, M. A. (2012). A recent progress in thin film composite membrane: A review. Desalination, 287, 190-199. doi:10.1016/j.desal.2011.04.004

Le, N. L., Wang, Y., & Chung, T.-S. (2011). Pebax/POSS mixed matrix membranes for ethanol recovery from aqueous solutions via pervaporation. Journal of Membrane Science, 379(1-2), 174-183. doi:10.1016/j.memsci.2011.05.060

Lee, S. Y., Kim, H. J., Patel, R., Im, S. J., Kim, J. H., & Min, B. R. (2007). Silver nanoparticles immobilized on thin film composite polyamide membrane: characterization, nanofiltration, antifouling properties. Polymers for Advanced Technologies, 18(7), 562-568. doi:10.1002/pat.918

Li, L., Wang, C., Wang, N., Cao, Y., & Wang, T. (2015). The preparation and gas separation properties of zeolite/carbon hybrid membranes. Journal of Materials Science, 50(6), 2561-2570. doi:10.1007/s10853-015-8819-1

Li, Y., Li, X., Wu, H., Xin, Q., Wang, S., Liu, Y., . . . Wang, B. (2015). Anionic surfactant-doped Pebax membrane with optimal free volume characteristics for efficient CO_2 separation. Journal of Membrane Science, 493, 460-469. doi:10.1016/j.memsci.2015.06.046

Li, Y., Xu, R., Wang, B., Wei, J., Wang, L., Shen, M., & Yang, J. (2019). Enhanced N-doped Porous Carbon Derived from KOH-Activated Waste Wool: A Promising Material for Selective Adsorption of CO_2/CH_4 and CH_4/N_2. Nanomaterials (Basel), 9(2). doi:10.3390/nano9020266

Libra, J. A., Ro, K. S., Kammann, C., Titirici, M.-M., Fühner, C., Bens, O., . . . Emmerich, K.-H. (2011). Hydrothermal carbonization of biomass residuals: a comparative review of the chemistry, processes and applications of wet and dry pyrolysis. Biofuels, 2(1), 89-124.

Lilleparg, J., Breitenkamp, S., Shishatskiy, S., Pohlmann, J., Wind, J., Scholles, C., & Brinkmann, T. (2019). Characteristics of Gas Permeation Behaviour in Multilayer Thin Film Composite Membranes for CO_2 Separation. Membranes (Basel), 9(2). doi:10.3390/membranes9020022

Liu, X., Liu, H., & Li, P. (2017). Effect of Polymer Dope Concentration on the Morphology and Performance of PES/PDMS Hollow Fiber Composite Membrane for Gas Separation. Juniper Online Journal Material Science, 1(5). doi:10.19080/jojms.2017.01.555573

Low, L. W., Tow Teng, T., Alkarkhi, A. F. M., Morad, N., & Azahari, B. (2014). Adsorption of Rhodamine B Dye on Elaeis guineensis Frond Fiber. Separation Science and Technology, 49(7), 1104-1118. doi:10.1080/01496395.2013.872148

Lu, P., & Hsieh, Y.-L. (2012). Highly pure amorphous silica nano-disks from rice straw. Powder Technology, 225, 149-155. doi:10.1016/j.powtec.2012.04.002

Lutpi, N. A., Shian, W. Y., & Kamarudzaman, A. N. (2011). Removal of methylene blue using pineapple peel powder as adsorbent. Proceedings of the 3rd (2011) CUTSE International Conference, 352.

Lv, D., Chen, J., Yang, K., Wu, H., Chen, Y., Duan, C., . . . Xia, Q. (2019). Ultrahigh CO_2/CH_4 and CO_2/N_2 adsorption selectivities on a cost-effectively L-aspartic acid based metal-organic framework. Chemical Engineering Journal, 375. doi:10.1016/j.cej.2019.122074

Mahamad, M. N., Zaini, M. A. A., & Zakaria, Z. A. (2015). Preparation and characterization of activated carbon from pineapple waste biomass for dye removal. International Biodeterioration & Biodegradation, 102, 274-280. doi:10.1016/j.ibiod.2015.03.009

Mahmoudi, A., Asghari, M., & Zargar, V. (2015). CO_2/CH_4 separation through a novel commercializable three-phase PEBA/PEG/NaX nanocomposite membrane. Journal of Industrial and Engineering Chemistry, 23, 238-242. doi:10.1016/j.jiec.2014.08.023

Maulina, S., & Anwari, F. (2018). Utilization of oil palm fronds in producing activated carbon using Na_2CO_3 as an activator. IOP Conference Series: Materials Science and Engineering, 309, 012087.

Meng, Y., Jiang, J., Gao, Y., Aihemaiti, A., Ju, T., Xu, Y., & Liu, N. (2019). Biogas upgrading to methane: Application of a regenerable polyethyleneimine-impregnated polymeric resin (NKA-9) via CO_2 sorption. Chemical Engineering Journal, 361, 294-303. doi:10.1016/j.cej.2018.12.091

Misdan, N., Lau, W. J., Ismail, A. F., & Matsuura, T. (2013). Formation of thin film composite nanofiltration membrane: Effect of polysulfone substrate characteristics. Desalination, 329, 9-18. doi:10.1016/j.desal.2013.08.021

Mohammad Zainol, M., Saidina Amin, N. A., & Asmadi, M. (2017). Preparation and Characterization of Impregnated Magnetic Particles on Oil Palm Frond Activated Carbon for Metal Ions Removal. Sains Malaysiana, 46(5), 773-782. doi:10.17576/jsm-2017-4605-12

Mohammed, J. (2019). Equilibrium, Kinetics and Thermodynamic Studies on the Removal of Safranin-O from Waste Water Using Activated Carbons Derived from Coconut Shell and Pineapple Peel. American Journal of Physical Chemistry, 8(1). doi:10.11648/j.ajpc.20190801.11

Mohd Sharif, N. S. A., Thor, E. S., Zainol, N., & Jamaluddin, M. F. (2017). Optimization of ferulic acid production from banana stem waste using central composite design. Environmental Progress & Sustainable Energy, 36(4), 1217-1223. doi:10.1002/ep.12560

Mozafari, M., Abedini, R., & Rahimpour, A. (2018). Zr-MOFs-incorporated thin film nanocomposite Pebax 1657 membranes dip-coated on polymethylpentyne layer for efficient separation of CO_2/CH_4. Journal of Materials Chemistry A, 6(26), 12380-12392. doi:10.1039/c8ta04806a

Muntha, S. T., Kausar, A., & Siddiq, M. (2017). A Review Featuring Fabrication, Properties, and Application of Polymeric Mixed Matrix Membrane Reinforced with Different Fillers. Polymer-Plastics Technology and Engineering, 56(18), 2043-2064. doi:10.1080/03602559.2017.1298801

Murali, R. S., Ismail, A. F., Rahman, M. A., & Sridhar, S. (2014). Mixed matrix membranes of Pebax-1657 loaded with 4A zeolite for gaseous separations. Separation and Purification Technology, 129, 1-8. doi:10.1016/j.seppur.2014.03.017

Ng, L. Y., Mohammad, A. W., Leo, C. P., & Hilal, N. (2013). Polymeric membranes incorporated with metal/metal oxide nanoparticles: A comprehensive review. Desalination, 308, 15-33. doi:10.1016/j.desal.2010.11.033

Nigiz, F. U., & Hilmioglu, N. D. (2017). Preparation of 3A Zeolite-Loaded Membrane for Hydrogen Recovery from Waste Gas. Journal of The Turkish Chemical Society, 1(1), 71-80.

Nik, O. G., Chen, X. Y., & Kaliaguine, S. (2012). Functionalized metal organic framework-polyimide mixed matrix membranes for CO_2/CH_4 separation. Journal of Membrane Science, 413-414, 48-61. doi:10.1016/j.memsci.2012.04.003

Nordin, N. A., Sulaiman, O., Hashim, R., & Mohamad Kassim, M. H. (2017). Oil Palm Frond Waste for the Production of Cellulose Nanocrystals. Journal of Physical Science, 28(2), 115-126. doi:10.21315/jps2017.28.2.8

Nuhnen, A., Dietrich, D., Millan, S., & Janiak, C. (2018). Role of Filler Porosity and Filler/Polymer Interface Volume in Metal-Organic Framework/Polymer Mixed-Matrix Membranes for Gas Separation. ACS Appl Mater Interfaces, 10(39), 33589-33600. doi:10.1021/acsami.8b12938

Obi, F. O., Ugwuishiwu, B. O., & Nwakaire, J. N. (2016). Agricultural Waste Concept, Generation, Utilization and Management. Nigerian Journal of Technology, 35(4). doi:10.4314/njt.v35i4.34

Olivares-Marín, M., & Maroto-Valer, M. M. (2012). Development of adsorbents for CO_2 capture from waste materials: a review. Greenhouse Gases: Science and Technology, 2(1), 20-35. doi:10.1002/ghg.45

Ooi, Z. X., Teoh, Y. P., Kunasundari, B., & Shuit, S. H. (2017). Oil palm frond as a sustainable and promising biomass source in Malaysia: A review. Environmental Progress & Sustainable Energy, 36(6), 1864-1874. doi:10.1002/ep.12642

Oschatz, M., & Antonietti, M. (2018). A search for selectivity to enable CO_2 capture with porous adsorbents. Energy & Environmental Science, 11(1), 57-70. doi:10.1039/c7ee02110k

Pandey, P., & Chauhan, R. S. (2001). Membranes for gas separation. Progress in Polymer Science, 26, 853-893.

Park, H. J., Bhatti, U. H., Nam, S. C., Park, S. Y., Lee, K. B., & Baek, I. H. (2019). Nafion/TiO_2 nanoparticle decorated thin film composite hollow fiber membrane for efficient removal of SO_2 gas. Separation and Purification Technology, 211, 377-390. doi:10.1016/j.seppur.2018.10.010

Pathak, P. D., Mandavgane, S. A., & Kulkarni, B. D. (2016). Characterizing Fruit and Vegetable Peels as Bioadsorbents. Current Science, 110(11). doi:10.18520/cs/v110/i11/2114-2123

Perera, D. H. N., Nataraj, S. K., Thomson, N. M., Sepe, A., Hüttner, S., Steiner, U., . . . Sivaniah, E. (2014). Room-temperature development of thin film composite reverse osmosis membranes from cellulose acetate with antibacterial properties. Journal of Membrane Science, 453, 212-220. doi:10.1016/j.memsci.2013.10.062

Pradhan, S., Hedberg, J., Blomberg, E., Wold, S., & Odnevall Wallinder, I. (2016). Effect of sonication on particle dispersion, administered dose and metal release of non-functionalized, non-inert metal nanoparticles. J Nanopart Res, 18(9), 285. doi:10.1007/s11051-016-3597-5

Rafizah, W. A. W., & Ismail, A. F. (2008). Effect of carbon molecular sieve sizing with poly(vinyl pyrrolidone) K-15 on carbon molecular sieve–polysulfone mixed matrix membrane. Journal of Membrane Science, 307(1), 53-61. doi:10.1016/j.memsci.2007.09.007

Rahman, A. S. (2019). Effects of nanofibers on properties of geopolymer composites. In Nanotechnology in Eco-efficient Construction (pp. 123-140).

Rahman, S. A., Haron, G. A. S., Kanasan, R. K. R., & Hasbullah, H. (2018). Preliminary study on gas separation performance of flat sheet mixed matrix (PVDF/Zeolite). IOP Conference Series: Materials Science and Engineering, 342, 012073.

Rajati, H., Navarchian, A. H., & Tangestaninejad, S. (2018). Preparation and characterization of mixed matrix membranes based on Matrimid/PVDF blend and MIL-101(Cr) as filler for CO_2/CH_4 separation. Chemical Engineering Science, 185, 92-104. doi:10.1016/j.ces.2018.04.006

Ramezani Darabi, R., Peyravi, M., & Jahanshahi, M. (2019). Modified forward osmosis membranes by two amino-functionalized ZnO nanoparticles: A comparative study. Chemical Engineering Research and Design, 145, 85-98. doi:10.1016/j.cherd.2019.02.019

Ramírez-García, R., Gohil, N., & Singh, V. (2019). Recent Advances, Challenges, and Opportunities in Bioremediation of Hazardous Materials. In Phytomanagement of Polluted Sites (pp. 517-568).

Rashidia, N. A., Yusupa, S., & Loong, L. H. (2013). Kinetic Studies on Carbon Dioxide Capture using Activated Carbon. Chemical Engineering Transactions, 35, 361-366. doi:10.3303/CET1335060

Razi, M. A. M., Hishammudin, M. N. A. M., Rahim, M. A. A., & Salleh, N. A. H. M. (2018). A review of agricultural waste activated carbon and effect on adsorption parameters. Int. J. Environmental Engineering, 9(3/4).

Robeson, L. M. (2008). The upper bound revisited. Journal of Membrane Science, 320(1-2), 390-400. doi:10.1016/j.memsci.2008.04.030

Romero-Cano, L. A., García-Rosero, H., Gonzalez-Gutierrez, L. V., Baldenegro-Pérez, L. A., & Carrasco-Marín, F. (2017). Functionalized adsorbents prepared from fruit peels: Equilibrium, kinetic and thermodynamic studies for copper adsorption in aqueous solution. Journal of Cleaner Production, 162, 195-204. doi:10.1016/j.jclepro.2017.06.032

Rozaidi, N. I. M., & Abu Samah, R. (2018). Peel Wastes of Ananas comosus (L.) Merr as Biosorbent for Fe(II) Ions Removal from Aqueous Solution. Research Communication in Engineering Science & Technology, 8.

Rozaidi, N. I. M., & Samah, R. A. (2018). Peel Wastes of Ananas comosus (L.) Merr as Biosorbent for Fe(II) Ions Removal from Aqueous Solution. Research Communication in Engineering Science & Technology, 1, 8.

Rugayah, A. F., Astimar, A. A., & Norzita, N. (2014). Preparation and Characterisation of Activated Carbon from Palm Kernel Shell by physical activation with steam. Journal of Oil Palm Research, 26(3), 251-264.

Sa'don, N. A., Rahim, A. A., Ibrahim, M. N. M., Brosse, N., & Hussin, M. H. (2017). Modification of oil palm fronds lignin by incorporation of m -cresol for improving structural and antioxidant properties. International Journal of Biological Macromolecules, 104, 251-260. doi:10.1016/j.ijbiomac.2017.06.038

Saadia, M., Ahmed, B., Nazha, O., Abdlemjid, A., & M'Hamed, C. (2012). Preparation and Characterization of Activated Carbon from Residues of Oregano. Journal of Surface Science and Technology, 28(3-4), 91-100.

Salehi, T. M., Peyravi, M., Jahanshahi, M., Lau, W.-J., & Rad, A. S. (2018). Impacts of zeolite nanoparticles on substrate properties of thin film nanocomposite membranes for engineered osmosis. Journal of Nanoparticle Research, 20(4). doi:10.1007/s11051-018-4154-1

Salim, N., Siddiqa, A., Shahida, S., & Qaisar, S. (2019). PVDF based Nanocomposite Membranes: Application towards Wastewater treatment. Madridge Journal of Nanotechnology & Nanoscience, 4(1), 139-147. doi:10.18689/mjnn-1000128

Salman, J. M. (2013). Batch Study for Insecticide Carbofuran Adsorption onto Palm-Oil-Fronds-Activated Carbon. Journal of Chemistry, 2013, 1-5. doi:10.1155/2013/630371

Salman, J. M., & Al-Saad, K. (2012). Batch study for herbicide bentazon adsorption onto palm oil fronds activated carbon. International Journal of Chemical Science, 10(2), 731-740.

Sanaeepur, H., Ahmadi, R., Ebadi Amooghin, A., & Ghanbari, D. (2019). A novel ternary mixed matrix membrane containing glycerol-modified poly(ether-block-amide) (Pebax 1657)/copper nanoparticles for CO_2 separation. Journal of Membrane Science, 573, 234-246. doi:10.1016/j.memsci.2018.12.012

Sanaeepur, H., Ahmadi, R., Sinaei, M., & Kargari, A. (2019). Pebax-Modified Cellulose Acetate Membrane for CO_2/N_2 Separation. Journal of Membrane Science and Research, 5, 25-32. doi:10.22079/JMSR.2018.85813.1190

Sanders, D. F., Smith, Z. P., Guo, R., Robeson, L. M., McGrath, J. E., Paul, D. R., & Freeman, B. D. (2013). Energy-efficient polymeric gas separation membranes for a sustainable future: A review. Polymer, 54(18), 4729-4761. doi:10.1016/j.polymer.2013.05.075

Sanip, S. M., Ismail, A. F., Goh, P. S., Soga, T., Tanemura, M., & Yasuhiko, H. (2011). Gas separation properties of functionalized carbon nanotubes mixed matrix membranes. Separation and Purification Technology, 78(2), 208-213. doi:10.1016/j.seppur.2011.02.003

Savic, I., Gajic, D., Stojiljkovic, S., Savic, I., & Gennaro, S. d. (2014). Modelling and Optimization of Methylene Blue Adsorption from Aqueous Solution Using Bentonite Clay. In 24th European Symposium on Computer Aided Process Engineering (pp. 1417-1422).

Scholes, C. A., Stevens, G. W., & Kentish, S. E. (2012). Membrane gas separation applications in natural gas processing. Fuel, 96, 15-28. doi:10.1016/j.fuel.2011.12.074

Selyanchyn, R., Ariyoshi, M., & Fujikawa, S. (2018). Thickness Effect on CO_2/N_2 Separation in Double Layer Pebax-1657/PDMS Membranes. Membranes (Basel), 8(4). doi:10.3390/membranes8040121

Shafiq, M., Sabir, A., Islam, A., Khan, S. M., Gull, N., Hussain, S. N., & Butt, M. T. Z. (2018). Cellulaose acetate based thin film nanocomposite reverse osmosis membrane incorporated with TiO_2 nanoparticles for improved performance. Carbohydr Polym, 186, 367-376. doi:10.1016/j.carbpol.2018.01.070

Shahadat, M., Rafatullah, **M.**, & Teng, T. T. (2015). Characterization and sorption behavior of natural adsorbent for exclusion of chromium ions from industrial effluents. Desalination and Water Treatment, 53, 1395-1403. doi:10.1080/19443994.2013.855678

Shen, Y., & Lua, A. C. (2012). Preparation and characterization of mixed matrix membranes based on PVDF and three inorganic fillers (fumed nonporous silica, zeolite 4A and mesoporous MCM-41) for gas separation. Chemical Engineering Journal, 192, 201-210. doi:10.1016/j.cej.2012.03.066

Shifera, L., Siraj, K., & Yifru, A. (2017). Adsorption of lead (II) and chromium (VI) onto activated carbon prepared from pineapple peel: Kinetics and thermodynamic study. Indian Journal of Chemical Technology, 24, 145-152.

Skoglund, S., Hedberg, J., Yunda, E., Godymchuk, A., Blomberg, E., & Odnevall Wallinder, I. (2017). Difficulties and flaws in performing accurate determinations of zeta potentials of metal nanoparticles in complex solutions-Four case studies. PLoS One, 12(7), e0181735. doi:10.1371/journal.pone.0181735

Sodeifian, G., Raji, M., Asghari, M., Rezakazemi, M., & Dashti, A. (2019). Polyurethane-SAPO-34 mixed matrix membrane for CO_2/CH_4 and CO_2/N_2 separation. Chinese Journal of Chemical Engineering, 27(2), 322-334. doi:10.1016/j.cjche.2018.03.012

Songolzadeh, M., Soleimani, M., Takht Ravanchi, M., & Songolzadeh, R. (2014). Carbon dioxide separation from flue gases: a technological review emphasizing reduction in greenhouse gas emissions. ScientificWorldJournal, 2014, 828131. doi:10.1155/2014/828131

Sridhar, S., Bhargava, S., & Bee, S. (2014). Membrane-based Gas Separation: Principle, Applications and Future Potential. Chemical Engineering Digest.

Sridhar, S., Smitha, B., Suryamurali, R., & Aminabhavi, T. M. (2012). Synthesis, Characterization and Gas Permeability of an Activated Carbon-Loaded PEBAX 2533 Membrane. Designed Monomers and Polymers, 11(1), 17-27. doi:10.1163/156855508x292392

Stawikowska, J., & Livingston, A. G. (2013). Assessment of atomic force microscopy for characterisation of nanofiltration membranes. Journal of Membrane Science, 425-426, 58-70. doi:10.1016/j.memsci.2012.08.006

Sulyman, M., Namiesnik, J., & Gierak, A. (2017). Low-cost Adsorbents Derived from Agricultural By-products/Wastes for Enhancing Contaminant Uptakes from Wastewater: A Review. Polish Journal of Environmental Studies, 26(2), 479-510. doi:10.15244/pjoes/66769

Sumathi, S., Bhatia, S., Lee, K. T., & Mohamed, A. R. (2010). Cerium impregnated palm shell activated carbon (Ce/PSAC) sorbent for simultaneous removal of SO_2 and NO-Process study. Chemical Engineering Journal, 162(1), 51-57. doi:10.1016/j.cej.2010.04.056

Surya Murali, R., Sridhar, S., Sankarshana, T., & Ravikumar, Y. V. L. (2010). Gas Permeation Behavior of Pebax-1657 Nanocomposite Membrane Incorporated with Multiwalled Carbon Nanotubes. Industrial & Engineering Chemistry Research, 49, 6530–6538.

Sutrisna, P. D., Hou, J., Li, H., Zhang, Y., & Chen, V. (2017). Improved operational stability of Pebax-based gas separation membranes with ZIF-8: A comparative study of flat sheet and composite hollow fibre membranes. Journal of Membrane Science, 524, 266-279. doi:10.1016/j.memsci.2016.11.048

Taer, E., Apriwandi, A., Ningsih, Y. S., Taslim, R., & Agustino. (2019). Preparation of Activated Carbon Electrode from Pineapple Crown Waste for Supercapacitor Application. International Journal of Electrochemical Science, 14, 2462-2475. doi:10.20964/2019.03.17

Tajuddin, M. H., Yusof, N., Wan Salleh, W. N., Ismail, A. F., Hairom, N. H. H., & Misdan, N. (2018). Incorporation of layered double nanomaterials in thin film nanocomposite nanofiltration membrane for magnesium sulphate removal. E3S Web of Conferences, 34. doi:10.1051/e3sconf/20183402003

Tseng, H.-H., Shih, K., Shiu, P.-T., & Wey, M.-Y. (2012). Influence of support structure on the permeation behavior of polyetherimide-derived carbon molecular sieve composite membrane. Journal of Membrane Science, 405-406, 250-260. doi:10.1016/j.memsci.2012.03.014

Upadhyay, A., Lama, J. P., & Tawata, S. (2010). Utilization of Pineapple Waste: A Review. Journal of Food Science and Technology Nepal, 6, 10-18.

Venkateswarlu, S., & Yoon, M. (2015). Rapid removal of cadmium ions using green-synthesized Fe_3O_4 nanoparticles capped with diethyl-4-(4 amino-5-mercapto-4H-1,2,4-triazol-3-yl)phenyl phosphonate. RSC Advances, 5(80), 65444-65453. doi:10.1039/c5ra10628a

Vicinanza, N., Svenum, I. H., Peters, T., Bredesen, R., & Venvik, H. (2018). New Insight to the Effects of Heat Treatment in Air on the Permeation Properties of Thin Pd77%Ag23% Membranes. Membranes (Basel), 8(4). doi:10.3390/membranes8040092

Vu, D. Q., Koros, W. J., & Miller, S. J. (2003). Mixed matrix membranes using carbon molecular sieves I. Preparation and experimental results. Journal of Membrane Science, 211, 311-334.

Wagner, J. R., Mount, E. M., & Giles, H. F. (2014). Design of Experiments. In Extrusion (pp. 291-308).

Wahab, M. S. A., & Rahman, S. A. (2017). Influence of PVDF/Pebax TFC Casting Temperature towards CO_2/N_2 Gas Separation. Indian Journal of Science and Technology, 10(2). doi:10.17485/ijst/2017/v10i2/110384

Waheed, N., Mushtaq, A., Tabassum, S., Gilani, M. A., Ilyas, A., Ashraf, F., . . . Khan, A. L. (2016). Mixed matrix membranes based on polysulfone and rice husk extracted silica for CO_2 separation. Separation and Purification Technology, 170, 122-129. doi:10.1016/j.seppur.2016.06.035

Wang, J., Zheng, L., Wu, Z., Zhang, Y., & Zhang, X. (2016). Fabrication of hydrophobic flat sheet and hollow fiber membranes from PVDF and PVDF-CTFE for membrane distillation. Journal of Membrane Science, 497, 183-193. doi:10.1016/j.memsci.2015.09.024

Wang, S., Liu, Y., Huang, S., Wu, H., Li, Y., Tian, Z., & Jiang, Z. (2014). Pebax–PEG–MWCNT hybrid membranes with enhanced CO_2 capture properties. Journal of Membrane Science, 460, 62-70. doi:10.1016/j.memsci.2014.02.036

Wang, Z., Chen, X., Li, K., Bi, S., Wu, C., & Chen, L. (2015). Preparation and catalytic property of PVDF composite membrane with polymeric spheres decorated by Pd nanoparticles in membrane pores. Journal of Membrane Science, 496, 95-107. doi:10.1016/j.memsci.2015.08.041

Wey, M.-Y., Tseng, H.-H., & Chiang, C.-k. (2014). Improving the mechanical strength and gas separation performance of CMS membranes by simply sintering treatment of α-Al_2O_3 support. Journal of Membrane Science, 453, 603-613. doi:10.1016/j.memsci.2013.11.039

Wong, K. C., Goh, P. S., & Ismail, A. F. (2016). Thin film nanocomposite: the next generation selective membrane for CO_2 removal. Journal of Materials Chemistry A, 4(41), 15726-15748. doi:10.1039/c6ta05145f

Xiang, L., Pan, Y., Jiang, J., Chen, Y., Chen, J., Zhang, L., & Wang, C. (2017). Thin poly(ether-block-amide)/attapulgite composite membranes with improved CO_2 permeance and selectivity for CO_2/N_2 and CO_2/CH_4. Chemical Engineering Science, 160, 236-244. doi:10.1016/j.ces.2016.11.037

Yadav, A. K., Abbassi, R., Gupta, A., & Dadashzadeh, M. (2013). Removal of fluoride from aqueous solution and groundwater by wheat straw, sawdust and activated bagasse carbon of sugarcane. Ecological Engineering, 52, 211-218. doi:10.1016/j.ecoleng.2012.12.069

Yahya, M. A., Mansor, M. H., Zolkarnaini, W. A. A. W., Rusli, N. S., Aminuddin, A., Mohamad, K., . . . Ozair, L. N. (2018). A brief review on activated carbon derived from agriculture by-product.

Yamuna, M., & Kamaraj, M. (2016). Pineapple peel waste activated carbon as an adsorbent for the effective removal of methylene blue dye from aqueous solution. International Journal of ChemTech Research, 9(5), 544-550.

Yi Suen, S. (2015). Mixed Matrix Membranes for Adsorption Application. Journal of Chemical Engineering & Process Technology, 06(01). doi:10.4172/2157-7048.1000e119

Yusuf, M., Elfghi, F. M., & Mallak, S. K. (2015). Kinetic studies of Safranin-O removal from Aqueous Solutions using Pineapple Peels. Iranica Journal OF Energy & Environment, 6(3). doi:10.5829/idosi.ijee.2015.06.03.04

Zahari, M. A., Zakaria, M. R., Ariffin, H., Mokhtar, M. N., Salihon, J., Shirai, Y., & Hassan, M. A. (2012). Renewable sugars from oil palm frond juice as an alternative novel fermentation feedstock for value-added products. Bioresour Technol, 110, 566-571. doi:10.1016/j.biortech.2012.01.119

Zarshenas, K., Raisi, A., & Aroujalian, A. (2016). Mixed matrix membrane of nano-zeolite NaX/poly (ether-block-amide) for gas separation applications. Journal of Membrane Science, 510, 270-283. doi:10.1016/j.memsci.2016.02.059

Zhang, C., Dai, Y., Johnson, J. R., Karvan, O., & Koros, W. J. (2012). High performance ZIF-8/6FDA-DAM mixed matrix membrane for propylene/propane separations. Journal of Membrane Science, 389, 34-42. doi:10.1016/j.memsci.2011.10.003

Zhang, W., Shi, Z., Zhang, F., Liu, X., Jin, J., & Jiang, L. (2013). Superhydrophobic and superoleophilic PVDF membranes for effective separation of water-in-oil emulsions with high flux. Adv Mater, 25(14), 2071-2076. doi:10.1002/adma.201204520

Zhang, Y., Sunarso, J., Liud, S., & Wanga, R. (2013). Current status and development of membranes for CO_2/CH_4 separation: A review. International Journal of Greenhouse Gas Control, 12, 84-107. doi:10.1016/j.ijggc.2012.10.009

Zhao, M., Zhang, H. F., Huang, H., & Zhang, Y. S. (2017). Preparation and Properties of Nanocomposite MWCNTs/Polyamide Reverse Osmosis Membrane for Desalination by Interfacial Polymerization. Key Engineering Materials, 727, 1016-1025. doi:10.4028/www.scientific.net/KEM.727.1016

Zhao, W., Liu, H., Meng, N., Jian, M., Wang, H., & Zhang, X. (2018). Graphene oxide incorporated thin film nanocomposite membrane at low concentration monomers. Journal of Membrane Science, 565, 380-389. doi:10.1016/j.memsci.2018.08.047

Zulkurnai, N. Z., Md. Ali, U. F., Ibrahim, N., & Abdul Manan, N. S. (2017). Carbon Dioxide (CO_2) Adsorption by Activated Carbon Functionalized with Deep Eutectic Solvent (DES). IOP Conference Series: Materials Science and Engineering, 206, 012001.

Zuwairi, M. Z., & Rahman, S. A. (2017). Study on CO_2/ N_2 separation: the effect of rubbery polymer coating on PVDF membrane. IOP Conf. Series: Materials Science and Engineering, 206, 012047.