REFERENCES

DEN - National Energy Council (2019) *Indonesia Energy Outlook, Outlook Energi Indonesia*. Available at: https://www.den.go.id/index.php/publikasi/documentread?doc=outlook-energi-indonesia-2018-id.pdf.

Abas, N., Kalair, A. and Khan, N. (2015) 'Review of fossil fuels and future energy technologies', *Futures*, 69(March 2015), pp. 31–49. doi: 10.1016/j.futures.2015.03.003.

Abdelrasoul, A. *et al.* (2015) 'Mass Transfer Mechanisms and Transport Resistances in Membrane Separation Process', in *Mass Transfer*.

Abdul Raman, A. A., Tan, H. W. and Buthiyappan, A. (2019) 'Two-Step Purification of Glycerol as a Value Added by Product From the Biodiesel Production Process', *Frontiers in Chemistry*, 7(November 2019), pp. 1–9. doi: 10.3389/fchem.2019.00774.

Ambroz, F. *et al.* (2018) 'Evaluation of the BET theory for the characterization of meso and microporous MOFs', *Small Methods*, 2(11). doi: 10.1002/smtd.201800173.

Amin, S. K. *et al.* (2016) 'An overview of production and development of ceramic membranes', *International Journal of Applied Engineering Research*, 11(12), pp. 7708–7721.

Atadashi, I. M. (2015) 'Purification of crude biodiesel using dry washing and membrane technologies', *Alexandria Engineering Journal*, 54(4), pp. 1265–1272. doi: 10.1016/j.aej.2015.08.005.

Atadashi, I. M., Aroua, M. K. and Aziz, A. A. (2011) 'Biodiesel separation and purification: A review', *Renewable Energy*, 36(2), pp. 437–443. doi: 10.1016/j.renene.2010.07.019.

Az'zura, N. Z. (2021) *Fabrication of Alumina-Kaolin Ceramic Microfiltration Membrane for Biodiesel Purification*. Swiss German University.

Badan Pusat Statistik (2019) *Produksi Barang Tambang Mineral*. Available at: https://www.bps.go.id/indicator/10/508/1/produksi-barang-tambang-mineral.html.

Balai Teknologi Bahan Bakar dan Rekayasa Disain (2014) *TanyaJawab Biodiesel*. Available at: https://btbrd.bppt.go.id/index.php/biodiesel-faq#:~:text=Bahan baku utama biodiesel yang digunakan di Indonesia,CPO terbesar nomor dua di dunia saat ini. (Accessed: 12 December 2021).

Bateni, H. *et al.* (2019) *Biodiesel Puri fi cation and Upgrading Technologies*. doi: 10.1007/978-3-030-00985-4.

Bondioli, P. and Della Bella, L. (2005) 'An alternative spectrophotometric method for the determination of free glycerol in biodiesel', *European Journal of Lipid Science and Technology*, 107(3), pp. 153–157. doi: 10.1002/ejlt.200401054.

BP (2020) *BP Annual Review of World Energy 2020*.

BP (2021) 'Statistical Review of World Energy globally consistent data on world energy markets . and authoritative publications in the field of energy', *BP Energy Outlook 2021*, 70, pp. 8–20.

Chozhavendhan, S. *et al.* (2020) 'A review on influencing parameters of biodiesel production and purification processes', *Current Research in Green and Sustainable Chemistry*, 1–2(October 2019), pp. 1–6. doi: 10.1016/j.crgsc.2020.04.002.

Desalination, W. T. in (no date) *Water Treatment Process*. Available at: http://www.thewatertreatments.com/desalination-water-treatment/water-treatment-process/.

Dewi, R. (2020) *SINTHESA AND CHARACTERIZATION OF CERAMIC MEMBRANE BASED ON KAOLIN SABANG AND ITS APPLICATION IN PROCESSING PEAT WATER WITH THE CROSS FLOW SYSTEM*. Universitas Sumatera Utara. Available at: https://repositori.usu.ac.id/bitstream/handle/123456789/23753/158103008.pdf?sequence=1&isAllowed=y.

Fangrui, M. and Milford, H. (1999) 'Biodiesel Production: A Review 1', *Bioresource Technology*, 70, pp. 1–15.

Faridha *et al.* (2021) *Jejak Panjang Sebuah Perjuangan*. Available at: www.litbang.esdm.go.id.

Foley, G. (2013) *Membrane fouling, Membrane Filtration*. doi: 10.1017/cbo9781139236843.011.

Ghouil, B. *et al.* (2015) 'Development and characterization of tubular composite ceramic membranes using natural alumino-silicates for microfiltration applications', *Materials Characterization*, 103, pp. 18–27. doi: 10.1016/j.matchar.2015.03.009.

Gomes, M. C. S. *et al.* (2021) 'Modeling of fouling mechanisms in the biodiesel purification using ceramic membranes', *Separation and Purification Technology*, 269(September 2020). doi: 10.1016/j.seppur.2021.118595.

Gomes, M. C. S., Arroyo, P. A. and Pereira, N. C. (2011) 'Biodiesel production from degummed soybean oil and glycerol removal using ceramic membrane', *Journal of Membrane Science*, 378(1–2), pp. 453–461. doi: 10.1016/j.memsci.2011.05.033.

Gomes, M. C. S., Pereira, N. C. and Barros, S. T. D. de (2010) 'Separation of biodiesel and glycerol using ceramic membranes', *Journal of Membrane Science*, 352(1–2), pp. 271–276. doi: 10.1016/j.memsci.2010.02.030.

Haryadi, H. (2016) 'Lost Opportunity (LO) Analysis of Indonesia Bauxite', *Jurnal Teknologi Mineral dan Batubara*, 12(1), pp. 45–57. Available at: https://jurnal.tekmira.esdm.go.id/index.php/minerba/article/viewFile/230/142.

Hasan, M. H., Mahlia, T. M. I. and Nur, H. (2012) 'A review on energy scenario and sustainable energy in Indonesia', *Renewable and Sustainable Energy Reviews*, 16(4), pp.

2316–2328. doi: 10.1016/j.rser.2011.12.007.

Huang, D., Zhou, H. and Lin, L. (2012) 'Biodiesel: An alternative to conventional fuel', *Energy Procedia*, 16(PART C), pp. 1874–1885. doi: 10.1016/j.egypro.2012.01.287.

IEA (2021) 'Global Energy Review 2021 – Analysis - IEA', *International Energy Agency*. Available at: https://www.iea.org/reports/global-energy-review-2021.

Irawati, U. and Suraida, S. (2013) 'Synthesis And Characterization Gamma Alumina (γ-Al2O3) From Kaolin Of Tatakan, South Kalimantan Based On Temperature Variation Of Calcination', *Molekul*, 8(1), pp. 31–42.

Ivanova, N. *et al.* (2016) 'We are IntechOpen , the world ' s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %', *Intech*, i(tourism), p. 13.

Johnsson, F., Kjärstad, J. and Rootzén, J. (2019) 'The threat to climate change mitigation posed by the abundance of fossil fuels', *Climate Policy*, 19(2), pp. 258–274. doi: 10.1080/14693062.2018.1483885.

Jonsson, A. S. (1995) 'Concentration Polarization and Fouling during Ultrafiltration of Colloidal Suspensions and Hydrophobic Solutes', *Separation Science and Technology*, 30(2), pp. 301–312. doi: 10.1080/01496399508015840.

Kaolin (2019) *Encyclopedia of Britannica*. Available at: https://www.britannica.com/science/kaolin.

Ladewig, B. and Al-Shaeli, M. N. Z. (2017) 'Fundamentals of Membrane Bioreactors', (November 2020), pp. 13–38. doi: 10.1007/978-981-10-2014-8.

Meliyanti, M. *et al.* (2018) 'Ceramic membrane development and characterization for microfiltration', *AIP Conference Proceedings*, 2024(November). doi: 10.1063/1.5064344.

MJ, A. *et al.* (2013) 'Biodiesel purification using micro and ultrafiltration membranes', *Renew Energy*, (58), pp. 15–20.

Pagliero, M. *et al.* (2020) 'Silanization of tubular ceramic membranes for application in membrane distillation', *Journal of Membrane Science*, 601(November 2019), p. 117911. doi: 10.1016/j.memsci.2020.117911.

Pasae, Y., Salla, Y. and Bulo, L. (2020) 'Properties of Biodiesel Purified by Membrane Technology', *Asian Journal of Applied Chemistry Research*, 5(0), pp. 21–27. doi: 10.9734/ajacr/2020/v5i430142.

Rahayu, S. S. and Mindaryani, A. (2007) 'Optimization of Biodiesel Washing by Water Extraction', *Wcecs 2007*, p. 1059.

Rapier, R. (2020) 'Fossil Fuels Still Supply 84 Percent of World Energy - and Other Eye Openers from BP's Annual Review', *Forbes*, June. Available at: https://www.forbes.com/sites/rrapier/2020/06/20/bp-review-new-highs-in-global-energy-consumption-and-carbon-emissions-in-2019/?sh=7f94e96666a1.

Redjeki, S. (2011) 'Direktorat Penelitian dan Pengabdian kepada Masyarakat (DP2M) Direktorat Jendral Pendidikan Tinggi Departement Pendidikan Nasional', *Proses Desalinasi Dengan Membran*, Direktorat, p. 215.

Rostami, M. *et al.* (2012) 'Liquid-liquid phase equilibria of systems of palm and soya biodiesels: Experimental and modeling', *Industrial and Engineering Chemistry Research*, 51(24), pp. 8302–8307. doi: 10.1021/ie300093p.

Saleh, J. (2011) 'A Membrane Separation Process for Biodiesel Purification', p. 242. Available at: https://ruor.uottawa.ca/bitstream/10393/19730/5/Saleh_Jehad_2011_thesis.pdf.

Saleh, J., Dubé, M. A. and Tremblay, A. Y. (2011) 'Separation of glycerol from FAME using ceramic membranes', *Fuel Processing Technology*, 92(7), pp. 1305–1310. doi: 10.1016/j.fuproc.2011.02.005.

Saleh, J., Tremblay, A. Y. and Dubé, M. A. (2010) 'Glycerol removal from biodiesel using membrane separation technology', *Fuel*, 89(9), pp. 2260–2266. doi: 10.1016/j.fuel.2010.04.025.

Schmidt, C. W. (2007) 'Biodiesel: cultivating alternative fuels', *Environmental health perspectives*, 115(2), pp. A86–A91. doi: 10.1289/ehp.115-a86.

Soleimani, E. and Zamani, N. (2017) 'Surface modification of alumina nanoparticles: A dispersion study in organic media', *Acta Chimica Slovenica*, 64(3), pp. 644–653. doi: 10.17344/acsi.2017.3459.

Song, S. *et al.* (2022) 'Pore-scale numerical study of intrinsic permeability for fluid flow through asymmetric ceramic microfiltration membranes', *Journal of Membrane Science*, 642(October), p. 119920. doi: 10.1016/j.memsci.2021.119920.

Suresh, K. and Pugazhenthi, G. (2017) 'Cross flow microfiltration of oil-water emulsions using clay based ceramic membrane support and TiO2 composite membrane', *Egyptian Journal of Petroleum*, 26(3), pp. 679–694. doi: 10.1016/j.ejpe.2016.10.007.

The American Ceramic Society and Ceramic and Glass Industry Foundation (no date) 'TEACHER INSTRUCTIONS - Ceramic Processing: Slip Casting', pp. 1–11. Available at: http://ceramics.org/wp-content/uploads/2014/04/Slip-Casting-Lesson-111.pdf.

Thommes, M. *et al.* (2015) 'Physisorption of gases, with special reference to the evaluation of surface area and pore size distribution (IUPAC Technical Report)', *Pure and Applied Chemistry*, 87(9–10), pp. 1051–1069. doi: 10.1515/pac-2014-1117.

Ulyani, V. (2008) *Reaksi Katalisis Oksidasi Vanili Menjadi Asam Vanilat Menggunakan Katalis TiO2Al2O3 (1:1) yang Dibuat dengan PEG 6000*. Universitas Indonesia.

US Energy Information Administration (2021) *International Energy Outlook 2021*.

USDA, U. S. D. of A. (2020) 'Biofuels Annual Report', pp. 1–20.

Utari, T. (1994) *Pembuatan Adsorben Alumina Dari Kaolin*. Universitas Indonesia.

Veljković, V. B., Banković-Ilić, I. B. and Stamenković, O. S. (2015) 'Purification of crude biodiesel obtained by heterogeneously-catalyzed transesterification', *Renewable and Sustainable Energy Reviews*, 49, pp. 500–516. doi: 10.1016/j.rser.2015.04.097.

Wang, Y. *et al.* (2009) 'Refining of biodiesel by ceramic membrane separation', *Fuel Processing Technology*, 90(3), pp. 422–427. doi: 10.1016/j.fuproc.2008.11.004.

Wibowo, A., Febriansyah, H. and Suminto, S. (2019) 'Pengembangan Standar Biodiesel B20 Mendukung Implementasi Diversifikasi Energi Nasional', *Jurnal Standardisasi*, 21(1), p. 55. doi: 10.31153/js.v21i1.736.

APPENDICES

Appendix 1. Microfiltration Experiment Documentations

Figure 1. Microfiltration Experiment with Feed of Biodiesel-Glycerol mixture

Figure 2. Collection of Permeate Samples

Figure 3. Mixing of Biodiesel and Glycerol-Water using Magnetic Stirrer

Figure 4. Pressure Gauge Reading at 0.5 kg/cm during Microfiltration Experiments

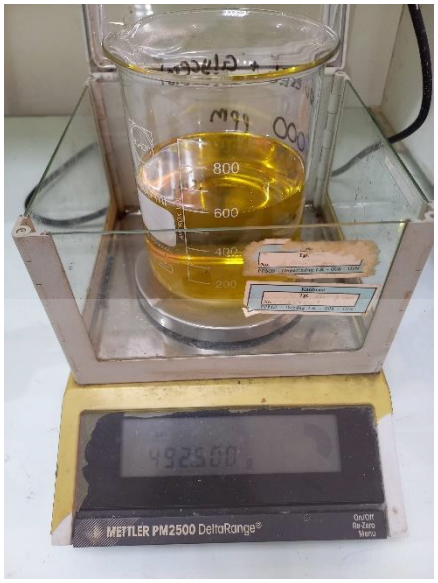


Figure 5. Weighing Biodiesel for Feed Mixture Preparations

Appendix 2. Pure Biodiesel Permeate Flux through Alumina-Kaolin Ceramic Membrane

Transmembrane Pressure = *0.5 kg/cm^2*
Retentate Flow Rate = *135 ml/min*
Membrane inner diameter = *5 mm*
Membrane length = *80 mm*
Active area of flow = *0.001256 m^2*

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [l/(m^{2}h)]
10	10	0.17	13.60	0.0136	64.97
20	10	0.17	14.24	0.0142	68.02
30	10	0.17	13.95	0.0140	66.64
40	10	0.17	14.02	0.0140	66.96
50	10	0.17	13.73	0.0137	65.57
60	10	0.17	13.60	0.0136	64.97
70	10	0.17	13.15	0.0132	62.82
80	10	0.17	13.15	0.0132	62.82
90	10	0.17	14.50	0.0145	69.27
100	10	0.17	13.88	0.0139	66.28
110	10	0.17	13.85	0.0139	66.16
120	10	0.17	13.75	0.0138	65.68
			Stable permeate flux [l/(m^{2}h)]		66.85

Appendix 3. Pure Biodiesel Permeate Flux through Commercial Alumina Membrane

Transmembrane Pressure = *0.5 kg/cm^2*
Retentate Flow Rate = *154 ml/min*
Membrane inner diameter = *7 mm*
Membrane length = *70 mm*
Active area of flow = *0.00154 m^2*

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [l/(m^{2}h)]
10	10	0.17	80.29	0.080	313.10
20	10	0.17	86.72	0.087	338.18
30	10	0.17	82.08	0.082	320.08
40	10	0.17	82.01	0.082	319.81
50	10	0.17	79.07	0.079	308.35
60	10	0.17	74.32	0.074	289.82
70	10	0.17	65.25	0.065	254.45
80	10	0.17	63.28	0.063	246.77
90	10	0.17	63.23	0.063	246.57
100	10	0.17	62.38	0.062	243.26
110	10	0.17	62.45	0.062	243.53
120	10	0.17	59.27	0.059	231.11
			Stable Permeate Flux [l/(m^{2}h)]		241.12

Appendix 4. Permeate Flux of Biodiesel with Glycerol Feed Concentration of 1000 ppm through Alumina-Kaolin Membrane

Transmembrane Pressure = *0.5 kg/cm^2*
Membrane inner diameter = *5 mm*
Membrane length = *80 mm*
Active area of flow = *0.001256 m^2*

Composition of Feed	Mass (gram)	Notes	Concentration (ppm)
Water	1	*0.2% wt	2000
Glycerol	0.5	*0.1% wt.	1000
Pure Biodiesel	498.5		
total	500		

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [l/(m^{2}h)]
10	10	0.17	15.14	0.015	72.31
20	10	0.17	14.68	0.015	70.10
30	10	0.17	14.40	0.014	68.77
40	10	0.17	13.23	0.013	63.18
50	10	0.17	14.35	0.014	68.55
60	10	0.17	14.36	0.014	68.60
70	10	0.17	14.55	0.015	69.51
80	10	0.17	14.30	0.014	68.31
90	10	0.17	13.85	0.014	66.16
100	11	0.18	13.95	0.014	60.58
111	10	0.17	14.00	0.014	66.88
121	10	0.17	14.25	0.014	68.07
			Stable permeate flux [l/(m^{2}h)]		65.42

Appendix 5. Permeate Flux of Biodiesel with Glycerol Feed Concentration of 5000 ppm through Alumina-Kaolin Membrane

Transmembrane Pressure = *0.5 kg/cm^2*
Membrane inner diameter = *5 mm*
Membrane length = *80 mm*
Active area of flow = *0.001256 m^2*

Compositions	Mass (gram)	Notes	Concentration (ppm)
Water	5	*1 wt.%	10000
Glycerol	2.5	* 0.5 wt.%	5000
Pure Biodiesel	492.5		
total	500		

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [l/(m^{2}h)]
10	10	0.166667	14.4	0.014	68.79
20	10	0.166667	13.6	0.014	64.97
30	10	0.166667	13.379	0.013	63.91
40	10	0.166667	14	0.014	66.88
50	10	0.166667	13.85	0.014	66.16
60	10	0.166667	13.65	0.014	65.211
70	10	0.166667	13.3	0.013	63.54
80	10	0.166667	12.9	0.013	61.62
90	10	0.166667	12.85	0.013	61.39
100	10	0.166667	12.75	0.013	60.91
110	10	0.166667	12.5	0.013	59.71
120	10	0.166667	13.05	0.013	62.34
			Stable permeate flux [l/(m^{2}h)]		61.09

Appendix 6. Permeate Flux of Biodiesel with Glycerol Feed Concentration of 10000 ppm through Alumina-Kaolin Membrane

Transmembrane Pressure = *0.5 kg/cm^2*
Membrane inner diameter = *5 mm*
Membrane length = *80 mm*
Active area of flow = *0.001256 m^2*

Composition of Feed	Mass (gram)	Notes	Concentration (ppm)
Water	10	*2% wt	20000
Glycerol	5	*1% wt.	10000
Pure Biodiesel	485		
total	500		

Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [l/(m^{2}h)]
10	0.17	12.90	0.013	61.62
10	0.17	12.55	0.013	59.95
10	0.17	12.00	0.012	57.32
10	0.17	11.84	0.012	56.56
10	0.17	11.71	0.011	55.94
10	0.17	11.31	0.011	54.03
10	0.17	11.50	0.012	54.94
11	0.18	11.41	0.011	49.55
10	0.17	11.19	0.011	53.46
10	0.17	10.60	0.011	50.64
10	0.17	11.01	0.011	52.60
10	0.17	11.50	0.012	54.94
		Stable permeate flux [l/(m^{2}h)]		52.91

Appendix 7. Permeate Flux of Biodiesel with Glycerol Feed Concentration of 1000 ppm through Commercial Alumina Membrane

Transmembrane Pressure = *0.5 kg/cm^2*
Membrane inner diameter = *7 mm*
Membrane length = *70 mm*
Active area of flow = *0.00154 m^2*

Composition of Feed	Mass (gram)	Notes	Concentration (ppm)
Water	2.4	*0.2% wt	2000
Glycerol	1.2	*0.1% wt.	1000
Pure Biodiesel	1196.4		
total	1200		

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [l/(m^{2}h)]
10	10	0.17	63.37	0.063	247.12
20	10	0.17	45.27	0.045	176.54
30	10	0.17	38.72	0.038	150.99
40	10	0.17	31.60	0.032	123.23
50	10	0.17	26.55	0.027	103.54
60	10	0.17	21.20	0.021	82.67
70	10	0.17	18.10	0.018	70.58
80	10	0.17	15.70	0.015	61.22
90	10	0.17	14.70	0.015	57.32
100	10	0.17	13.85	0.014	54.01
110	10	0.17	12.50	0.013	48.75
120	10	0.17	11.80	0.012	46.02
			Stable Permeate Flux [l/(m^{2}h)]		49.59

Appendix 8. Permeate Flux of Biodiesel with Glycerol Feed Concentration of 5000 ppm through Commercial Alumina Membrane

Transmembrane Pressure = *0.5 kg/cm^2*
Membrane inner diameter = *7 mm*
Membrane length = *70 mm*
Active area of flow = *0.00154 m^2*

Composition of Feed	Mass (gram)	Notes	Concentration (ppm)
Water	12	*1% wt	10000
Glycerol	6	*0.5% wt.	5000
Pure Biodiesel	1182		
total	1200		

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [l/(m^{2}h)]
10	10	0.17	31.10	0.031	121.28
20	10	0.17	25.63	0.026	99.95
30	10	0.17	24.26	0.024	94.59
40	10	0.17	22.80	0.023	88.91
50	10	0.17	20.85	0.021	81.31
60	10	0.17	21.55	0.022	84.04
70	10	0.17	20.58	0.021	80.25
80	10	0.17	20.48	0.020	79.85
90	10	0.17	19.54	0.020	76.20
100	10	0.17	19.95	0.020	77.80
110	10	0.17	19.40	0.019	75.65
120	10	0.17	18.68	0.019	72.83
			Stable Permeate Flux [l/(m^{2}h)]		75.62

Appendix 9. Permeate Flux of Biodiesel with Glycerol Feed Concentration of 10000 ppm through Commercial Alumina Membrane

Transmembrane Pressure = *0.5 kg/cm^2*
Membrane inner diameter = *7 mm*
Membrane length = *70 mm*
Active area of flow = *0.00154 m^2*

Composition of Feed	Mass (gram)	Notes	Concentration (ppm)
Water	15	*2% wt	20000
Glycerol	7.5	*1% wt.	10000
Pure Biodiesel	727.5		
total	750		

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (l)	permeate flux [l/(m^{2}h)]
10	10	0.17	26.70	0.027	104.12
20	10	0.17	23.48	0.023	91.54
30	10	0.17	22.93	0.023	89.42
40	10	0.17	21.89	0.022	85.36
50	10	0.17	21.37	0.021	83.32
60	10	0.17	21.54	0.022	84.00
70	10	0.17	20.68	0.021	80.64
80	10	0.17	19.34	0.019	75.40
90	10	0.17	19.08	0.019	74.39
100	10	0.17	19.01	0.019	74.11
110	10	0.17	18.12	0.018	70.64
120	10	0.17	18.72	0.019	73.00
			Stable Permeate Flux [l/(m^{2}h)]		73.04

Appendix 10. Glycerol Rejection Rate of Alumina-Kaolin

- **Preparation of the Standard Curve**
  - Concentration of glycerol reference Solution = 0.03 mg/ml = 30 ppm
  - Final standard sample volume = 2 ml
  - Concentration of standard samples

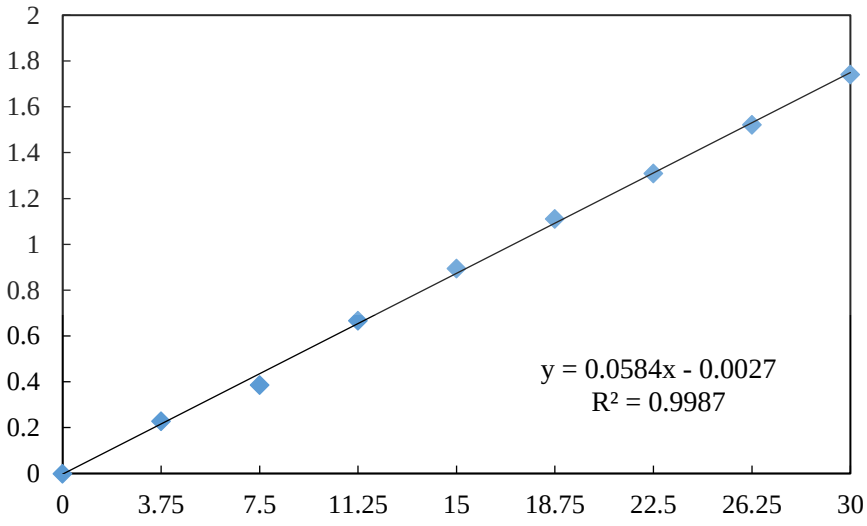
$$[Standard] = \frac{[Reference\ ] \times Volume\ \ Glycerol\ Reference\ Solution}{Final\ Volume}$$

Example of calculation:

Volume of glycerol reference solution = 0 ml
Volume of working solvent = 2 ml
Final volume = 2 ml
Glycerol reference concentration = 30 ppm
Concentration of Standard:

$$[Standard] = \frac{30\ ppm \times 0\ ml}{2\ ml} = \ 0\ ppm$$

Volume Glycerol Working Solution (ml)	Working solvent (ml)	Final Volume of Standard Solution (ml)	Concentration of the Standard Solution (ppm)	Absorbance Value at λ =410 nm
0.00	2	2	0	0
0.25	1.75	2	3.75	0.228
0.50	1.50	2	7.5	0.386
0.75	1.25	2	11.25	0.667
1.00	1.00	2	15	0.895
1.25	0.75	2	18.75	1.111
1.50	0.50	2	22.5	1.31
1.75	0.25	2	26.25	1.522
2.00	0.00	2	30	1.742



- **Dilution Factor (DF) Calculation**

  Assumption of Biodiesel density = 1 g/ml

  a. 1st Dilution Factor : Liquid-Liquid Extraction of glycerol using hexane (non-polar) and ethanol aqueous solution (polar)

Weight of Permeate Sample	*:*	*1 g*
Maximum concentration in the permeate sample	*:*	*1000 mg/l = 1 mg/ml*
Volume of Hexane phase (non-polar; contain biodiesel)	*:*	*4 ml*
Volume of working solvent phase (polar; contain glycerol)	*:*	*4 ml*
Concentration of glycerol in polar phase	*:*	*1 mg/ 4 ml = 0.25 mg/ml*

$$Dilution\ Factor\ (DF) = \frac{Final\ Volume\ of\ Diluted\ Solution}{Initial\ Volume\ of\ Undiluted\ Sample} = \frac{4\ ml}{1\ ml} = 4$$

  b. 2nd Dilution Factor : Sample Dilution before UV-Vis Spectrophotometer Reading

Sample Initial Volume	*:*	*4 ml*
Volume taken from the Sample to be diluted	*:*	*0.5 ml*
Volume of Final Solution	*:*	*2 ml*
Concentration of glycerol in the transferred solution	*:*	*0.25 mg/ml*
Concentration of glycerol the final solution	*:*	*0.0625 mg/ml*

$$Dilution\ Factor\ (DF) = \frac{Final\ Volume\ of\ Diluted\ Solution}{Initial\ Volume\ of\ Undiluted\ Sample} = \frac{2\ ml}{0.5\ ml} = 4$$

Thus, the total dilution factor used in this experiment become:

$$Dilution\ Factor\ (DF) = 1st\ DF \times 2nd\ DF = 4 \times 4 = 16$$

- **Calculation of the Glycerol Concentration in the Permeate**

Calculation to convert the sample absorbance value into concentration of glycerol according to the standard curve (ppm) were done based on the linear regression of the standard curve as shown in Figure 4.4:

$$y = 0.0584x - 0.0027$$

x = Glycerol Concentration based on Standard Curve (ppm)

y = Absorbance value

Example of calculation for glycerol concentration in permeate:

- Absorbance value (y) = 0.24
- Glycerol Concentration (Calibration Curve) (x)

$$= \frac{y + 0.0027}{0.0584} = \frac{0.24 + 0.0027}{0.0584} = 4.14\ ppm$$

After the calculation of the concentration according to the standard, the actual concentration of glycerol in the permeate C_p (ppm):

$C_p =$ [Glycerol Standard Curve] × DF

DF = 16

Example of calculation of glycerol concentration in permeate C_p (ppm):

- Glycerol Concentration (Calibration Curve) = 4.14
- Permeate glycerol concentration C_p

$$C_p = [Glycerol\ Standard\ Curve] \times 16 = 4.14 \times 16 = 66.22\ ppm$$

- **Calculation of Glycerol Rejection Rate**
  Calculation was done based on the equation below:

$$R = \left(1 - \frac{C_p}{C_f}\right) \times 100\%$$

Example of calculation:

- Concentration of glycerol in permeate C_p = 66.22 ppm
- Concentration of glycerol in Feed C_f = 1000 ppm
- Rejection rate =

$$R = \left(1 - \frac{C_p}{C_f}\right) \times 100\% = \left(1 - \frac{66.2\ ppm}{1000\ ppm}\right) \times 100\% = 93.38\%$$

1) Data of Glycerol Concentration in Permeate C_p and Rejection Rate of C_f at 1000 ppm of Alumina-Kaolin Membrane

time (min)	permeate volume (L)	Glycerol Absorbance Value	Glycerol Concentration (Calibration Curve) (ppm)	Permeate Glycerol Concentration C_p (ppm)	Glycerol Rejection Rate (%)
10	0.015	0.239	4.14	66.22	93.38
20	0.015	0.264	4.57	73.07	92.69
30	0.014	0.160	2.79	44.58	95.54
40	0.013	0.220	3.81	61.01	93.90
50	0.014	0.298	5.15	82.38	91.76
60	0.014	0.350	6.04	96.63	90.34
70	0.015	0.336	5.80	92.79	90.72
80	0.014	0.339	5.85	93.62	90.64
90	0.014	0.345	5.95	95.26	90.47
100	0.014	0.325	5.61	89.78	91.02
111	0.014	0.333	5.75	91.97	90.80
121	0.014	0.231	4.00	64.03	93.60
Average				**79.28**	**92.07**
Standard Deviation				**17.07**	

2) Data of Glycerol Concentration in Permeate C_p and Rejection Rate of C_f at 5000 ppm of Alumina-Kaolin Membrane

time (min)	permeate volume (L)	Glycerol Absorbance Value	Glycerol Concentration (Calibration Curve) (ppm)	Sample Actual Concentration (ppm)	Glycerol Rejection Rate (%)
10	0.014	0.194	3.37	53.89	98.92
20	0.014	0.228	3.95	63.21	98.74
30	0.013	0.209	3.63	58.00	98.84
40	0.014	0.284	4.91	78.55	98.43
50	0.014	0.243	4.21	67.32	98.65
60	0.014	0.285	4.93	78.82	98.42
70	0.013	0.383	6.60	105.67	97.89
80	0.013	0.283	4.89	78.27	98.43
90	0.013	0.323	5.58	89.23	98.22
100	0.013	0.264	4.57	73.07	98.54
110	0.013	0.280	4.84	77.45	98.45
120	0.013	0.233	4.04	64.58	98.71
Average				**74.00**	**98.52**
Standard Deviation				**14.21**	

3) Data of Glycerol Concentration in Permeate C_p and Rejection Rate of C_f at 10000 ppm of Alumina Kaolin Membrane

time (min)	permeate volume (L)	Glycerol Absorbance Value	Glycerol Concentration (Calibration Curve) (ppm)	Sample Actual Concentration (ppm)	Glycerol Rejection Rate (%)
10	0.013	0.216	3.74	59.92	98.80
20	0.013	0.202	3.51	56.08	98.88
30	0.012	0.192	3.33	53.34	98.93
40	0.012	0.208	3.61	57.73	98.85
50	0.012	0.152	2.65	42.38	99.15
60	0.011	0.135	2.36	37.73	99.25
70	0.012	0.235	4.07	65.12	98.70
81	0.011	0.189	3.28	52.52	98.95
90	0.011	0.202	3.51	56.08	98.88
100	0.011	0.24	4.16	66.49	98.67
110	0.011	0.155	2.70	43.21	99.14
120	0.012	0.164	2.85	45.67	99.09
Average				**53.02**	**98.94**
Standard Deviation				**9.12**	

4) Data of Glycerol Concentration in Permeate C_p and Rejection Rate of C_f at 1000 ppm of Commercial Alumina Membrane

time (min)	permeate volume (L)	Glycerol Absorbance Value	Glycerol Concentration (Calibration Curve) (ppm)	Sample Actual Concentration (ppm)	Glycerol Rejection Rate (%)
10	0.063	0.342	5.90	94.44	90.56
20	0.045	0.354	6.11	97.73	90.23
30	0.039	0.336	5.80	92.79	90.72
40	0.032	0.306	5.29	84.58	91.54
50	0.027	0.336	5.80	92.79	90.72
60	0.021	0.342	5.90	94.44	90.56
70	0.018	0.363	6.26	100.19	89.98
80	0.016	0.385	6.64	106.22	89.38
90	0.015	0.353	6.09	97.45	90.25
100	0.014	0.288	4.98	79.64	92.04
110	0.013	0.282	4.88	78.00	92.20
120	0.012	0.271	4.69	74.99	92.50
Average				**91.11**	**90.89**
Standard Deviation				**9.67**	

5) Data of Glycerol Concentration in Permeate C_p and Rejection Rate of C_f at 5000 ppm of Commercial Alumina Membrane

time (min)	permeate volume (L)	Glycerol Absorbance Value	Glycerol Concentration (Calibration Curve) (ppm)	Sample Actual Concentration (ppm)	Glycerol Rejection Rate (%)
10	0.031	0.197	3.42	54.71	98.91
20	0.026	0.190	3.30	52.79	98.94
30	0.024	0.184	3.20	51.15	98.98
40	0.023	0.164	2.85	45.67	99.09
50	0.021	0.172	2.99	47.86	99.04
60	0.022	0.194	3.37	53.89	98.92
70	0.021	0.161	2.80	44.85	99.10
80	0.020	0.045	0.82	13.07	99.74
90	0.020	0.145	2.53	40.47	99.19
100	0.020	0.146	2.55	40.74	99.19
110	0.019	0.142	2.48	39.64	99.21
120	0.019	0.167	2.91	46.49	99.07
Average				**44.28**	**99.11**
Standard Deviation				**11.13**	

6) Data of Glycerol Concentration in Permeate C_p and Rejection Rate of C_f at 10000 ppm of Commercial Alumina Membrane

time (min)	permeate volume (L)	Glycerol Absorbance Value	Glycerol Concentration (Calibration Curve) (ppm)	Sample Actual Concentration (ppm)	Glycerol Rejection Rate (%)
10	0.027	0.136	2.38	38.00	99.62
20	0.023	0.203	3.52	56.36	99.44
30	0.023	0.162	2.82	45.12	99.55
40	0.022	0.214	3.71	59.37	99.41
50	0.021	0.141	2.46	39.37	99.61
60	0.022	0.225	3.90	62.38	99.38
70	0.021	0.341	5.89	94.16	99.06
80	0.019	0.389	6.71	107.32	98.93
90	0.019	0.288	4.98	79.64	99.20
100	0.019	0.336	5.80	92.79	99.07
110	0.018	0.370	6.38	102.11	98.98
Average				**70.60**	**99.29**
Standard Deviation				**25.60**	

- **Documentations of Experiment**

Figure 6. pH test for the Buffer Solution using Universal Indicator shows the value between 5.0-6.0

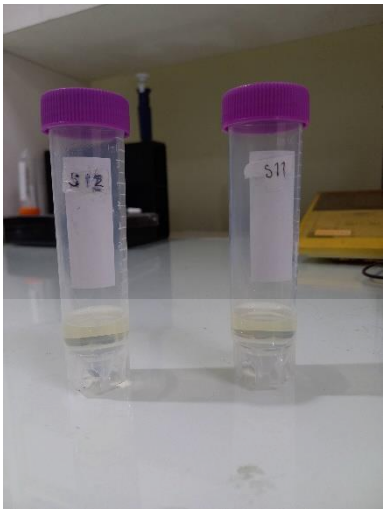


Figure 7. Addition of Hexane and ethanol 95% aqueous 1:1 solution to the sample

Appendix 11. Flux Decline Ratio (FDR) Calculation

All of the calculation done for the Flux Decline Ratio were based on the equation in subchapter 3.4.2.3 which is:

$$FDR = \left(1 - \frac{J_s}{J_1}\right) \times 100\%$$

With J_s as the permeate flux of biodiesel containing glycerol in ([l/(m^{2}h)]), J_1 as the initial pure biodiesel permeate flux in ([l/(m^{2}h)])

The example of the calculation of FDR was as followed:

- Glycerol Feed Concentration = 1000 ppm
- Permeate flux of biodiesel containing glycerol, J_s = 65.42 [l/(m^{2}h)]
- Initial Pure Biodiesel permeate flux, J_1 = 66.85 [l/(m^{2}h)]

$$FDR = \left(1 - \frac{65.42}{66.85}\right) \times 100\% = 2.13\%$$

Membrane Type	Glycerol Feed Concentration (ppm)	Stable Permeate Flux (*Js*) ([l/(m^{2}h)])	Initial Pure Biodiesel Flux (J_1) ([l/(m^{2}h)]	FDR (%)
Alumina - Kaolin Membrane	1000	65.42	66.85	2.13
	5000	61.09		8.62
	10000	52.91		20.86
Alumina Membrane	1000	49.59	241.12	79.43
	5000	75.62		68.64
	10000	73.04		69.71

Appendix 12. Permeate flux of Biodiesel after Alumina-Kaolin Ceramic Membrane Washing using Pure Biodiesel (After Experiment of Feed Concentration 10000 ppm)

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (l)	permeate flux ([l/(m^{2}h)])
10	10	0.17	8.82	0.01	42.11
20	10	0.17	9.62	0.01	45.96
30	10	0.17	9.59	0.01	45.79
40	10	0.17	9.19	0.01	43.90
50	10	0.17	8.89	0.01	42.47
60	10	0.17	9.03	0.01	43.14
70	10	0.17	9.00	0.01	42.97
80	10	0.17	8.70	0.01	41.54
90	10	0.17	9.09	0.01	43.40
100	10	0.17	9.21	0.01	44.00
110	10	0.17	9.33	0.01	44.55
120	10	0.17	9.48	0.01	45.26
			Stable Permeate Flux ([l/(m^{2}h)])		44.30

Appendix 13. Permeate flux of Biodiesel after Commercial Alumina Ceramic Membrane Washing using Pure Biodiesel

- **Washing after 1000 ppm**

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [L/(m²h)]
10	10	0.17	17.4	0.017	67.85
20	10	0.17	20.5	0.021	79.94
30	10	0.17	25.08	0.025	97.80
40	10	0.17	26.27	0.026	102.44
50	10	0.17	28.9	0.029	112.70
60	10	0.17	28.21	0.028	110.01
70	10	0.17	28.65	0.029	111.72
80	10	0.17	28.05	0.028	109.39
90	10	0.17	29.2	0.029	113.87
100	10	0.17	29.25	0.029	114.06
110	10	0.17	29.15	0.029	113.67
120	10	0.17	28.75	0.029	112.11
			Stable Permeate Flux [L/(m²h)]		113.43

- **Washing after 5000 ppm**

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [L/(m²h)]
10	10	0.17	33.66	0.034	131.26
20	10	0.17	33.10	0.033	129.08
30	10	0.17	34.20	0.034	133.37
40	10	0.17	34.10	0.034	132.98
50	10	0.17	34.20	0.034	133.37
60	10	0.17	33.99	0.034	132.55
70	10	0.17	33.24	0.033	129.62
80	10	0.17	32.28	0.032	125.88
90	10	0.17	30.46	0.030	118.76
100	11	0.18	30.14	0.030	106.85
111	10	0.17	29.77	0.030	116.07
121	10	0.17	29.12	0.029	113.54
			Stable Permeate Flux [L/(m²h)]		113.81

- **Washing after 10000 ppm**

time (min)	Δ time (min)	Δ time (hour)	permeate volume (ml)	permeate volume (L)	permeate flux [L/(m²h)]
10	11	0.18	19.24	0.019	68.19
21	10	0.17	17.14	0.017	66.82
31	10	0.17	16.70	0.017	65.12
41	10	0.17	16.60	0.017	64.73
51	10	0.17	17.10	0.017	66.68
61	10	0.17	16.92	0.017	65.96
71	10	0.17	16.91	0.017	65.92
81	10	0.17	16.10	0.016	62.78
91	10	0.17	15.24	0.015	59.43
101	11	0.18	15.53	0.016	55.04
111	10	0.17	15.38	0.015	59.98
121	10	0.17	15.74	0.016	61.36
			Stable Permeate Flux [L/(m²h)]		58.95

Appendix 14. Flux Recovery Ratio (FRR) Calculation

All of the calculation done for the Flux Decline Ratio were based on the equation in subchapter 3.4.2.3 which is:

$$FRR = \left(\frac{J_2}{J_1}\right) \times 100\%$$

With J_1 as the initial pure biodiesel permeate flux in ([l/(m^{2}h)]) and J_2 is the pure biodiesel permeate flux after the washing process of 1 hour.

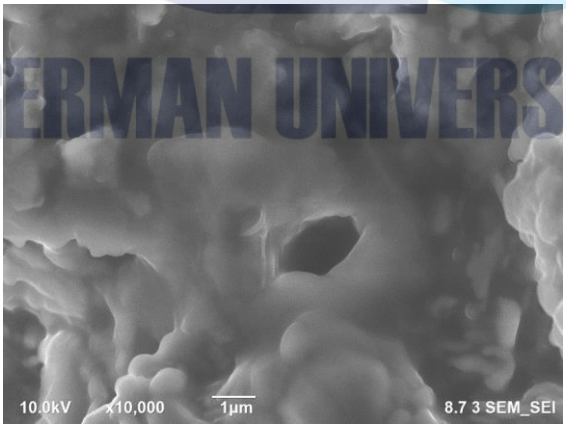
The example of the calculation of FDR was as followed:

- Glycerol Feed Concentration = 1000 ppm
- Initial Pure Biodiesel permeate flux, J_1 = 66.85 [l/(m^{2}h)]
- Pure biodiesel permeate flux after washing, J_2 = 44.30 [l/(m^{2}h)]

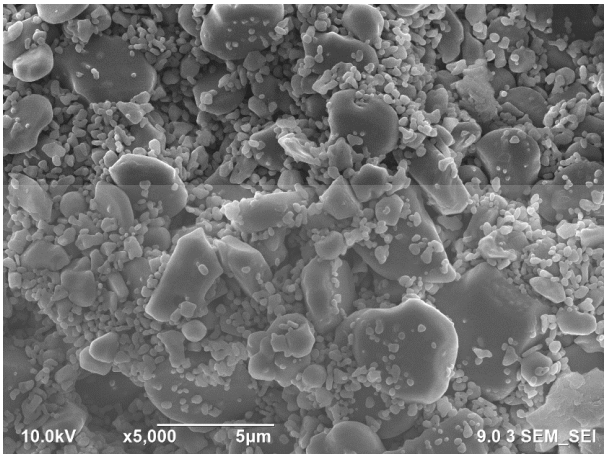
$$FRR = \left(\frac{J_2}{J_1}\right) \times 100\% = \left(\frac{44.30\ [\mathrm{l/(m2h)}]}{66.85\ [\mathrm{l/(m2h)}]}\right) \times 100\% = 66.27\%$$

Membrane Type	**Glycerol Feed Concentration Before Washing (ppm)**	**Initial Pure Biodiesel Flux (J_1) ([l/(m^{2}h)]**	**Pure Biodiesel Flux After Washing (J_2)**	**FDR (%)**
Alumina - Kaolin Membrane	10000	66.85	44.30	66.27
Alumina Membrane	1000	241.12	113.43	47.04
	5000		113.81	49.24
	10000		58.95	24.45

Appendix 15. SEM Image of Alumina-Kaolin Ceramic Membrane Inner Surface at 10000x Magnification



Appendix 16. SEM Image of Commercial Alumina Ceramic Membrane Inner Surface at 5000x Magnification



Appendix 17. Documentations of Fabrication of the Alumina-Kaolin Ceramic Membrane Processes

Figure 8. Weighing Dry Powder for Preparation of the Alumina-Kaolin Ceramic Suspension

Figure 9. Dolapix PC67 (Left) and Dolapix CE64 (Right) as the Deflocculant

Figure 10. Ceramic suspension mixing using Pot Mill

Figure 11. Slip Casting the Ceramic Suspension into the Tubular Gypsum Mould

Figure 12. Drying of the Casted Membrane in Room Temperature

Figure 13. Finishing of the Casted Membrane before Drying in Oven

Figure 14. Drying the Casted Membrane in the Oven

Figure 15. Sintering the Casted Membrane using Furnace

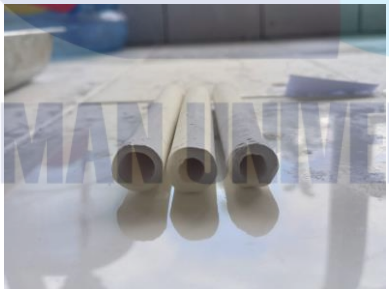


Figure 16. Alumina-Kaolin Membrane Produced using Dolapix PC67 in different Slip Casting Time (3 minutes, 5 minutes and 6 minutes)

Figure 17. Alumina-Kaolin Membrane Produced using Dolapix CE64 in different Slip Casting Time (3 minutes, 5 minutes and 6 minutes)

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Education

2021	Fachhochschule Südwestfalen, Soest, Germany (majoring in Chemical Engineering as part of the double degree program)
2018 – 2022	Swiss German University, Tangerang (majoring in Pharmaceutical Chemical Engineering)
2015 – 2018	SMA Plus Pembangunan Jaya (majoring in Science)
2012 – 2015	SMP Pembangunan Jaya
2006 – 2012	SD Pembangunan Jaya

Organizational Experience

2019 – 2021	Secretary of SGU Student House of Representatives
2020	Head of SGU Traditional Dance Club (Tratan)
2020	Treasurer of SGU Association of Chemical Engineering Student (ACES)
2019	Secretary in LS Night Event
2018 – 2019	Member of SGU Student House of Representatives Assessor and Developer division

Internship Experience

03/2021 – 08/ 2021	Internship at Apotheke im Centr-o-med, Datteln, Germany in the Pharmacy Laboratory
12/2019 - 02/2020	Internship at PT Sandoz Indonesia, East Jakarta, Indonesia in the Manufacturing Science and Technology (MS&T) department

Key Skills & Interest

Language Skills	Bahasa Indonesia (*mother tongue)* English (*fluent*) German (Basic B1)
Computer Skills	Microsoft Office (*proficient in Word, Excel, Powerpoint)*
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