

BAB V

KESIMPULAN DAN SARAN

KESIMPULAN

1. Kapasitas adsorpsi MIL101Fe@Alg adalah yang tertinggi, yakni bernilai 109,439 mg/g, sedangkan kapasitas adsorpsi MIL100Fe@Alg adalah 103,413 mg/g dan kapasitas adsorpsi Fe@Alg sebesar 75,244 mg/g.
2. Ketiga adsorben dapat digunakan kembali sebanyak 2 kali.
3. Adsorben mampu melepaskan fosfat sekitar 6% untuk Fe@Alg dan sekitar 2% untuk MIL100Fe@Alg dan MIL101Fe@Alg dalam waktu 6 jam pemaparan cahaya matahari.

SARAN

1. Jika ingin menjalankan percobaan serupa, sebaiknya gunakan metode *in situ* dalam mengkombinasikan MOF dengan hidrogel alginat agar proses sintesa lebih cepat dan tidak mengkonsumsi banyak energi.
2. Direkomendasikan untuk melakukan uji coba kadar besi pada larutan fosfat sisa untuk memperkuat teori yang ada.

DAFTAR PUSTAKA

1. Karunarathna, M.H.J.S., Hatten, Z.R., Bailey, K.M., Lewis, E.T., Morris, A.L., Kolk, A.R., Laib, J.C., Tembo, N., Williams, R.A., Phillips, B.T., Ash, B.L., Midden, W.R., and Ostrowski, A.D., “Reclaiming Phosphate from Waste Solutions with Fe(III)-Polysaccharide Hydrogel Beads for Photo-Controlled-Release Fertilizer,” *J. Agric. Food Chem.* 2019, 67(44), 12155–12163, doi:10.1021/acs.jafc.9b02860.
2. Fahmi, “The Effect of Interaction of Nitrogen and Phosphorus Nutrients on Maize (*Zea Mays* L .) Grown In Regosol and Latosol Soils,” *Ber. Biol.* 2010, 10(3), 297–304.
3. Nursanti, I., “Pengaruh Bakteri Pelarut Fosfat Terhadap Ketersediaan Fosfat Dan Pertumbuhan Tanaman,” *J. Ilm. Univ. Batanghari Jambi* 2008, 8(2), 44–49.
4. Cordell, D., Drangert, J.O., and White, S., “The story of phosphorus: Global food security and food for thought,” *Glob. Environ. Chang.* 2009, 19(2), 292–305, doi:10.1016/j.gloenvcha.2008.10.009.
5. W. Hartatik dan K. Idris, “Kelarutan Fosfat Alam dan SP-36 dalam Gambut yang Diberi Bahan Amelioran Tanah Mineral,” *Tanah Dan Iklim* 2008, (27), 45–56.
6. Wahyuningsih, S., “The Prospect of Rock Phosphate as P Supplier in Ultisol Based Industrial Plantation Forest,” 2012, 15–21.
7. Couper, J.R., Penney, W.R., Fair, J.R., and Walas, S.M., “Chemical Process Equipment : Selection and Design,” 2005, 5572.
8. Siwek, H., Bartkowiak, A., and Włodarczyk, M., “Adsorption of phosphates from aqueous solutions on alginate/goethite hydrogel composite,” *Water (Switzerland)* 2019, 11(4), 1–13, doi:10.3390/w11040633.

9. Li, S., Lei, T., Jiang, F., Liu, M., Wang, Y., Wang, S., and Yang, X., “Tuning the morphology and adsorption capacity of Al-MIL-101 analogues with Fe³⁺ for phosphorus removal from water,” *J. Colloid Interface Sci.* 2020, 560, 321–329, doi:10.1016/j.jcis.2019.10.077.
10. Xie, Q., Li, Y., Lv, Z., Zhou, H., Yang, X., Chen, J., and Guo, H., “Effective Adsorption and Removal of Phosphate from Aqueous Solutions and Eutrophic Water by Fe-based MOFs of MIL-101,” *Sci. Rep.* 2017, 7(1), 1–15, doi:10.1038/s41598-017-03526-x.
11. Wang, L., Shi, C., Pan, L., Zhang, X., and Zou, J.J., “Rational design, synthesis, adsorption principles and applications of metal oxide adsorbents: A review,” *Nanoscale* 2020, 12(8), 4790–4815, doi:10.1039/c9nr09274a.
12. Siwek, H., Bartkowiak, A., Włodarczyk, M., and Sobecka, K., “Removal of Phosphate from Aqueous Solution Using Alginate/Iron (III) Chloride Capsules: a Laboratory Study,” *Water. Air. Soil Pollut.* 2016, 227(11), doi:10.1007/s11270-016-3128-0.
13. Benyoucef, S. and Amrani, M., “Removal of phosphorus from aqueous solutions using chemically modified sawdust of Aleppo pine (*Pinus halepensis* Miller): Kinetics and isotherm studies,” *Environmentalist* 2011, 31(3), 200–207, doi:10.1007/s10669-011-9313-1.
14. Dionisiou, N.S., Matsi, T., and Misopolinos, N.D., “Phosphorus adsorption-desorption on a surfactant-modified natural zeolite: A laboratory study,” *Water. Air. Soil Pollut.* 2013, 224(1), doi:10.1007/s11270-012-1362-7.
15. Deppe, T. and Benndorf, J., “Phosphorus reduction in a shallow hypereutrophic reservoir by in-lake dosage of ferrous iron,” *Water Res.* 2002, 36(18), 4525–4534, doi:10.1016/S0043-1354(02)00193-

- 8.
16. Huo, S.H. and Yan, X.P., "Metal-organic framework MIL-100(Fe) for the adsorption of malachite green from aqueous solution," *J. Mater. Chem.* 2012, 22(15), 7449–7455, doi:10.1039/c2jm16513a.
17. Hasan, Z. and Jhung, S.H., "Removal of hazardous organics from water using metal-organic frameworks (MOFs): Plausible mechanisms for selective adsorptions," *J. Hazard. Mater.* 2015, 283, 329–339, doi:10.1016/j.jhazmat.2014.09.046.
18. Zhu, He, Qi Zhang, and S.Z., "Alginate Hydrogel : A Shapeable and Versatile Platform for In-Situ Preparation of MOF-Polymer Composites," 2016, doi:10.1021/acsami.6b04505.
19. Chakrabarti, S., "Eutrophication - A Global Aquatic Environmental Problem : A Review," 2018, 6(1), 2–7.
20. Biswajit, Q. and Ahamad, K.U., "Ecohydrology & Hydrobiology A review on lake eutrophication dynamics and recent developments in lake modeling," *Integr. Med. Res.* 2018, (2016), 1–12, doi:10.1016/j.ecohyd.2018.03.002.
21. Yigit, N.Ö. and Mazlum, S., "Phosphate recovery potential from wastewater by chemical precipitation at batch conditions," *Environ. Technol.* 2007, 28(1), 83–93, doi:10.1080/09593332808618768.
22. Luo, W., Hai, F.I., Price, W.E., Guo, W., Ngo, H.H., Yamamoto, K., and Nghiem, L.D., "Phosphorus and water recovery by a novel osmotic membrane bioreactor-reverse osmosis system," *Bioresour. Technol.* 2016, 200, 297–304, doi:10.1016/j.biortech.2015.10.029.
23. Zarrabi, M., Soori, M.M., Sepehr, M.N., Amrane, A., Borji, S., and Ghaffari, H.R., "REMOVAL OF PHOSPHORUS BY ION-EXCHANGE RESINS: EQUILIBRIUM , KINETIC AND THERMODYNAMIC STUDIES," 2014, 13(4), 2014.

24. Artioli, Y., "Adsorption," *Encycl. Ecol. Five-Volume Set* 2008, 60–65, doi:10.1016/B978-008045405-4.00252-4.
25. Wiroesoedarmo, R., Kurniati, E., and Ardika, J., "Adsorpsi Senyawa Fosfat Total (PO 4) dalam Air Buangan Laundry dengan Zeolit Termodifikasi Adsorption of Total Phosphate (PO₄) in Laundry ' s Wastewater Using Modified Zeolit Jurnal Sumberdaya Alam dan Lingkungan," 2001, 35–42.
26. Syauqiah, I., Amalia, M., and Kartini, H.A., "Analisis Variasi Waktu Dan Kecepatan Pengaduk Pada Proses Adsorpsi Limbah Logam Berat Dengan Arang Aktif," *Anal. Variasi Waktu Dan Kecepatan Pengaduk Pada Proses Adsorpsi Limbah Logam Berat Dengan Arang Aktif* 2011, 12(1), 11–20.
27. Nehra, M., Dilbaghi, N., Singhal, N.K., Hassan, A.A., Kim, K.H., and Kumar, S., "Metal organic frameworks MIL-100(Fe) as an efficient adsorptive material for phosphate management," *Environ. Res.* 2019, 169, 229–236, doi:10.1016/j.envres.2018.11.013.
28. Li, G., Gao, S., Zhang, G., and Zhang, X., "Enhanced adsorption of phosphate from aqueous solution by nanostructured iron(III)-copper(II) binary oxides," *Chem. Eng. J.* 2014, 235(Iii), 124–131, doi:10.1016/j.cej.2013.09.021.
29. Liu, X. and Zhang, L., "Removal of phosphate anions using the modified chitosan beads: Adsorption kinetic, isotherm and mechanism studies," *Powder Technol.* 2015, 277, 112–119, doi:10.1016/j.powtec.2015.02.055.
30. Zhang, G., Liu, H., Liu, R., and Qu, J., "Removal of phosphate from water by a Fe-Mn binary oxide adsorbent," *J. Colloid Interface Sci.* 2009, 335(2), 168–174, doi:10.1016/j.jcis.2009.03.019.
31. Sukma, N.S. and Arryanto, Y., "Characterization and Study of

- Iron(III)-Released From Alginate/Zelite/Fe Composite,” (Iii), 80–93.
32. Kragović, M., Stojmenović, M., Petrović, J., Loredó, J., Pašalić, S., Nedeljković, A., and Ristović, I., “Influence of Alginate Encapsulation on Point of Zero Charge (pH pzc) and Thermodynamic Properties of the Natural and Fe(III)-Modified Zeolite,” *Procedia Manuf.* 2019, 32, 286–293, doi:10.1016/j.promfg.2019.02.216.
 33. Jin Li, Guoqiang Jiang, F.D., “The Effect of pH on the Polymer Degradation and Drug Release from PLGA-mPEG Microparticles,” *J. Appl. Polym. Sci.* 2008, 109(5), 475–482, doi:10.1002/app.
 34. Agulhon, P., Robitzer, M., David, L., and Quignard, F., “Structural regime identification in ionotropic alginate gels: Influence of the cation nature and alginate structure,” *Biomacromolecules* 2012, 13(1), 215–220, doi:10.1021/bm201477g.
 35. Veres, P., Sebők, D., Dékány, I., Gurikov, P., Smirnova, I., Fábrián, I., and Kalmár, J., “A redox strategy to tailor the release properties of Fe(III)-alginate aerogels for oral drug delivery,” *Carbohydr. Polym.* 2018, 188(Iii), 159–167, doi:10.1016/j.carbpol.2018.01.098.
 36. Mileo, P.G.M., Ho Cho, K., Park, J., Devautour-Vinot, S., Chang, J.S., and Maurin, G., “Unraveling the Water Adsorption Mechanism in the Mesoporous MIL-100(Fe) Metal-Organic Framework,” *J. Phys. Chem. C* 2019, 123(37), 23014–23025, doi:10.1021/acs.jpcc.9b06228.
 37. Cai, J., Mao, X., and Song, W.G., “Adsorption behavior and structure transformation of mesoporous metal-organic frameworks towards arsenates and organic pollutants in aqueous solution,” *Mater. Chem. Front.* 2018, 2(7), 1389–1396, doi:10.1039/c8qm00002f.

38. Liu, R., Chi, L., Wang, X., Wang, Y., Sui, Y., Xie, T., and Arandiyan, H., "Effective and selective adsorption of phosphate from aqueous solution via trivalent-metals-based amino-MIL-101 MOFs," *Chem. Eng. J.* 2019, 357, 159–168, doi:10.1016/j.cej.2018.09.122.
39. Li, Z., Liu, X., Jin, W., Hu, Q., and Zhao, Y., "Adsorption behavior of arsenicals on MIL-101 (Fe): The role of arsenic chemical structures," *J. Colloid Interface Sci.* 2019, 554, 692–704, doi:10.1016/j.jcis.2019.07.046.
40. Simon, M.A., An, E., Soetaredjo, F.E., Santoso, S.P., Irawaty, W., Thanh, T.C., Hartono, S.B., and Maria, Y., "Hydrothermal Synthesize of HF- Free MIL-100 (Fe) for Isoniazid-Drug Delivery," 2019, 100(43), 1–11, doi:10.1038/s41598-019-53436-3.
41. Wang, J., Chen, D., Li, B., He, J., Duan, D., Shao, D., and Nie, M., "Fe-MIL-101 exhibits selective cytotoxicity and inhibition of angiogenesis in ovarian cancer cells via downregulation of MMP," *Nat. Publ. Gr.* 2016, (April), 1–13, doi:10.1038/srep26126.
42. Habibah, N., Ayu, I.G., Dhyanaputri, S., Karta, I.W., Widhya, C.D., Sundari, H., Hadi, M.C., Kesehatan, P., Denpasar, K., Kesehatan, J.A., Sanitasi, J., Sidakarya, N., and Selatan, D., "A SIMPLE SPECTROPHOTOMETRIC METHOD FOR THE QUANTITATIVE ANALYSIS OF PHOSPHATE IN THE WATER," 2018, 7(2), 198–204.
43. Ayoub, G.M., Damaj, A., El, H., Mahmoud, R., Hindi, A., and Zayyat, R.M., "Equilibrium and kinetic studies on adsorption of chromium (VI) onto pine - needle - generated activated carbon," *SN Appl. Sci.* 2019, 1(12), 1–13, doi:10.1007/s42452-019-1617-7.
44. Rehman, T.U., Bibi, S., Khan, M., Ali, I., Shah, L.A., Khan, A., and

- Ateeq, M., "Fabrication of stable superabsorbent hydrogels for successful removal of crystal violet from waste," *RSC Adv.* 2019, 9.68, 40051–40061, doi:10.1039/c9ra08079a.
45. Ayawei, N., Ebelegi, A.N., and Wankasi, D., "Modelling and Interpretation of Adsorption Isotherms," *J. Chem.* 2017, 2017, doi:10.1155/2017/3039817.
 46. Adeogun, A.I. and Balakrishnan, R.B., "Kinetics, isothermal and thermodynamics studies of electrocoagulation removal of basic dye rhodamine B from aqueous solution using steel electrodes," *Appl. Water Sci.* 2017, 7(4), 1711–1723, doi:10.1007/s13201-015-0337-4.
 47. Yang, C. hai, "Statistical mechanical study on the Freundlich isotherm equation," *J. Colloid Interface Sci.* 1998, 208(2), 379–387, doi:10.1006/jcis.1998.5843.
 48. Armbruster, M.H. and Austin, J.B., "The Adsorption of Gases on Plane Surfaces of Mica," *J. Am. Chem. Soc.* 1938, 60(2), 467–475, doi:10.1021/ja01269a066.
 49. Boparai, H.K., Joseph, M., and O'Carroll, D.M., "Kinetics and thermodynamics of cadmium ion removal by adsorption onto nano zerovalent iron particles," *J. Hazard. Mater.* 2011, 186(1), 458–465, doi:10.1016/j.jhazmat.2010.11.029.
 50. Wang, J. and Guo, X., "Adsorption isotherm models: Classification, physical meaning, application and solving method," *ECSN* 2020, 127279, doi:10.1016/j.chemosphere.2020.127279.
 51. Azizian, S., "Kinetic models of sorption: A theoretical analysis," *J. Colloid Interface Sci.* 2004, 276(1), 47–52, doi:10.1016/j.jcis.2004.03.048.
 52. Qu, Z., Sun, F., Liu, X., Gao, J., Qie, Z., and Zhao, G., "The effect of nitrogen-containing functional groups on SO₂ adsorption on carbon

- surface: enhanced physical adsorption interactions,” *Surf. Sci.* 2018, doi:10.1016/j.susc.2018.05.019.
53. Wang, J. and Guo, X., “Adsorption kinetic models: Physical meanings, applications, and solving methods,” *J. Hazard. Mater.* 2020, 390(November 2019), 122156, doi:10.1016/j.jhazmat.2020.122156.
 54. Ismadji, Suryadi., dkk., “ADSORPSI PADA FASE CAIR: Keseimbangan, Kinetika, Dan Termodinamika edisi 1,” ISBN 9786239400767.
 55. Chemsoon, A Professional Supplier of MOF Materials and Linkers, diakses pada 15 Maret, 2022 pukul 21.35.
 56. Dong, Y., Dong, W., Cao, Y., Han, Z., and Ding, Z., “Preparation and catalytic activity of Fe alginate gel beads for oxidative degradation of azo dyes under visible light irradiation,” *Catal. Today* 2011, 175(1), 346–355, doi:10.1016/j.cattod.2011.03.035.
 57. Quintero-álvarez, F.G., Rojas-mayorga, C.K., Mendoza-castillo, D.I., and Aguayo-villarreal, I.A., “Physicochemical Modeling of the Adsorption of Pharmaceuticals on MIL-100-Fe and MIL-101-Fe MOFs,” 2022, 2022.
 58. Bruice, P.Y., “Organic Chemistry,” Pearson Education, ISBN 9780134042282.
 59. Panias, D., Taxiarchou, M., Paspaliaris, I., and Kontopoulos, A., “Mechanisms of dissolution of iron oxides in aqueous oxalic acid solutions,” 1996, 42, 257–265.
 60. Roquero, Daniel Massana, et al, “Iron (III)-cross-linked alginate hydrogels: A critical review,” 2022, (January), doi:10.1039/D1MA00959A.
 61. Rizwan, M., Yahya, R., Hassan, A., Yar, M., Azzahari, A.D.,

- Selvanathan, V., and Sonsudin, F., “pH Sensitive Hydrogels in Drug Delivery: Brief History , Properties , Swelling , and Release Mechanism , Material Selection and Applications,” doi:10.3390/polym9040137.
62. George, M. and Abraham, T.E., “Polyionic hydrocolloids for the intestinal delivery of protein drugs: Alginate and chitosan — a review,” 2006, 114, 1–14, doi:10.1016/j.jconrel.2006.04.017.
 63. Li, M., Liu, J., Xu, Y., Qian, G., Li, M., and Xu, Y., “Phosphate adsorption on metal oxides and metal hydroxides: A comparative review,” 1–58.
 64. Wang, Nan, et al, “Fabrication of Composite Beads Based on Calcium Alginate and Tetraethylenepentamine-Functionalized Aqueous Solutions,” 2018, (Ii), doi:10.3390/polym10070750.
 65. Zhao, G. and Li, C., “Characterization and properties of sodium alginate from brown algae used as an ecofriendly superabsorbent Characterization and properties of sodium alginate from brown algae used as an ecofriendly superabsorbent,” doi:10.1088/1742-6596/755/1/011001.
 66. Wang, L., Xu, H., Gao, J., Yao, J., and Zhang, Q., “Recent progress in metal-organic frameworks-based hydrogels and aerogels and their applications,” *Coord. Chem. Rev.* 2019, 398, 213016, doi:10.1016/j.ccr.2019.213016.
 67. Gao, N., Huang, J., Wang, L., Feng, J., Huang, P., and Wu, F., “Ratiometric fluorescence detection of phosphate in human serum with a and nanocomposite immobilized agarose hydrogels,” *Appl. Surf. Sci.* 2018, doi:10.1016/j.apsusc.2018.08.092.
 68. Chen, R., Liu, T., Rong, H., Zhong, H., and Wei, C., “Effect of Organic Substances on Nutrients Recovery by Struvite

- Electrochemical Precipitation from Synthetic Anaerobically Treated Swine Wastewater,” 2021.
69. Sahoo, T.R. and Prelot, B., “Chapter 7 - Adsorption processes for the removal of contaminants from wastewater: the perspective role of nanomaterials and nanotechnology,” Elsevier Inc., ISBN 9780128184899, doi:10.1016/B978-0-12-818489-9.00007-4.
 70. Zhuang, Yuan, et al, “Novel one step preparation of a 3D alginate based MOF hydrogel for water treatment,” 2019, doi:10.1039/C8NJ06031B.
 71. Xiong, C., Wei, F., Li, W., Liu, P., Wu, Y., Dai, M., and Chen, J., “Mechanism of Polyacrylamide Hydrogel Instability on High-Temperature Conditions,” *ACS Omega* 2018, 3, 10716–10724, doi:10.1021/acsomega.8b01205.
 72. Zhi, Y., Zhang, C., Hjorth, R., Baun, A., Duckworth, O.W., Call, D.F., Knappe, D.R.U., Jones, J.L., and Grieger, K., “Emerging lanthanum (III) -containing materials for phosphate removal from water : A review towards future developments,” *Environ. Int.* 2020, 145, 106115, doi:10.1016/j.envint.2020.106115.
 73. Zhang, H., Cheng, J., and Ao, Q., “Preparation of Alginate-Based Biomaterials and Their Applications in Biomedicine,” 2021, 1–24.
 74. Andreas, A., Gerald, Z., Permatasari, S., Elisa, A., Yuliana, M., Edi, F., Ismadji, S., Hsu, H., Woo, A., and Ju, Y., “Biocomposite hydrogel beads from glutaraldehyde-crosslinked phytochemicals in alginate for effective removal of methylene blue,” *J. Mol. Liq.* 2021, 329, 115579, doi:10.1016/j.molliq.2021.115579.
 75. Wegeberg, C. and Wenger, O.S., “Luminescent First-Row Transition Metal Complexes,” 2021, doi:10.1021/jacsau.1c00353.
 76. Giammanco, G.E., Sosnofsky, C.T., and Ostrowski, A.D., “Light-

Responsive Iron (III) – Polysaccharide Coordination Hydrogels for Controlled Delivery,” (Iii), doi:10.1021/am506772x.

77. Chen, J. and Browne, W.R., “Photochemistry of iron complexes,” *Coord. Chem. Rev.* 2018, 374, 15–35, doi:10.1016/j.ccr.2018.06.008.
78. Guo, Lizhen, et al, “Synthesis of bio-based MIL-100 (Fe)@ CNF-SA composite hydrogel and its application in slow-release N-fertilizere,” *J. Clean. Prod.* 2021, 324(129274).