

DAFTAR PUSTAKA

- Abbasi, Z. (2017). Investigation of the adsorption properties and structures of porous materials for adsorptive removal of pollutants from water [Monash University]. In *Monash University*.
<https://doi.org/https://doi.org/10.4225/03/5953495daa231>
- Ahmed, M. K., Ali, S., & Wojcik, E. (2012). The C-O Stretching Infrared Band as a Probe of Hydrogen Bonding in Ethanol–Water and Methanol–Water Mixtures. *Spectroscopy Letters*, *45*(6), 420–423.
<https://doi.org/10.1080/00387010.2011.627529>
- Albiss, B., & Abu-Dalo, M. (2021). Photocatalytic Degradation of Methylene Blue Using Zinc Oxide Nanorods Grown on Activated Carbon Fibers. *Sustainability*, *13*(9), 4729. <https://doi.org/10.3390/su13094729>
- An, K., Wang, Z., Yang, X., Qu, Z., Sun, F., Zhou, W., & Zhao, H. (2022). Reasons of low formaldehyde adsorption capacity on activated carbon: Multi-scale simulation of dynamic interaction between pore size and functional groups. *Journal of Environmental Chemical Engineering*, *10*(6), 108723. <https://doi.org/10.1016/j.jece.2022.108723>
- Chafa, A. T., Chirinda, G. P., & Matope, S. (2022a). Design of a real-time water quality monitoring and control system using Internet of Things (IoT). *Cogent Engineering*, *9*(1). <https://doi.org/10.1080/23311916.2022.2143054>
- Chafa, A. T., Chirinda, G. P., & Matope, S. (2022b). Design of a real-time water quality monitoring and control system using Internet of Things (IoT). *Cogent Engineering*, *9*(1). <https://doi.org/10.1080/23311916.2022.2143054>
- Dawes, A., Mason, N. J., & Fraser, H. J. (2016). Using the C–O stretch to unravel the nature of hydrogen bonding in low-temperature solid methanol–water condensates. *Physical Chemistry Chemical Physics*, *18*(2), 1245–1257. <https://doi.org/10.1039/C5CP05299H>
- Desai, M. R., & Shabadi, L. (2022). Measuring Quality of Water in Real Time Environment by Using Sensors. *2022 Second International Conference on Advanced Technologies in Intelligent Control, Environment, Computing & Communication Engineering (ICATIECE)*, 1–4. <https://doi.org/10.1109/ICATIECE56365.2022.10071949>
- Dimbo, D., Abewaa, M., Adino, E., Mengistu, A., Takele, T., Oro, A., & Rangaraju, M. (2024a). Methylene blue adsorption from aqueous solution using activated carbon of *spathodea campanulata*. *Results in Engineering*, *21*, 101910. <https://doi.org/10.1016/j.rineng.2024.101910>
- Dimbo, D., Abewaa, M., Adino, E., Mengistu, A., Takele, T., Oro, A., & Rangaraju, M. (2024b). Methylene blue adsorption from aqueous solution using activated carbon of *spathodea campanulata*. *Results in Engineering*, *21*, 101910. <https://doi.org/10.1016/j.rineng.2024.101910>
- El-Naggar, M. E., Abu Ali, O. A., Saleh, D. I., Abu-Saied, M. A., Ahmed, M. K., & Mansour, S. F. (2022). Degradation of methylene blue by ZnO/Mg and Se in an hydroxyapatite composite. *Luminescence*, *37*(10), 1083–1090. <https://doi.org/10.1002/bio.4183>
- Orsi, T. M., Abuelela, A. M., Hassan, A. E., Alhakemy, A. Z., & Chou, H.-H. (2020). Direct sunlight-active Na-doped ZnO photocatalyst for the mineralization of organic pollutants at different pH values. *Journal of the Taiwan Institute of Chemical Engineers*, *115*, 187–194. <https://doi.org/10.1016/j.jtice.2020.10.018>



- Erdem, U., Dogan, D., Bozer, B. M., Karaboga, S., Turkoz, M. B., Metin, A. Ü., & Yildirim, G. (2022). Evolution of dynamics of physico-chemical and mechanical properties of hydroxyapatite with fluorine addition and degradation stability of new matrices. *Journal of the Mechanical Behavior of Biomedical Materials*, 135, 105454. <https://doi.org/10.1016/j.jmbbm.2022.105454>
- Ferdoush, S., & Li, X. (2014). Wireless Sensor Network System Design Using Raspberry Pi and Arduino for Environmental Monitoring Applications. *Procedia Computer Science*, 34, 103–110. <https://doi.org/10.1016/j.procs.2014.07.059>
- Fernández-Pérez, A., & Marbán, G. (2022). Visible Light Spectroscopic Analysis of Methylene Blue in Water. *Journal of Applied Spectroscopy*, 88(6), 1284–1290. <https://doi.org/10.1007/s10812-022-01310-y>
- Fu, R., Liu, L., Huang, W., & Sun, P. (2003). Studies on the structure of activated carbon fibers activated by phosphoric acid. *Journal of Applied Polymer Science*, 87(14), 2253–2261. <https://doi.org/10.1002/app.11607>
- George, A., Rahul, S., Raj, A. D., & Yang, Q. (2024). Gas sensing response and photocatalytic efficiency of pH tuned NiV2O6 nanorods. *Sensors and Actuators B: Chemical*, 413, 135809. <https://doi.org/10.1016/j.snb.2024.135809>
- Ghazaly, C., Hébrant, M., Langlois, E., Castel, B., Guillemot, M., & Etienne, M. (2019). Real-Time Ozone Sensor Based on Selective Oxidation of Methylene Blue in Mesoporous Silica Films. *Sensors*, 19(16), 3508. <https://doi.org/10.3390/s19163508>
- Gunawan, G., Haris, A., Uswatun, E., & Wijaya, R. A. (2022). Study of Methylene Blue Adsorption with Silver Chloride Coagulants from Photographic Film Waste. *Journal of Environment and Earth Science*. <https://doi.org/10.7176/JEES/12-4-06>
- He, Y., Ni, L., Gao, Q., Ren, H., Su, M., Hou, Y., & Liu, Z. (2023). Activated Carbon with Ultrahigh Specific Surface Derived from Bamboo Shoot Shell through K₂FeO₄ Oxidative Pyrolysis for Adsorption of Methylene Blue. *Molecules*, 28(8), 3410. <https://doi.org/10.3390/molecules28083410>
- Heryanto, H., & Tahir, D. (2021). The correlations between structural and optical properties of magnetite nanoparticles synthesised from natural iron sand. *Ceramics International*, 47(12), 16820–16827. <https://doi.org/10.1016/j.ceramint.2021.02.255>
- Hussain, O. A., Hathout, A. S., Abdel-Mobdy, Y. E., Rashed, M. M., Abdel Rahim, E. A., & Fouzy, A. S. M. (2023). Preparation and characterization of activated carbon from agricultural wastes and their ability to remove chlorpyrifos from water. *Toxicology Reports*, 10, 146–154. <https://doi.org/10.1016/j.toxrep.2023.01.011>
- Idrees, K. B., Li, Z., Xie, H., Kirlikovali, K. O., Kazem-Rostami, M., Wang, X., Wang, X., Tai, T.-Y., Islamoglu, T., Stoddart, J. F., Snurr, R. Q., & Farha, O. K. (2022). Separation of Aromatic Hydrocarbons in Porous Materials. *Journal of the Chemical Society*, 144(27), 12212–12218. <https://doi.org/10.1021/jacs.2c03114>
- İz, C., Gharehkhani, S., & Affi, A. B. M. (2016). Adsorption of methylene blue on activated carbon synthesized from coconut shell. *Carbon Letters*, doi.org/10.5714/CL.2016.20.001
- Jiang, J., Zhongyuan Guo, Xi Jiang, Jonathan M. Larson, Haoyue Zhu, Yiqian Gu, Brian Blankenship, Min Chen, Zilong Wu, Suichu Kosteci, Andrew M. Minor, Costas P. Grigoropoulos, Deji



- Akinwande, Mauricio Terrones, Joa, Y. Z. (2023). Light-driven C-H bond activation mediated by 2D transition metal dichalcogenides. *Materials Science*, 1(1), 1–23. <https://doi.org/https://doi.org/10.48550/arXiv.2208.07902>
- Jurgelane, I., & Locs, J. (2023). Activated Carbon and Clay Pellets Coated with Hydroxyapatite for Heavy Metal Removal: Characterization, Adsorption, and Regeneration. *Materials*, 16(9), 3605. <https://doi.org/10.3390/ma16093605>
- Kalagatur, N. K., Karthick, K., Allen, J. A., Nirmal Ghosh, O. S., Chandranayaka, S., Gupta, V. K., Krishna, K., & Mudili, V. (2017). Application of Activated Carbon Derived from Seed Shells of *Jatropha curcas* for Decontamination of Zearalenone Mycotoxin. *Frontiers in Pharmacology*, 8. <https://doi.org/10.3389/fphar.2017.00760>
- Khan, I., Saeed, K., Zekker, I., Zhang, B., Hendi, A. H., Ahmad, A., Ahmad, S., Zada, N., Ahmad, H., Shah, L. A., Shah, T., & Khan, I. (2022). Review on Methylene Blue: Its Properties, Uses, Toxicity and Photodegradation. *Water*, 14(2), 242. <https://doi.org/10.3390/w14020242>
- Komaril Sofi'i, Y., Siswanto, E., Winarto, & Wardana, I. N. G. (2020). Hydrogen production by photocatalysis method of glutamic acid and activated carbon. *E3S Web of Conferences*, 181, 01009. <https://doi.org/10.1051/e3sconf/202018101009>
- Kremenović, A., Grujić-Brojčin, M., Tomić, N., Lazović, V., Bajuk-Bogdanović, D., Krstić, J., & Šćepanović, M. (2022). Size–strain line-broadening analysis of anatase/brookite (TiO₂)-based nanocomposites with carbon (C): XRPD and Raman spectroscopic analysis. *Acta Crystallographica Section B Structural Science, Crystal Engineering and Materials*, 78(2), 214–222. <https://doi.org/10.1107/S2052520622001731>
- Kristianto, H., Arie, A. A., Susanti, R. F., Halim, M., & Lee, J. K. (2016). The effect of activated carbon support surface modification on characteristics of carbon nanospheres prepared by deposition precipitation of Fe-catalyst. *IOP Conference Series: Materials Science and Engineering*, 162(1), 012034. <https://doi.org/10.1088/1757-899X/162/1/012034>
- Lionetti, V., Poselle Bonaventura, C., Conte, G., De Luca, O., Policicchio, A., Caruso, T., Desiderio, G., Papagno, M., & Agostino, R. G. (2024). Production and physical-chemical characterization of walnut shell-derived activated carbons for hydrogen storage application. *International Journal of Hydrogen Energy*, 61, 639–649. <https://doi.org/10.1016/j.ijhydene.2024.02.213>
- Liu, Y., Liu, X., Dong, W., Zhang, L., Kong, Q., & Wang, W. (2017). Efficient Adsorption of Sulfamethazine onto Modified Activated Carbon: A Plausible Adsorption Mechanism. *Scientific Reports*, 7(1), 12437. <https://doi.org/10.1038/s41598-017-12805-6>
- Machado, A. E. da H., & Alves Machado, W. (2022). Hydrogen production by photocatalysis using new composites based on SiO₂ coated by TiO₂. *PeerJ Materials Science*, 4, e25. <https://doi.org/10.7717/peerj-matsci.25>
- ... (2023). M., Hekmati, M., Monajjemi, M., & Shekarabi, A. S. (2023). removal from aqueous solution using modified Met-SWCNTs: optimization using RSM-CCD. *International Journal of Reactor Engineering*, 21(10), 1177–1197. <https://doi.org/10.1515/ijcre-2022-0240>
- ... (2023). S., Naniwadikar, M., Patil, G., & Jadhav, S. D. (2023). Investigations of the Removal of Methylene Blue from Waste



- Water using Agricultural Adsorbant. *International Journal of Membrane Science and Technology*, 10(1), 1–7. <https://doi.org/10.15379/ijmst.v10i1.1069>
- Mariah, M. A. A., Rovina, K., Vonnie, J. M., & Erna, K. H. (2023). Characterization of activated carbon from waste tea (*Camellia sinensis*) using chemical activation for removal of methylene blue and cadmium ions. *South African Journal of Chemical Engineering*, 44, 113–122. <https://doi.org/10.1016/j.sajce.2023.01.007>
- Nagalakshmi, T. V., Emmanuel, K. A., Suresh Babu, Ch., Chakrapani, Ch., & Divakar, P. P. (2015). Preparation of Mesoporous Activated Carbon from Jackfruit PPI-1 Waste and Development of Different Surface Functional Groups. *International Letters of Chemistry, Physics and Astronomy*, 54, 189–200. <https://doi.org/10.18052/www.scipress.com/ILCPA.54.189>
- Oladoye, P. O., Ajiboye, T. O., Omotola, E. O., & Oyewola, O. J. (2022). Methylene blue dye: Toxicity and potential elimination technology from wastewater. *Results in Engineering*, 16, 100678. <https://doi.org/10.1016/j.rineng.2022.100678>
- Park, M.-S., Lee, S.-E., Kim, M. II, & Lee, Y.-S. (2015). CO₂ adsorption characteristics of slit-pore shaped activated carbon prepared from cokes with high crystallinity. *Carbon Letters*, 16(1), 45–50. <https://doi.org/10.5714/CL.2015.16.1.045>
- Pirzadeh, K., & Ghoreyshi, A. A. (2014). Phenol removal from aqueous phase by adsorption on activated carbon prepared from paper mill sludge. *Desalination and Water Treatment*, 52(34–36), 6505–6518. <https://doi.org/10.1080/19443994.2013.821034>
- Ragupathy, S., Manikandan, V., Devanesan, S., Ahmed, M., Ramamoorthy, M., & Priyadharsan, A. (2022). Enhanced sun light driven photocatalytic activity of Co doped SnO₂ loaded corn cob activated carbon for methylene blue dye degradation. *Chemosphere*, 295, 133848. <https://doi.org/10.1016/j.chemosphere.2022.133848>
- Ramutshatsha-Makhwedzha, D., Munyengabe, A., Mavhungu, M. L., Mbaya, R., & Baloyi, J. (2023). Breakthrough studies for the sorption of methylene blue dye from wastewater samples using activated carbon derived from waste banana peels. *Biomass Conversion and Biorefinery*. <https://doi.org/10.1007/s13399-023-04329-z>
- Ristianingsih, Y., Lestari, I., & Istiani, A. (2022). Adsorption Equilibrium of Methylene Blue By Activated Carbon From Post-Anthesis Male Flower Palm Oil Waste. *Eksergi*, 19(3), 129. <https://doi.org/10.31315/e.v19i3.8055>
- Rocher, J., Jimenez, J. M., Tomas, J., & Lloret, J. (2023). Low-Cost Turbidity Sensor to Determine Eutrophication in Water Bodies. *Sensors*, 23(8), 3913. <https://doi.org/10.3390/s23083913>
- Safrianti, E., Feranita, Nurhalim, & Wahyu Dwi Reza. (2022). Design of pH Measuring Equipment for Liquid Waste from Coal Mining Using Arduino Uno. *Journal of Electrical, Energy and Power System Engineering*, <https://doi.org/10.31258/ijeepse.5.3.61-66>
- Suri, M., Maleki, B., & Esmaeili, H. (2023). Modified characteristics of activated carbon derived from the Astragalus shrub for catalytic degradation of methylene blue from water. *International Environmental Analytical Chemistry*, 1–17. <https://doi.org/10.1080/03067319.2023.2220288>



- Seetharaman, R., Nivetha, N., Dakshin, S. V., Anandan, K., & Sreeja, R. R. (2022). Arduino based System for Domestic Waste Water Management using pH Sensor. *2022 Sixth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)*, 352–355. <https://doi.org/10.1109/I-SMAC55078.2022.9987299>
- Serafin, J., Ouzzine, M., Sreńscek-Nazzal, J., & Llorca, J. (2022a). Photocatalytic hydrogen production from alcohol aqueous solutions over TiO₂-activated carbon composites decorated with Au and Pt. *Journal of Photochemistry and Photobiology A: Chemistry*, 425, 113726. <https://doi.org/10.1016/j.jphotochem.2021.113726>
- Serafin, J., Ouzzine, M., Sreńscek-Nazzal, J., & Llorca, J. (2022b). Photocatalytic hydrogen production from alcohol aqueous solutions over TiO₂-activated carbon composites decorated with Au and Pt. *Journal of Photochemistry and Photobiology A: Chemistry*, 425, 113726. <https://doi.org/10.1016/j.jphotochem.2021.113726>
- Shaeri, M. A., & Mohagheghi, M. M. B. (2021). Synthesis and structural and optical properties of SiO₂/activated carbon nanocomposites. *Journal of Materials Science: Materials in Electronics*, 32(13), 18425–18438. <https://doi.org/10.1007/s10854-021-06388-2>
- Shaikh, A. S. (2021). A Survey on Exchanging Data Using MQTT Protocol in Arduino. *International Journal for Research in Applied Science and Engineering Technology*, 9(VII), 3081–3082. <https://doi.org/10.22214/ijraset.2021.37007>
- Smirnova, D., Grishin, I., & Smirnov, N. (2022). The COMPARISON OF SORPTION PROPERTIES OF SILICON-CARBON ADSORBENTS SYNTHESIZED BY VARIOUS METHODS. *ChemChemTech*, 65(12), 44–52. <https://doi.org/10.6060/ivkkt.20226512.6694>
- Sofi'i, Y. K., Siswanto, E., Winarto, Ueda, T., & Wardana, I. N. G. (2020). The role of activated carbon in boosting the activity of clitoria ternatea powder photocatalyst for hydrogen production. *International Journal of Hydrogen Energy*, 45(43), 22613–22628. <https://doi.org/10.1016/j.ijhydene.2020.05.103>
- Sofyan, N., Alfaruq, S., Zulfia, A., & Subhan, A. (2018). Characteristics of Vanadium Doped And Bamboo Activated Carbon Coated LiFePO₄ And Its Performance For Lithium Ion Battery Cathode. *Jurnal Kimia Dan Kemasan*, 40(1), 9. <https://doi.org/10.24817/jkk.v40i1.3767>
- Suharyadi, E., Muzakki, A., Nofrianti, A., Istiqomah, N. I., Kato, T., & Iwata, S. (2020). Photocatalytic activity of magnetic core-shell CoFe₂O₄@ZnO nanoparticles for purification of methylene blue. *Materials Research Express*, 7(8), 085013. <https://doi.org/10.1088/2053-1591/abafd1>
- Sybounya, S., & Nitorisavut, R. (2021). Hybrid composite of modified commercial activated carbon and Zn-Ni hydrotalcite for fermentative hydrogen production. *Journal of Environmental Chemical Engineering*, 9(1), 104801. <https://doi.org/10.1016/j.jece.2020.104801>
- ..., I., & Yaqoob, K. (2023). Chemically Activated Carbon from Rice Husk for Adsorption of Methylene Blue in Polluted. *Environmental Engineering Science*, 40(8), 307–317. <https://doi.org/10.1089/ees.2022.0373>
- ..., F., Mao, G., Huang, X., & Lu, S. (2023). Photocatalytic reaction from water and wastepaper on Pt/TiO₂ composites.













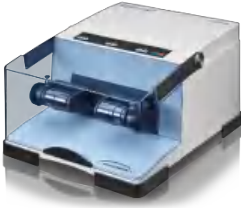





- Chemical Physics Letters*, **826**, 140650.
<https://doi.org/10.1016/j.cplett.2023.140650>
- Wulansarie, R., Jannah, R., Bismo, S., Safitri, R., & Rengga, W. (2023). Degradation of Methylene Blue Dye in Wastewater Using Ozonation Method with H₂O₂ Catalyst. *IOP Conference Series: Earth and Environmental Science*, *1203*(1), 012051. <https://doi.org/10.1088/1755-1315/1203/1/012051>
- Xiong, Y., Wang, Q., Duan, M., Tan, J., Fang, S., & Wu, J. (2018). Real-Time Monitoring of Azo Dye Interfacial Adsorption at Silica–Water Interface by Total Internal Reflection-Induced Surface Evanescent Wave. *Langmuir*, *34*(26), 7612–7623. <https://doi.org/10.1021/acs.langmuir.8b00722>
- Yakubson, K. I. (2022). Prospects for Using Hydrogen in Various Branches of the World Economy as One of the Directions of Its Decarbonization. *Russian Journal of Applied Chemistry*, *95*(3), 309–340. <https://doi.org/10.1134/S1070427222030016>
- Zhang, C., Qi, H., Zhang, Y., Li, C., Zhang, Q., Hu, G., & Li, Z. (2023a). Carbon/ <sc> Mn₃O₄ </sc> / <sc> SrTiO₃ </sc> microsphere photocatalyst for the efficient removal of high-concentration methylene blue from water. *Journal of Chemical Technology & Biotechnology*, *98*(6), 1453–1464. <https://doi.org/10.1002/jctb.7364>
- Zhang, C., Qi, H., Zhang, Y., Li, C., Zhang, Q., Hu, G., & Li, Z. (2023b). Carbon/ <sc> Mn₃O₄ </sc> / <sc> SrTiO₃ </sc> microsphere photocatalyst for the efficient removal of high-concentration methylene blue from water. *Journal of Chemical Technology & Biotechnology*, *98*(6), 1453–1464. <https://doi.org/10.1002/jctb.7364>
- Zhang, T., Xiong, W., Zhang, H., & Li, J. (2022). Activated carbon prepared by co-pyrolysis of waste tobacco straw and waste LDPE mulch film: characterization and application for methylene blue removal. *RSC Advances*, *12*(53), 34165–34175. <https://doi.org/10.1039/D2RA06153H>



LAMPIRAN

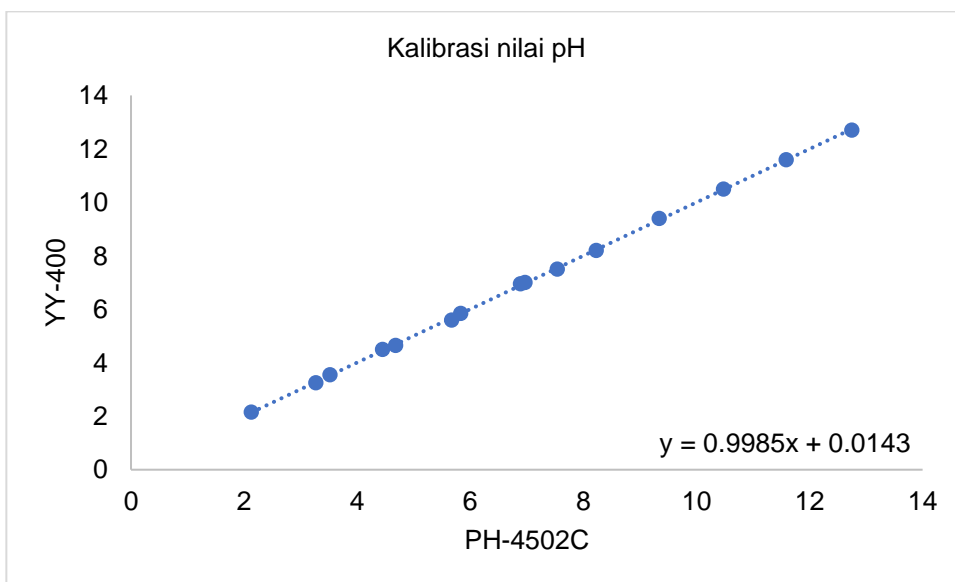
Lampiran 1. Alat dan Bahan Penelitian

Nama	Gambar	Fungsi
Arduino Uno		Mengolah data pembacaan sensor
NodeMCU ESP8266		Mengirim data pembacaan ke basis data
Sensor PH-4502C		Mengukur pH larutan
Sensor TCS3200		Mengukur Warna larutan
Sensor DS18B20		Mengukur suhu larutan
Sensor MQ-8		Mengukur kadar produksi hidrogen
Water Tester YY400		Sebagai alat pembanding sensor pH
		Mengukur nilai absorbansi larutan

Furnace		Alat karbonisasi sampel adsorban
Mixing (Retsch MM 400)		Alat pencampur karbon aktif dan hidroksiapatit
FT-IR (Fourier Transform Infrared)		Pendeteksi gugus fungsi sampel
XRD (X-Ray Diffraction)		Pendeteksi sifat struktur pada sampel
SEM (Scanning Electron Microscope)		Melihat morfologi permukaan sampel
		Pembanding nilai konsentrasi hidrogen

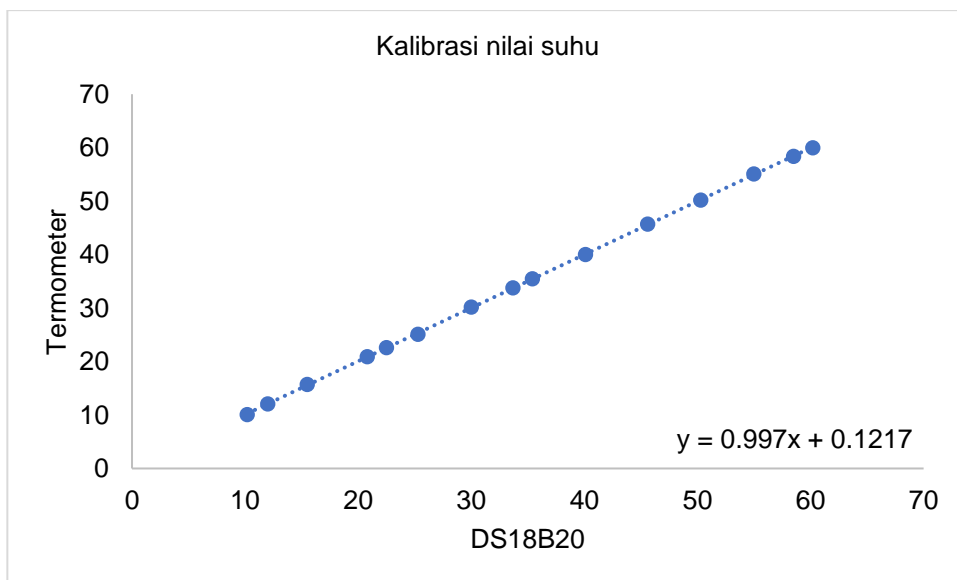
Lampiran 2. Data kalibrasi sensor PH-4502C

Sampel Ke	Data Pengukuran pH		Error
	PH-4502C	YY-400	
1	2,13	2,15	0,94%
2	3,27	3,25	0,61%
3	4,45	4,50	1,12%
4	5,67	5,60	1,23%
5	6,89	6,95	0,87%
6	7,54	7,50	0,53%
7	8,23	8,20	0,36%
8	9,34	9,40	0,64%
9	10,48	10,50	0,19%
10	11,59	11,60	0,09%
11	12,75	12,70	0,39%
12	3,52	3,55	0,85%
13	4,68	4,65	0,64%
14	5,83	5,85	0,34%
15	6,97	7,00	0,43%
Rata-rata			0,6153%



Lampiran 3. Data kalibrasi sensor DS18B20

Sampel Ke	Data Pengukuran suhu (°C)		Error
	DS18B20	Termometer	
1	10,2	10,1	0,98%
2	15,5	15,7	1,29%
3	20,8	20,9	0,48%
4	25,3	25,1	0,79%
5	30,0	30,2	0,67%
6	35,4	35,5	0,28%
7	40,1	40,0	0,25%
8	45,6	45,7	0,22%
9	50,3	50,2	0,20%
10	55,0	55,1	0,18%
11	58,5	58,4	0,17%
12	60,2	60,0	0,33%
13	12,0	12,1	0,83%
14	22,5	22,6	0,44%
15	33,7	33,8	0,30%
Rata-rata			0,494%

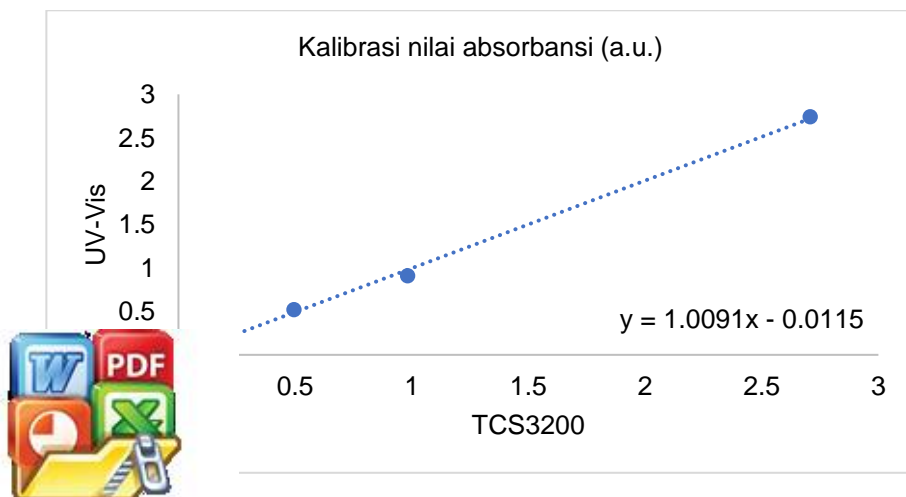


Lampiran 4. Data kalibrasi sensor TCS3200

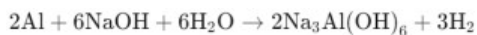
No,	Warna	Data Pengukuran Warna (R, G, B)		Error (R,G,B)
		TCS3200	Standar Warna	
1	Putih	(253, 254, 255)	(255, 255, 255)	(0,78%, 0,39%, 0%)
2	Merah	(250, 0, 0)	(255, 0, 0)	(1,96%, 0%, 0%)
3	Hijau	(0, 250, 0)	(0, 255, 0)	(0%, 1,96%, 0%)
4	Biru	(0, 0, 250)	(0, 0, 255)	(0%, 0%, 1,96%)
5	Kuning	(255, 253, 0)	(255, 255, 0)	(0%, 0,78%, 0%)
6	Cyan	(0, 253, 253)	(0, 255, 255)	(0%, 0,78%, 0,78%)
7	Magenta	(253, 0, 253)	(255, 0, 255)	(0,78%, 0%, 0,78%)
8	Orange	(250, 161, 0)	(255, 165, 0)	(1,96%, 2,42%, 0%)
9	Ungu	(126, 0, 126)	(128, 0, 128)	(1,56%, 0%, 1,56%)
10	Coklat	(137, 68, 18)	(139, 69, 19)	(1,44%, 1,45%, 5,26%)
11	Abu-abu	(127, 127, 127)	(128, 128, 128)	(0,78%, 0,78%, 0,78%)
12	Pink	(253, 180, 191)	(255, 182, 193)	(0,78%, 1,10%, 1,04%)
13	Lime	(190, 253, 0)	(191, 255, 0)	(0,52%, 0,78%, 0%)
14	Emas	(253, 210, 0)	(255, 215, 0)	(0,78%, 2,33%, 0%)
15	Silver	(191, 191, 191)	(192, 192, 192)	(0,52%, 0,52%, 0,52%)

Rumus Beer-Lambert : $A = \log_{10} \left(\frac{I_0}{I} \right)$

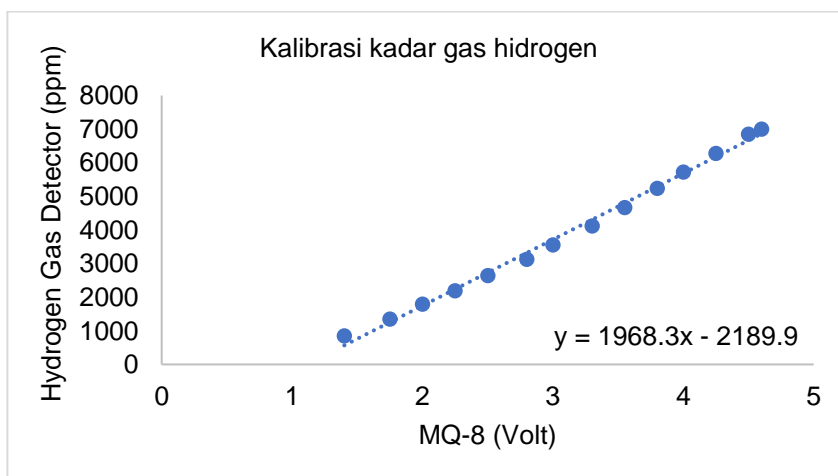
No, Sampel	Sensor TCS3200			Abs (UV-Vis)
	I_0	I	Abs	
1	250	0,49	2,708	2,74
2	250	240	0,017	0,01
3	250	179	0,145	0,15
4	250	80	0,495	0,52
5	250	26	0,983	0,91



Lampiran 5. Data kalibrasi sensor MQ-8



Detik ke-	Nilai MQ-8 (Volt)	Hydrogen Gas detector (ppm)
30	1,40	850
60	1,75	1345
90	2,00	1789
120	2,25	2190
150	2,50	2637
180	2,80	3124
210	3,00	3550
240	3,30	4120
270	3,55	4667
300	3,80	5234
330	4,00	5721
360	4,25	6280
390	4,50	6850
420	4,60	7000
450	1,40	850



- Dari nilai ppm diubah menjadi μmol dengan rumus gas ideal



$$(\mu\text{mol/L}) = \frac{\text{Konsentrasi (ppm)} \times 1000}{\text{Massa Molar (g/mol)} \times \text{Volume Molar (L/mol)}}$$

da kondisi standar (STP) adalah 22.414 L/mol

ah 2.016 g/mol

$v_L = 0,1 \text{ L}$

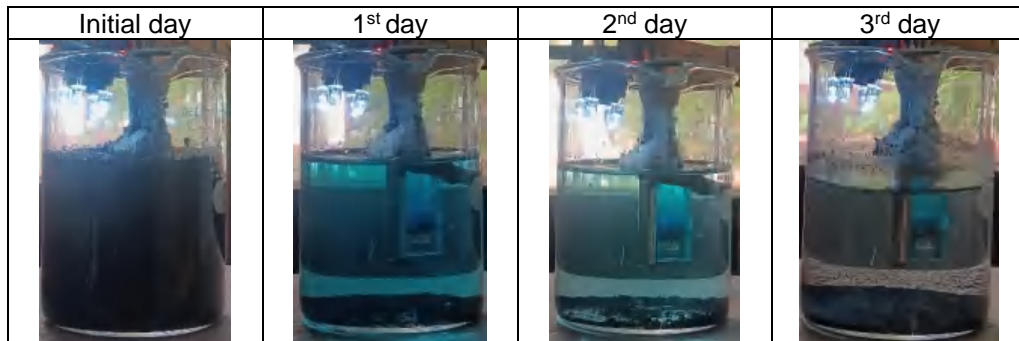
$$\text{Konsentrasi } (\mu\text{mol}) = \frac{\text{Konsentrasi (ppm)} \times 1000}{2,016 \text{ g/mol} \times 22,414 \text{ L/mol}} \times 0,1 \text{ L}$$

Diperoleh nilai konsentrasi H₂ pada massa adsorben 1 g dengan satuan μmol/g

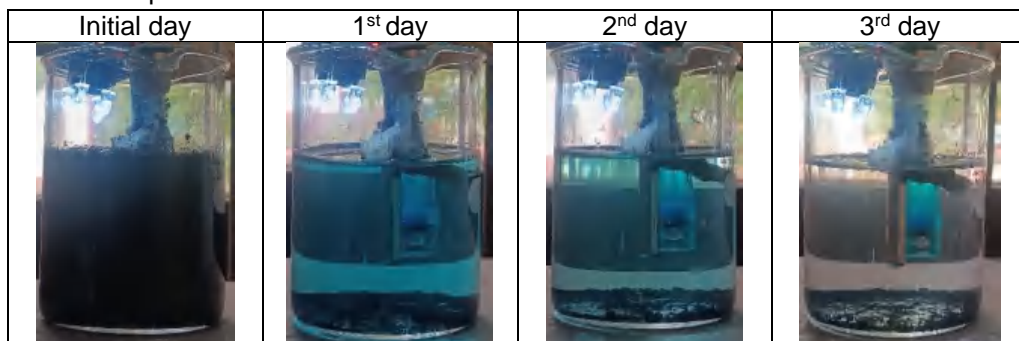


Lampiran 6. Perubahan larutan

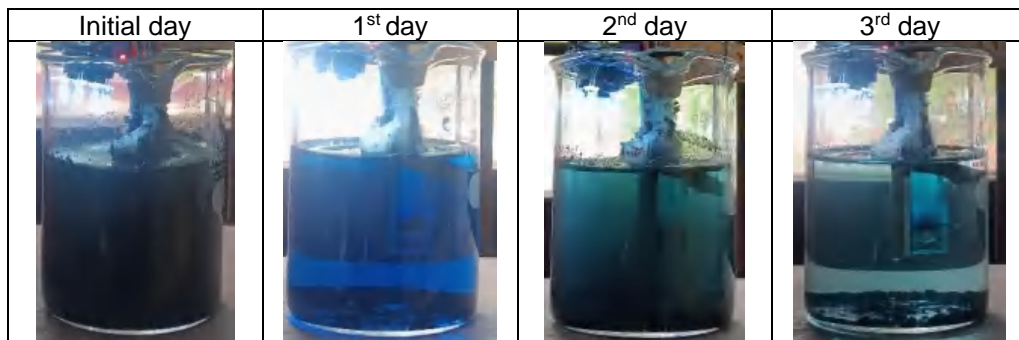
1. AC₁



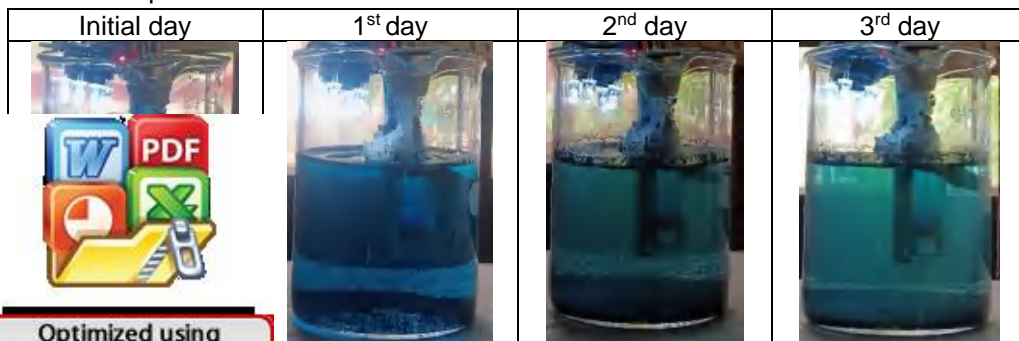
2. AC₁/Hap



3. AC₂



4. AC₂/Hap



Lampiran 7. Perhitungan

1. Ukuran Kristalit

- $AC_1 \rightarrow D = \frac{K\lambda}{\beta \cdot \cos\theta} = \frac{0,9 \times 0,154}{(0,2891 \times \pi / 180) \times \cos(13,23295 \times \pi / 180)} = 28,218 \text{ nm}$
- $AC_1/HAp \rightarrow D = \frac{K\lambda}{\beta \cdot \cos\theta} = \frac{0,9 \times 0,154}{(0,223 \times \pi / 180) \times \cos(13,26635 \times \pi / 180)} = 36,587 \text{ nm}$
- $AC_2 \rightarrow D = \frac{K\lambda}{\beta \cdot \cos\theta} = \frac{0,9 \times 0,154}{(0,5168 \times \pi / 180) \times \cos(13,29365 \times \pi / 180)} = 15,789 \text{ nm}$
- $AC_2/HAp \rightarrow D = \frac{K\lambda}{\beta \cdot \cos\theta} = \frac{0,9 \times 0,154}{(0,2732 \times \pi / 180) \times \cos(13,2476 \times \pi / 180)} = 29,682 \text{ nm}$

2. Degradasi Metilen Biru

$$\%D = \left(\frac{C_o - C_t}{C_o} \right) \times 100\%$$

- AC_1
 - Hari Pertama : $\%D = \left(\frac{2,74 - 0,81}{2,74} \right) \times 100\% = 70,59\%$
 - Hari Kedua : $\%D = \left(\frac{2,74 - 0,22}{2,74} \right) \times 100\% = 92,01\%$
 - Hari Ketiga : $\%D = \left(\frac{2,74 - 0,01}{2,74} \right) \times 100\% = 99,64\%$
- AC_1/HAp
 - Hari Pertama : $\%D = \left(\frac{2,74 - 1,04}{2,74} \right) \times 100\% = 62,24\%$
 - Hari Kedua : $\%D = \left(\frac{2,74 - 0,53}{2,74} \right) \times 100\% = 80,76\%$
 - Hari Ketiga : $\%D = \left(\frac{2,74 - 0,15}{2,74} \right) \times 100\% = 94,56\%$
- AC_2
 - Hari Pertama : $\%D = \left(\frac{2,74 - 2,17}{2,74} \right) \times 100\% = 21,21\%$
 - Hari Kedua : $\%D = \left(\frac{2,74 - 1,98}{2,74} \right) \times 100\% = 28,11\%$
 - Hari Ketiga : $\%D = \left(\frac{2,74 - 0,52}{2,74} \right) \times 100\% = 81,12\%$
- AC_2/HAp
 - Hari Pertama : $\%D = \left(\frac{2,74 - 2,28}{2,74} \right) \times 100\% = 17,21\%$
 - Hari Kedua : $\%D = \left(\frac{2,74 - 1,91}{2,74} \right) \times 100\% = 30,65\%$
 - Hari Ketiga : $\%D = \left(\frac{2,74 - 0,091}{2,74} \right) \times 100\% = 66,96\%$



Lampiran 8. Program

1. Arduino Uno

```

#include <OneWire.h>
#include <DallasTemperature.h>

//sensor pH
const int ph_pin = A0;
float Po;
float PH_step;
int nilai_analog_PH;
double TeganganPh;
float PH4 = 3.474; //nilai Kalibrasi
float PH7 = 3.023 ; //nilai Kalibrasi

//Sensor Suhu
const int oneWireBusPin = 4; // pin D4
OneWire oneWire(oneWireBusPin);
DallasTemperature sensors(&oneWire);

//Sensor Warna
const int s0 = 8;
const int s1 = 9;
const int s2 = 10;
const int s3 = 11;
const int out = 12;
// values
int blue = 0;

//Sensor Hydrogen
const int AOUTpin=A2;//the AOUT pin of the h
int value;

void setup(){
  Serial.begin(9600);
  pinMode(ph_pin, INPUT);
  pinMode(DOUTpin, INPUT);//sets the pin as

  //Sensor Suhu
  sensors.requestTemperatures(); // Minta sensor untuk membaca suhu
  float celsius = sensors.getTempCByIndex(0); //Suhu dari sensor
  float temp = (0,997*celsius)- 0,1217; //Suhu hasil kalibrasi

  //Sensor Warna
  digitalWrite(s2, LOW);
  digitalWrite(s3, LOW);
  digitalWrite(s3, HIGH);
  blue = pulseIn(out, digitalRead(out) == HIGH ? LOW : HIGH);
  digitalWrite(s2, HIGH);
  int absorbance = log(250/blue);
  int ab = (1,0091*absorbance) + 0,0115; //kalibrasi absorbanansi

  //Sensor Hydrogen
  value= analogRead(AOUTpin);//reads the analog value from the hydrogen sensor's AOUT pin
  int ppm = (1966,3*value)-2169,9; // nilai ppm
  int hydro = (ppm*1000*0,1)/(2,016*22,414); //nilai mikromol

  //sediakan variabel penampung data yang akan dikirim
  String datakirin = String(pH,3) + "*" + String(temp) + "*" + String(ab, DEC) + "*" + String(hydro);
  //kirim data ke NodeMCU
  Serial.println(datakirin);
}

pinMode(s0, OUTPUT);
pinMode(s1, OUTPUT);
pinMode(s2, OUTPUT);
pinMode(s3, OUTPUT);
pinMode(out, INPUT);

digitalWrite(s0, HIGH);
digitalWrite(s1, HIGH);

sensors.begin();
}

void loop(){
  //baca permintaan dari NodeMCU
  String minta = "";
  //baca
  while(Serial.available()>0){
    minta += char(Serial.read());
  }
  //buang spasi data yang diterima
  minta.trim();
  //uji variable minta
  if(minta == "Ya"){
    kirimdata();
  }
  minta = "";
  delay(1000);
}

void kirimdata(){
  //Sensor pH
  nilai_analog_PH = analogRead(ph_pin);
  TeganganPh = (5/1022.0) * nilai_analog_PH;
  PH_step = (PH4-PH7)/(6.86-4.01);
  Po = 7.00 + ((PH7 - TeganganPh)/PH_step);
  pH = (0,9985*Po) - 0,0143;//pH hasil kalibrasi
}

```



2. NodeMCU ESP8266

```

#include <SoftwareSerial.h>
#include <ESP8266WiFi.h>
#include <WiFiClientSecureBearSSL.h>
#include <ESP8266HTTPClient.h>

//buat variable untuk software serial (Rx, Tx)
SoftwareSerial DataSerial(12, 13);

//millis sebagai pengganti delay
unsigned long previousMillis = 0;
const long interval = 120000;

//variabel array data parsing
String arrData[4];

//Variabel PIN LED
#define LED_PIN 4 //pin D2 NodeMCU

String respon;
WiFiClient client;
HTTPClient http;

const char* server = "https://adsorptionmonitor.com/post.php";
const char* ssid = "MIPA HOTSPOT";
const char* pass = "";
String apiKeyValue = "1234567890";

void setup() {
  Serial.begin(9600);
  DataSerial.begin(9600);
  pinMode(LED_PIN, OUTPUT);

  //Koneksi ke WiFi

  //Koneksi ke WiFi
  WiFi.mode(WIFI_STA);
  WiFi.begin(ssid, pass);
  Serial.println("Connecting...");
  //cek koneksi
  while(WiFi.status() != WL_CONNECTED){
    Serial.print(".");
    delay(500);
    digitalWrite(LED_PIN, LOW);
  }
  //apabila terkoneksi
  digitalWrite(LED_PIN, HIGH);
  Serial.print("Connected");

  void loop() {
    //konfigurasi millis
    unsigned long currentMillis = millis(); //baca waktu millis saat ini
    if(currentMillis - previousMillis >= interval){
      //update previousMillis
      previousMillis = currentMillis;

      //pembacaan data dari arduino uno
      //baca data serial
      String data = "";
      while(DataSerial.available()>0){
        data += char(DataSerial.read());
      }
      //uang spasi
      data.trim();

      //uji data
      if(data != ""){
        //parsing data

        // Your Domain name with URL path or IP address with path
        https.begin("client, server);

        // Specify content-type header
        https.addHeader("Content-Type", "application/x-www-form-urlencoded");

        // Prepare your HTTP POST request data
        String httpRequestData = "api_key=" + apiKeyValue + "&ph=" + String(ph)
          + "&suhu=" + String(suhu) + "&color=" + String(color)
          + "&hydrogen=" + String(hydrogen) + "";
        Serial.print("httpRequestData: ");
        Serial.println(httpRequestData);

        // Send HTTP POST request
        int httpResponseCode = https.POST(httpRequestData);

        if (httpResponseCode>0) {
          Serial.print("HTTP Response code: ");
          Serial.println(httpResponseCode);
        }
        else {
          Serial.print("Error code: ");
          Serial.println(httpResponseCode);
        }
        // Free resources
        https.end();

        lee {
          Serial.println("WiFi Disconnected");

          Serial.println(httpResponseCode);
          // Free resources
          https.end();
        }
        else {
          Serial.println("WiFi Disconnected");

          //Koneksi kembali ke WiFi
          WiFi.mode(WIFI_STA);
          WiFi.begin(ssid, pass);
          Serial.println("Connecting...");
          //cek koneksi
          while(WiFi.status() != WL_CONNECTED){
            Serial.print(".");
            delay(500);
            digitalWrite(LED_PIN, LOW);
          }
          //Apabila terkoneksi
          digitalWrite(LED_PIN, HIGH);
          Serial.print("Connected");
          return;
        }

        arrData[0] = "";
        arrData[1] = "";
        arrData[2] = "";
        arrData[3] = "";

        //kirim data ke arduino uno
        DataSerial.println("Pa");
      }
    }
  }
}

```



3. Website

- Index.html

```

<!DOCTYPE html>
<html>
<head>
<meta charset="utf-8">
<meta name="viewport" content="width=device-width, initial-scale=1">
<title>AdsorptionMonitor</title>
<link rel="stylesheet" type="text/css" href="style.css">
<link href="img/logo.png" rel="shortcut icon">
</head>
<body>
<header>
<div class="logo">
</div>
<div class="navban">
<ul>
<li class="active"><a href="index.html">HOME</a></li>
<li><a href="data/index.php">MONITORING</a></li>
<li><a href="grafiksensordata/index.php">GRAFIK</a></li>
<li><a href="tabel/index.php">TABEL DATA</a></li>
</ul>
</div>
</header>
<main>
<div class="contents">
<h1>ADSORPTION <span class="color">MONITOR</span></h1>
<p>Ini adalah website monitoring proses fotokatalis secara realtime. Variabel yang diukur adalah pH, Suhu, Kejernihan, dan Kadar Gas Hidrogen</p>
</div>
<div class="button">
<a href="data/index.php" class="btn">Get Started</a>
</div>
<div class="footer">
<h3>©Vicram Setiawan</h3>
</div>
</main>
</body>
</html>

```

- post.php

```

<?php
$servername = "localhost";
$dbname = "u642069453_dbmonitorin";
$username = "u642069453_root";
$password = "Vcrn2901";

$sapi_key_value = "1234567890";

$sapi_key = $ph= $suhu= $color= $hydrogen= "";
date_default_timezone_set('Asia/Makassar');

if ($_SERVER["REQUEST_METHOD"] == "POST") {
    $sapi_key = test_input($_POST["sapi_key"]);
    if($sapi_key == $sapi_key_value){
        $ph = test_input($_POST["ph"]);
        $suhu = test_input($_POST["suhu"]);
        $color = test_input($_POST["color"]);
        $hydrogen = test_input($_POST["hydrogen"]);
        $tanggal = date("Y-m-d H:i:s");

        //Create connection
        $conn = new mysqli($servername, $username, $password, $dbname);
        //Check connection
        if($conn->connect_error){
            die("Connection failed: " . $conn->connect_error);
        }
        $sql = "INSERT INTO tbmonitoring (pH, Suhu, Color, Hidrogen, tanggal)
VALUES (" . $ph . ", " . $suhu . ", " . $color . ", " . $hydrogen . ", " . $tanggal . ")";

        if ($conn->query($sql) == TRUE) {
            echo "New record created successfully";
        }
        else {
            echo "Error: " . $sql . "<br> " . $conn->error;
        }
        $conn->close();
    }
    else {
        echo "Wrong API Key provided.";
    }
}
else {
    echo "Data not posted with HTTP POST.";
}

```



- koneksi.php

```

<?php

$host      = "localhost";
$username  = "u642069453_root";
$password  = "Vcrm2901";
$databse   = "u642069453_dbmonitorin";

$koneksi = new mysqli($host, $username, $password, $databse);
if(!$koneksi){
    echo "database tidak terkoneksi";
}
?>

```

- data

```

<?php
class Laporan {
    // constructor
    public function __construct($koneksi, $judul, $nama) {
        $this->koneksi = $koneksi;
        $this->judul = $judul;
        $this->nama = $nama;
    }

    // method untuk mengambil data
    public function ambilData($tipe) {
        $query = "SELECT * FROM $tipe";
        $result = $this->koneksi->query($query);
        $data = array();
        while($row = $result->fetch_assoc()) {
            $data[] = $row;
        }
        return $data;
    }

    // method untuk menampilkan data
    public function tampilkan($tipe) {
        $data = $this->ambilData($tipe);
        $table = <table border="1"><tr><th>No</th><th>Nama</th><th>Alamat</th></tr><tbody><tr><td>1</td><td>John</td><td>Jember</td></tr><tr><td>2</td><td>Jane</td><td>Jember</td></tr></tbody></table>";
        echo <table border="1"><tr><th>No</th><th>Nama</th><th>Alamat</th></tr><tbody><tr><td>1</td><td>John</td><td>Jember</td></tr><tr><td>2</td><td>Jane</td><td>Jember</td></tr></tbody></table>";
    }

    // method untuk menampilkan data
    public function tampilkan($tipe) {
        $data = $this->ambilData($tipe);
        $table = <table border="1"><tr><th>No</th><th>Nama</th><th>Alamat</th></tr><tbody><tr><td>1</td><td>John</td><td>Jember</td></tr><tr><td>2</td><td>Jane</td><td>Jember</td></tr></tbody></table>";
        echo <table border="1"><tr><th>No</th><th>Nama</th><th>Alamat</th></tr><tbody><tr><td>1</td><td>John</td><td>Jember</td></tr><tr><td>2</td><td>Jane</td><td>Jember</td></tr></tbody></table>";
    }
}

// contoh penggunaan
$koneksi = new mysqli("localhost", "root", "password", "database");
$laporan = new Laporan($koneksi, "Laporan", "Jember");
$laporan->tampilkan("nama");

```



- grafik

```

<!DOCTYPE html>
<html>
<head>
<meta charset="utf-8">
<meta name="viewport" content="width=device-width, initial-scale=1">
<title>Grafik Sensor</title>
<link rel="stylesheet" type="text/css" href="style.css">
<link href="../img/logo.png" rel="shortcut icon">

<!-- panggil file bootstrap -->
<link rel="stylesheet" type="text/css" href="assets/css/bootstrap.min.css">
<script type="text/javascript" src="assets/js/jquery-3.4.0.min.js"></script>
<script type="text/javascript" src="assets/js/mdb.min.js"></script>
<script type="text/javascript" src="jquery-latest.js"></script>

<!-- memanggil data grafik -->
<script type="text/javascript">
var refreshid = setInterval(function(){
    $('#grafikph').load('data.php');
    $('#grafiksuhu').load('data1.php');
    $('#grafikcolor').load('data2.php');
    $('#grafikhidrogen').load('data3.php');
    }, 1000);
</script>
</head>
<body>
<header>
<div class="navbar">
<div class="logo">
<ul>
<li><a href="..">HOME</a></li>
<li><a href="..">MONITORING</a></li>
<li class="active"><a href="index.php">GRAFIK</a></li>
<li><a href="..">TABEL DATA</a></li>
</ul>
</div>
</div>
<!-- tempat untuk tampilan grafik -->
<div class="container" style="text-align: center;">
<h3 style="color: white; text-shadow: -2px 2px 2px grey; text-align: center;">Grafik Monitoring Realtime</h3>
<p style="color: white;">(Vicram Setiawan)</p>
</div>

<!-- grafik pH -->
<div class="container">
<div class="container" id="grafikph" style="width: 80%; text-align: center;"></div>
</div>

<!-- grafik Suhu -->
<div class="container">
<div class="container" id="grafiksuhu" style="width: 80%; text-align: center;"></div>
</div>

<!-- grafik Warna -->
<div class="container">
<div class="container" id="grafikcolor" style="width: 80%; text-align: center;"></div>
</div>

<!-- grafik Hidrogen -->
<div class="container">
<div class="container" id="grafikhidrogen" style="width: 80%; text-align: center;"></div>
</div>
</header>
</body>
</html>

```



- tabel

```




<!DOCTYPE html>
<html>
<head>
  <meta charset="utf-8">
  <meta name="viewport" content="width=device-width, initial-scale=1">
  <title>Tabel Data</title>
  <link rel="stylesheet" type="text/css" href="style.css">
  <link href="../img/logo.png" rel="shortcut icon">
</head>
<style type="text/css">
  h2{
    text-align: center;
  }
  table{
    width: 800px;
    height: auto;
    border: 1px solid white;
  }
  .container{
    position: absolute;
    top: 30%;
    left: 20%;
    transform: translate(-50px, -50px);
  }
</style>
<body>
  <header>
    <div class="navbar">
      <div class="logo">
      <ul>
        <li><a href="../index.html">HOME</a></li>
        <li><a href="../data/index.php">MONITORING</a></li>
        <li><a href="../grafiksensor/index.php">GRAFIK</a></li>
        <li class="active"><a href="tabel/index.php">TABEL DATA</a></li>
      </ul>
    </div>
  </div>
  <div class="container" style="text-align: center;">
    <h2 style="color: white; text-shadow: -2px 2px 2px grey; text-align: center;">DATA MONITORING REALTIME</h2>
    <table style="margin-left:auto;margin-right:auto;text-align:center;color: white;" border="1">
      <tr bgcolor="darkblue">
        <th>ID</th>
        <th>Tanggal, Waktu</th>
        <th>pH</th>
        <th>Suhu (°C)</th>
        <th>Kejernihan (X)</th>
        <th>Kadar Gas Hidrogen</th>
      </tr>
      <?php
      <?php
        include "koneksi.php";
        $data = mysqli_query($koneksi, "SELECT * FROM tbmonitoring");
        while($row = mysqli_fetch_array($data)){
          ?>
          <tr>
            <td><?php echo $row['id']; ?></td>
            <td><?php echo $row['tanggal']; ?></td>
            <td><?php echo $row['pH']; ?></td>
            <td><?php echo $row['Suhu']; ?></td>
            <td><?php echo $row['Color']; ?></td>
            <td><?php echo $row['Hidrogen']; ?></td>
          </tr>
          <?php
          |
          }
          ?>
        </table>
      </div>
    </header>
  </body>
</html>

```



Lampiran 9. Tampilan Data

- Webservice

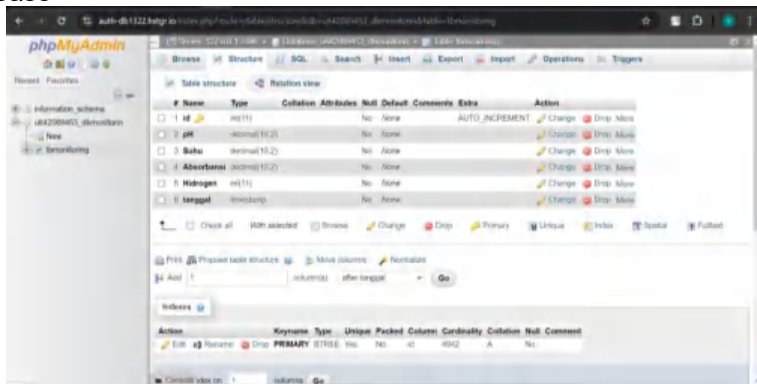
<p>Dashboard</p>									
<p>Data</p>	 <table border="1" data-bbox="462 795 1083 934"> <thead> <tr> <th>pH</th> <th>Suhu (°C)</th> </tr> </thead> <tbody> <tr> <td>7.49</td> <td>27.97</td> </tr> <tr> <th>Absorbansi (a.u)</th> <th>Kadar Gas Hidrogen (voltage)</th> </tr> <tr> <td>0.12</td> <td>3162</td> </tr> </tbody> </table>	pH	Suhu (°C)	7.49	27.97	Absorbansi (a.u)	Kadar Gas Hidrogen (voltage)	0.12	3162
pH	Suhu (°C)								
7.49	27.97								
Absorbansi (a.u)	Kadar Gas Hidrogen (voltage)								
0.12	3162								
<p>Grafik</p>									



Tabel

ID	tanggal	waktu	pH	Suhu (C)	Absorbansi (a.u.)	Kadar Gas Hidrogen (ppm/dl)
1	2024-06-20	18:57:26	6.29	27.65	-0.43	99
2	2024-06-20	18:59:29	5.76	27.71	-0.41	119
3	2024-06-20	19:03:26	7.34	28.02	-1.19	103
4	2024-06-20	19:05:26	7.80	23.89	-1.02	94
5	2024-06-20	19:07:26	7.69	24.02	-1.09	91
6	2024-06-20	19:43:26	6.22	28.76	-0.46	102
7	2024-06-20	20:35:26	6.36	28.28	-0.61	102
8	2024-06-20	20:37:26	6.44	28.22	-0.49	102
9	2024-06-20	20:39:26	6.38	28.22	-0.52	102
10	2024-06-20	20:41:26	6.41	28.28	-0.49	103
11	2024-06-20	20:43:34	6.41	28.22	-0.50	102
12	2024-06-20	20:45:26	6.38	28.28	-0.52	102
13	2024-06-20	20:47:26	6.38	28.28	-0.61	102
14	2024-06-20	20:49:26	6.30	28.28	-0.50	102
15	2024-06-20	20:51:26	6.47	28.34	-0.54	100
16	2024-06-20	20:53:26	6.50	28.28	-0.52	99
17	2024-06-20	20:55:26	6.50	28.28	-0.52	99
18	2024-06-20	20:57:26	6.56	28.28	-0.52	99
19	2024-06-20	20:59:26	6.53	28.34	-0.51	99
20	2024-06-20	21:01:26	6.59	28.34	-0.49	99

- Data Base



- File Manager

