Original Article

Available online at
www.heca-analitika.com/ljes

Leuser Journal of Environmental Studies

Vol. 1, No. 2, 2023

Utilizing Bentonite as a Natural Material to Enhance the Quality of Community Water Resources in the Urban Area

Muhammad Zia Ulhaq [1], Dafif Hanan [1], Athaya Salsabila [2], Andi Lala [3,*], Muslem Muslem [4], Zulhiddin Akbar [5] and Zahriah Zahriah [6]

[1] Universitas Syiah Kuala, Banda Aceh 23111, Indonesia; ziaswatfbicia@gmail.com (M.Z.U.); dafifhanan30@gmail.com (D.H.)
[2] Universitas Indonesia, Depok 16424, Indonesia; athayasalsabila03@gmail.com (A.S.)
[3] School of Mathematics and Applied Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia; andi_lala@usk.ac.id (A.L.)
[4] Department of Chemistry, Faculty of Science and Technology, Universitas Islam Negeri Ar-Raniry, Banda Aceh 23111, Indonesia; moslem_coolam@yahoo.com (M.M.)
[5] Department of Agricultural Product Technology, Faculty of Agriculture, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia; zullhiddin.akbar@usk.ac.id (Z.A.)
[6] Department of Architecture and Urban Planning, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia; zahriah@usk.ac.id (Z.Z.)

* Correspondence: andi_lala@usk.ac.id

Article History

Received 30 August 2023
Revised 3 October 2023
Accepted 16 October 2023
Available Online 24 October 2023

Keywords:
Water quality assessment
Bentonite treatment
Contamination
Sustainable

Abstract

In this study, the researchers investigated the state of water sources and the potential of bentonite as a water treatment agent. The study encompassed measurements of key water quality parameters for river and well water sources, including pH, TDS, conductivity, and salinity. The findings revealed that while pH levels were generally within the clean water standards, TDS values exceeded the threshold, particularly in river water samples. This suggests contamination due to urban activities and rising sea levels. Furthermore, the study explored using both activated and non-activated bentonite as an adsorption agent to remove contaminants from water sources. The results indicated that bentonite effectively increased pH levels, especially in well water samples, and significantly reduced TDS, conductivity, and salinity values, with non-activated bentonite being a preferred option for river water treatment and activated bentonite for well water treatment. These findings emphasize the potential of bentonite as a valuable water treatment solution. The specific characteristics of the water source should guide the choice between activated and non-activated bentonite. This tailored approach can lead to more effective and sustainable water treatment, contributing to improved water quality and availability for the community in the coastal region.

1. Introduction

Clean water is vital in supporting the livelihoods and health of individuals in a specific area. The availability and quality of clean water sources, such as springs, rivers, lakes, and underground water (wells), determine the community's quality of life [1, 2]. Ironically, the quality of these water sources is highly vulnerable to the community's activities [3, 4]. Even without heavy industrial activities in the area [5], household activities, markets, agriculture, and livestock can still pollute these water sources [6]. These sources of pollution can affect standard water quality parameters such as acidity, microorganisms, and dissolved substances in the water [7–9]. Urban areas are the most affected by the problem of declining water quality, which is closely related to high population density, population growth, and community activities in these areas [10].

A maritime country like Indonesia demonstrates that most of its cities are located on the coast, as can be observed in Aceh Province. Geographic data indicates that 17 of the 23 district/municipal cities in Aceh Province are along the coast [11]. The issue of clean water in coastal areas is becoming increasingly severe, with clean water sources being influenced by seawater, leading to elevated water salinity levels. Over the past two decades, the impact of seawater on land-based clean water sources has expanded significantly [12–14]. This phenomenon is driven by global climate change, which results in rising sea levels [15]. Consequently, this condition has a notable effect on the increased contact area of seawater, both infiltrating well water and entering river basins [16].

The majority of city residents near the coast in Aceh can hardly use wells or rivers as a direct source of clean water anymore. Their clean water supply depends on companies the regional government owns that process river water into clean water. Water treatment is carried out from sources far from coastal areas and then distributed through a network of pipes to every corner of urban residential areas [17]. Dependence on a single system for important and continuous needs, such as water, poses a significant risk to its supply stability. If there is a disruption to the processing system or the distribution network, water scarcity will also occur. Therefore, having an alternative water treatment method is crucial for every urban resident.

The water treatment process in clean water supply companies is generally carried out by injecting chemicals such as potassium alum sulfate, sodium carbonate, and chlorine gas [18, 19]. Water monitoring systems have become increasingly sophisticated to complement these treatment processes, incorporating machine learning techniques [20, 21]. Machine learning involves using algorithms and statistical models to enable computer systems to learn from data and make predictions without explicit programming [22–24]. This proactive approach ensures the delivery of safe and clean drinking water to consumers while optimizing the efficiency of chemical usage and treatment operations. However, this procedure is challenging to implement on a household scale because it requires a complex processing and control system. Therefore, a simple method is needed that can be independently carried out by the general public. The use of natural adsorbent materials offers opportunities for clean water treatment. Several natural adsorbents, such as zeolite and bentonite, have shown good effectiveness in adsorbing pollutants in water [25]. Besides being easy to apply, bentonite is highly environmentally friendly and cost-effective. Bentonite resources in Aceh are abundant, and Aceh bentonite has been reported to exhibit excellent efficacy in eliminating *Escherichia coli* bacteria in water, even without activation [26].

In this study, our primary objectives encompassed comprehensive water quality assessment within the coastal region of Banda Aceh City, the capital city of Aceh. Specifically, we aimed to achieve the following goals: Firstly, we conducted extensive measurements of key water quality parameters, including pH, TDS (Total Dissolved Solids), Conductivity, and Salinity, focusing on river and well water sources. This enabled us to thoroughly understand the current state of water quality in the area. Furthermore, our study delved into water treatment techniques utilizing bentonite as an adsorption agent. We examined the efficacy of both inactivated and thermally activated bentonite in removing contaminants from these water sources. This investigation aimed to provide insights into potential sustainable and accessible water treatment methods for the community in this coastal region.

2. Materials and Methods

2.1. Equipment

The equipment used in this study included a pH Meter (WTW-3110), TDS Meter (Milwaukee-Mi 306), Conductometer (Milwaukee-Mi 306), Salinometer (Milwaukee-Mi 306), Beaker Glass, Motor Stirrer, Magnetic Stirrer, Polyethylene Bottles, Erlenmeyer Flask, 125 mm Filter Paper, and Separating Funnel.

2.2. Sampling Location

Water samples were collected from the Krueng Aceh River and community wells within Banda Aceh, Indonesia. Before entering the city, the Krueng Aceh River splits into two branches, with the first branch emptying into Alue Naga and the second into Lampulo. The sampling points are detailed in Table 1. There were three sampling points (SKA 1-A, SKA 1-B, and SKA 1-C) in the branch of the Krueng Aceh River that empties into Alue Naga, three points (SKA 2-A, SKA 2-B, and SKA 2-C) in the branch that empties into Lampulo, and three points (AS-1, AS-2, and AS-3) in community wells located in Lampriet, Kp. Laksana, and Beurawe areas. The coordinate sampling locations for river and well water are presented in Table 1.

The samples were collected using the purposive sampling method. The collected water samples were then analyzed

Table 1. Coordinates and names of water sampling locations.

Sampling Points	Location Name	Coordinates	
		N	E
SKA 1-A	Alue Naga	5°36'05"	95°20'52"
SKA 1-B	Lamnyong Bridge	5°34'19"	95°21'36"
SKA 1-C	Cot Iri Bridge	5°32'08"	95°22'19"
SKA 2-A	Old Lampulo Fish Market	5°34'33"	95°19'22"
SKA 2-B	Peunayong Bridge	5°33'38"	95°19'06"
SKA 2-C	Beurawe Bridge	5°33'13"	95°19'49"
AS-1	Gampong Lampriet	5°33'58"	95°19'48"
AS-2	Gampong Laksana	5°34'14”	95°19'31”
AS-3	Gampong Beurawe	5°33'30"	95°20'06"

on-site for various parameters such as pH (acidity or alkalinity), TDS (the amount of dissolved solids in water), salinity (the salt concentration in water), and conductivity (the ability of water to conduct electrical current). Each parameter was measured three times to ensure precision. Additionally, samples intended for further analysis and treatment in the laboratory were carefully collected in polyethylene bottles to maintain their integrity during transportation. This ensures that the samples remain representative of the conditions at the sampling sites when subjected to subsequent laboratory testing and analysis.

2.3. Work Procedure

The Bentonite used in this research was obtained from a local supplier. The Bentonite was finely ground using a mortar and pestle, and the resulting Bentonite powder was sieved through a 100-mesh sieve. This procedure produced activated Bentonite adsorbent. A total of 100 grams of the sieved Bentonite was activated using thermal methods at a temperature of 120 °C, resulting in activated Bentonite adsorbent. Next, 4 grams of Bentonite were placed into a beaker containing 50 mL of water sample. The mixture was stirred for 120 minutes. The water was then filtered using a 125 mm filter paper. The filtrate was analyzed for pH, TDS, conductivity, and salinity parameters. These measurements were repeated three times for random error measurement.

3. Results and Discussion

3.1. Measurement Data of River Water and Well Water Samples

Parameters such as pH, TDS, conductivity, and salinity are determinants of water quality in Banda Aceh City. This is based on the suspicion of contamination of these parameters, which urban activities and rising sea levels may cause due to climate change. The measurement results of these parameters are presented in Table 2.

The measurement results indicate that the pH of both river water and well water samples is still within the standard limits for clean water (6.5-8.5). However, the TDS values for all water samples exceed the clean water threshold (1 g/L). High conductivity and salinity values were observed in the measurements of river water samples, while well water samples showed relatively low values. Freshwater salinity is generally <5 ‰, while conductivity is <2 mV.

TDS values refer to the amount of organic and inorganic substances dissolved in water, which are closely related to human activities and their waste products in general. The distribution of TDS values in river water indicates that the closer to the estuary, the higher the TDS values. This is due to the accumulation of dissolved substances in the downstream of the river and the high human activity in the area, such as markets and fish auction places [27]. Conductivity and salinity values are closely related to the number of ions of dissolved salts in the water. The conductivity and salinity values variation in river water is similar to TDS, increasing towards the estuary. This is due to the influence of seawater that is pushed into and mixed with the river water. The very high TDS values in all three well water samples suggest the possibility of household wastewater seepage into the wells. Due to the static nature of well water, the accumulation process leads to increasing TDS values over time. Meanwhile, the relatively low conductivity and salinity values in well water indicate that seawater intrusion has not yet contaminated the well water source [28].

3.2. Water Sample Treatment using Bentonite

Measurement of water after the adsorption process using bentonite shows a relative increase in pH values (Figure 1). However, the increase in pH for river water samples is not significant, remaining within the normal range for clean water. In contrast, well water samples show a significant increase in pH, surpassing the clean water quality standards. The pH increase is attributed to the release of carbonate from bentonite into the water during the adsorption process [29]. The relatively low pH values of river water samples are influenced by the high salinity of the water, which can bind carbonate at

Table 2. In situ water data from river and well samples in the field.

Sampling Points	pH ± SD	TDS ± SD (g/L)	Conductivity ± SD (mV)	Salinity ± SD(‰)
SKA 1-A	8.12 ± 0.01	12.94 ± 0.09	22.65 ± 5.62	49.83 ± 1.43
SKA 1-B	7.85 ± 0.01	9.37 ± 0.12	18.27 ± 0.34	35.30 ± 0.58
SKA 1-C	7.60 ± 0.05	7.17 ± 0.04	15.83 ± 2.73	27.87 ± 0.15
SKA 2-A	7.84 ± 0.02	18.92 ± 0.09	14.14 ± 1.47	34.60 ± 4.37
SKA 2-B	7.88 ± 0.02	4.97 ± 1.64	7.37 ± 0.09	15.87 ± 3.50
SKA 2-C	7.89 ± 0.27	1.87 ± 0.16	7.40 ± 2.08	7.83 ± 1.64
AS-1	7.80 ± 0.01	19.97 ± 0.38	0.38 ± 0.01	1.00 ± 0.20
AS-2	7.43 ± 0.02	88.55 ± 0.10	7.01 ± 0.48	3.50 ± 0.10
AS-3	7.60 ± 0.10	68.53 ± 0.15	1.40 ± 0.01	2.70 ± 0.10

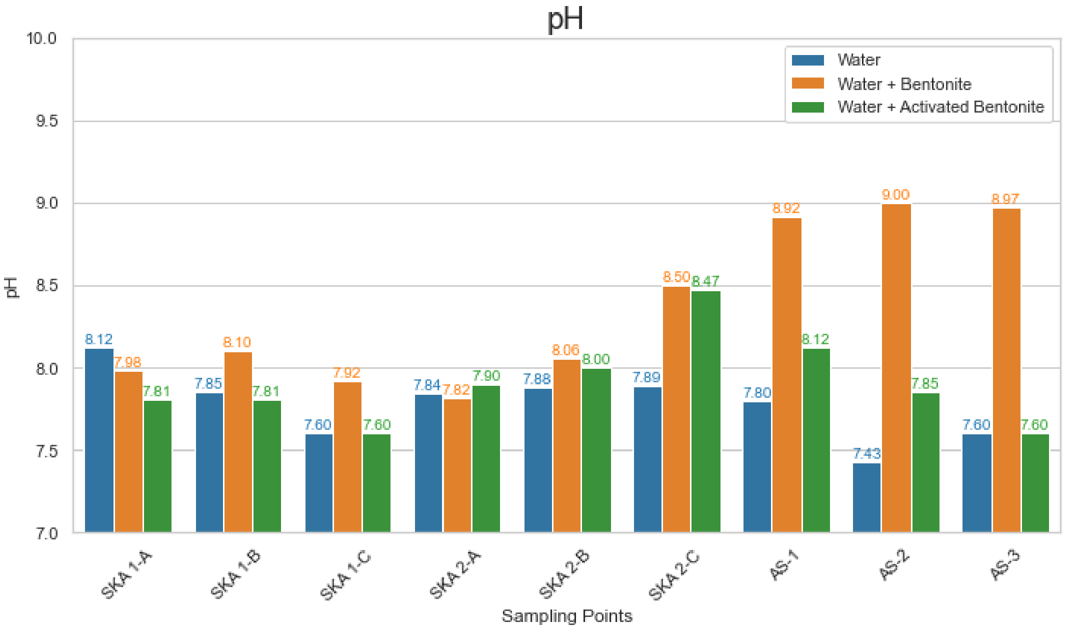

Figure 1. The comparison of pH.

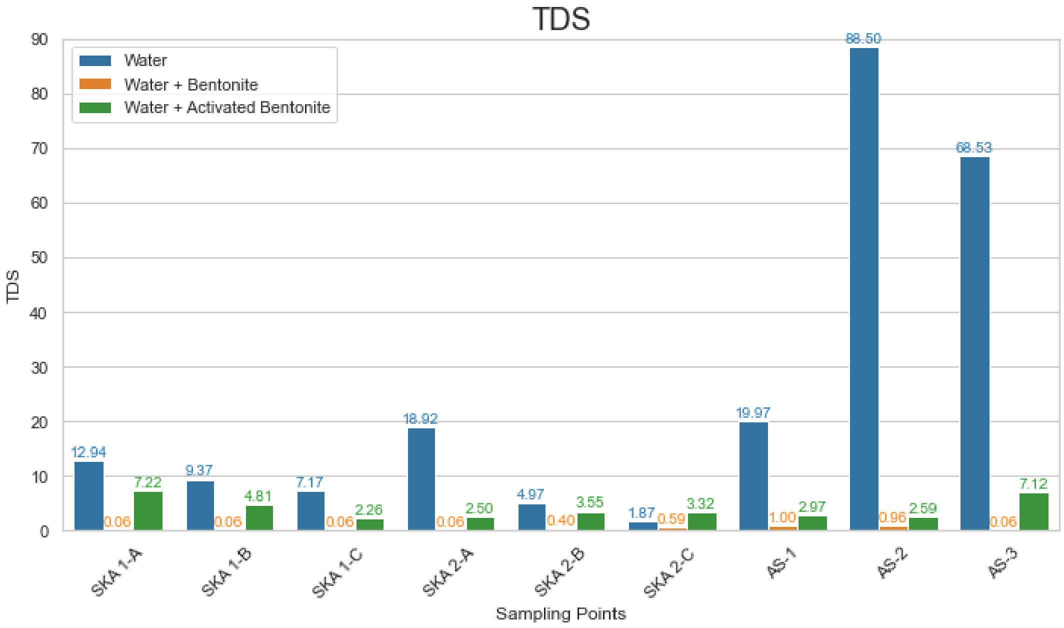

Figure 2. The comparison of TDS.

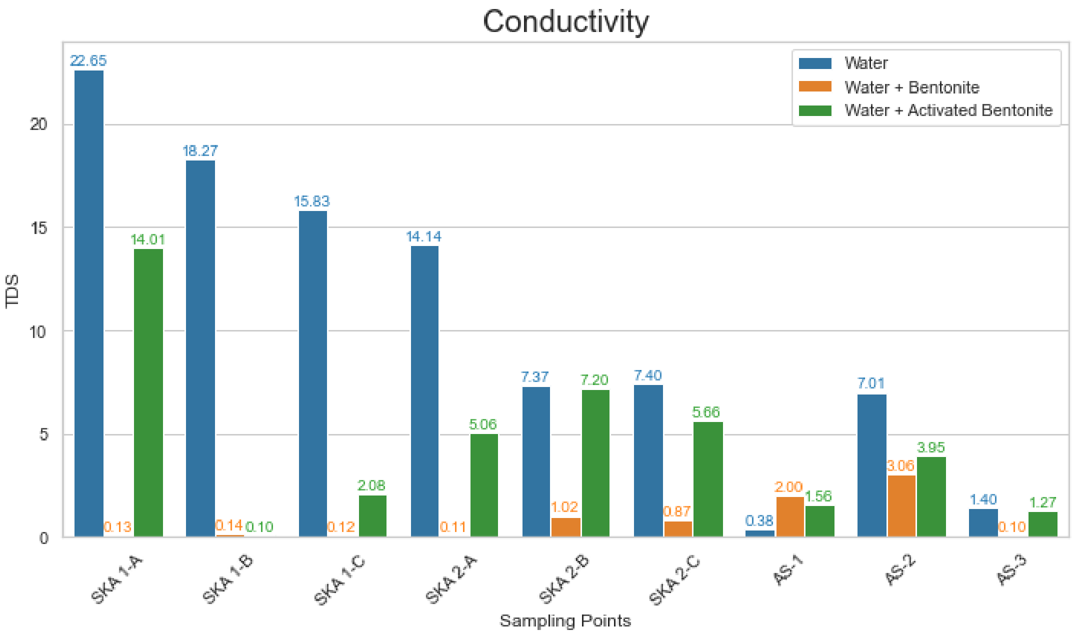

Figure 3. The comparison of conductivity.

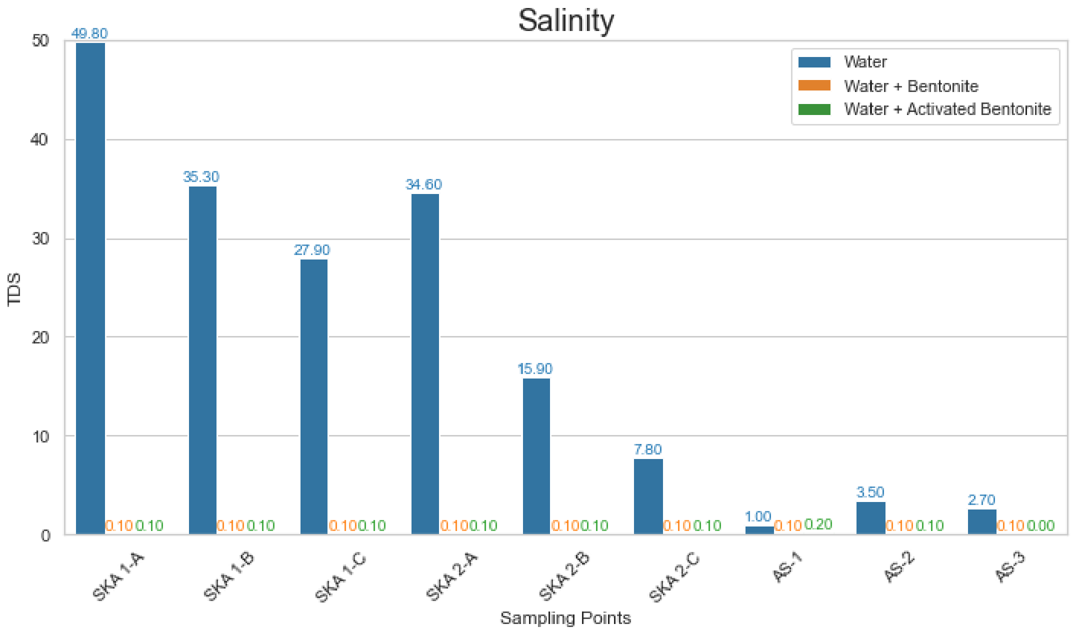

Figure 4. The comparison of salinity.

relatively low pH levels. The use of both activated and non-activated bentonite has an impact on pH values. The use of activated bentonite results in a non-significant increase in pH (within the clean water quality standards). This is influenced by carbonate degradation during the activation process (heating at 120°C).

Bentonite also exhibits good activity in adsorbing dissolved substances. This is evident from the significant decrease in TDS values (Figure 2), even for well water samples with initially very high TDS values. The influence of bentonite activation is also observed in the adsorption of dissolved substances. Activated bentonite shows a lower ability to adsorb dissolved substances than non-activated bentonite. This may be influenced by the reduction in adsorption sites due to the degradation of functional groups during the heating process.

Bentonite also demonstrates fairly good performance in reducing conductivity (Figure 3) and salinity (Figure 4) in both river and well water samples. Both activated and non-activated bentonite exhibit similar capabilities in reducing the salinity of water samples. However, for the conductivity parameter, activated bentonite shows a relatively lower adsorption capacity for non-metallic ion adsorption. This is influenced by the loss of adsorption sites from highly efficient functional groups capable of capturing non-metal ions.

4. Conclusions

This study demonstrates the effectiveness of both activated and non-activated bentonite in reducing TDS, conductivity, and salinity in river and well water samples. Bentonite shows promise as a water treatment agent, choosing between activated and non-activated forms depending on the water source's unique characteristics. Non-activated bentonite is preferable for high-salinity river water, maintaining acceptable pH levels. Activated bentonite is better suited for low-salinity well water despite potential pH elevation. Tailoring treatment methods to specific water source attributes is essential for effective and sustainable solutions, enhancing water quality for diverse societal needs.

Author Contributions: Conceptualization, M.Z.U., D.H., and A.S.; methodology, M.Z.U., A.L. M.M., Z.A., and Z.Z.; software, D.H., A.S., and A.L.; validation, A.L., M.M., Z.A., and Z.Z.; formal analysis, M.Z.U., D.H., and A.S.; investigation, M.Z.U. A.L., and M.M.; resources, A.L. and M.M.; data curation, A.L., M.M., and Z.A.; writing—original draft preparation, M.Z.U., D.H., and A.S.; writing—review and editing, A.L., M.M., Z.A., and Z.Z.; visualization, A.S., and Z.Z.; supervision, A.L.; project administration, A.L. All authors have read and agreed to the published version of the manuscript.

Funding: This study does not receive external funding.

Ethical Clearance: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: We express our deep gratitude to Mr. Muhibbul Khibri, Mrs. Cut Anizar, and the entire SMA Negeri 10 Fajar Harapan Banda Aceh teaching staff for their invaluable support in conducting this research.

Conflicts of Interest: All the authors declare that there are no conflicts of interest.

References

1. Falkenmark, M., and Widstrand, C. (1992). Population and water resources: a delicate balance, *Population Bulletin*, Vol. 47, No. 3, 1–36.
2. Li, P., and Wu, J. (2019). Drinking water quality and public health, *Exposure and Health*, Vol. 11, No. 2, 73–79.
3. Chaudhry, F. N., and Malik, M. F. (2017). Factors affecting water pollution: a review, *J. Ecosyst. Ecography*, Vol. 7, No. 1, 225–231.
4. Fatimah, S., Farida, I., and Sukmawardani, Y. (2023). Interactive Learning for Water Pollution Awareness: A Game-Based Approach, *Journal of Educational Management and Learning*, Vol. 1, No. 1, 31–36. doi:10.60084/jeml.v1i1.52.
5. Prasad, B., Kumari, P., Bano, S., and Kumari, S. (2014). Ground water quality evaluation near mining area and development of heavy metal pollution index, *Applied Water Science*, Vol. 4, No. 1, 11–17.
6. Winarsih, A., Idroes, R., Zulfiani, U., Yusuf, M., Mahmudi, M., Saiful, S., and Rahman, S. A. (2023). Method Validation for Pesticide Residues on Rice Grain in Aceh Besar District, Indonesia Using Gas Chromatography-Electron Capture Detector (GC-ECD), *Leuser Journal of Environmental Studies*, Vol. 1, No. 1, 18–24. doi:10.60084/ljes.v1i1.37.
7. Kumar Reddy, D. H., and Lee, S. M. (2012). Water pollution and treatment technologies, *J Environ Anal Toxicol*, Vol. 2, e103.
8. Hayati, R., Sari, A., Hanum, F., Nabilah, N., Earlia, N., and Lukitaningsih, E. (2023). Formulation and Antibacterial Activity of Averrhoa bilimbi L. Fruits Extract in Vegetable Oil-Based Liquid Hand Soap, *Malacca Pharmaceutics*, Vol. 1, Nos. 1 SE-Article, 30–36. doi:10.60084/mp.v1i1.35.
9. Maulydia, N. B., Khairan, K., and Noviandy, T. R. (2023). Prediction of Pharmacokinetic Parameters from Ethanolic Extract Mane Leaves (Vitex pinnata L.) in Geothermal Manifestation of Seulawah Agam Ie-Seu'um, Aceh, *Malacca Pharmaceutics*, Vol. 1, No. 1, 16–21. doi:10.60084/mp.v1i1.33.
10. Liyanage, C., and Yamada, K. (2017). Impact of Population Growth on the Water Quality of Natural Water Bodies, *Sustainability*, Vol. 9, No. 8, 1405. doi:10.3390/su9081405.
11. Badan Pusat Statistik Provinsi Aceh. (2021). *Provinsi Aceh Dalam Angka 2021*.
12. Naseem, S., Bashir, E., Ahmed, P., Rafique, T., Hamza, S., and Kaleem, M. (2018). Impact of seawater intrusion on the geochemistry of groundwater of Gwadar District, Balochistan and its appraisal for drinking water quality, *Arabian Journal for Science and Engineering*, Vol. 43, 281–293.
13. Chowdhury, S. (2022). Effects of seawater intrusion on the formation of disinfection byproducts in drinking water, *Science of The Total Environment*, Vol. 827, 154398.
14. Idroes, G. M., Hardi, I., Nasir, M., Gunawan, E., Maulidar, P., and Maulana, A. R. R. (2023). Natural Disasters and Economic Growth in Indonesia, *Ekonomikalia Journal of Economics*, Vol. 1, No. 1, 33–39. doi:10.60084/eje.v1i1.55.
15. Idroes, G. M., Syahnur, S., Majid, M. S. A., Idroes, R., Kusumo, F., and Hardi, I. (2023). Unveiling the Carbon Footprint: Biomass vs. Geothermal Energy in Indonesia, *Ekonomikalia Journal of Economics*, Vol. 1, No. 1, 10–18. doi:10.60084/eje.v1i1.47.
16. Dasgupta, S., AKHTER KAMAL, F., HUQUE KHAN, Z., Choudhury, S., and Nishat, A. (2015). River salinity and climate change: evidence from coastal Bangladesh, *World Scientific Reference on Asia and the World Economy*, World Scientific, 205–242.
17. Jiang, Y., and Rohendi, A. (2018). Domestic water supply, residential water use behaviour, and household willingness to pay: The case of Banda Aceh, Indonesia after ten years since the 2004 Indian Ocean Tsunami, *Environmental Science & Policy*, Vol. 89, 10–22.
18. Aziz, N., Effendy, N., and Basuki, K. T. (2017). Comparison of poly aluminium chloride (pac) and aluminium sulphate coagulants efficiency in waste water treatment plant, *Jurnal Inovasi Teknik Kimia*, Vol. 2, No. 1.
19. Faust, S. D., and Aly, O. M. (2018). *Chemistry of Water Treatment*, CRC press.
20. Ghasemigoudarzi, P., Huang, W., De Silva, O., Yan, Q., and Power, D. (2020). A machine learning method for inland water detection using CYGNSS data, *IEEE Geoscience and Remote Sensing Letters*, Vol. 19, 1–5.
21. Muharemi, F., Logofătu, D., and Leon, F. (2019). Machine learning approaches for anomaly detection of water quality on a real-world data set, *Journal of Information and Telecommunication*, Vol. 3, No. 3, 294–307.
22. Noviandy, T. R., Maulana, A., Emran, T. B., Idroes, G. M., and Idroes, R. (2023). QSAR Classification of Beta-Secretase 1 Inhibitor Activity in Alzheimer's Disease Using Ensemble Machine Learning Algorithms, *Heca Journal of Applied Sciences*, Vol. 1, No. 1, 1–7. doi:10.60084/hjas.v1i1.12.
23. Maulana, A., Faisal, F. R., Noviandy, T. R., Rizkia, T., Idroes, G. M., Tallei, T. E., El-Shazly, M., and Idroes, R. (2023). Machine Learning

Approach for Diabetes Detection Using Fine-Tuned XGBoost Algorithm, *Infolitika Journal of Data Science*, Vol. 1, No. 1, 1–7. doi:10.60084/ijds.v1i1.72.

24. Noviandy, T. R., Maulana, A., Idroes, G. M., Maulydia, N. B., Patwekar, M., Suhendra, R., and Idroes, R. (2023). Integrating Genetic Algorithm and LightGBM for QSAR Modeling of Acetylcholinesterase Inhibitors in Alzheimer's Disease Drug Discovery, *Malacca Pharmaceutics*, Vol. 1, No. 2, 48–54. doi:10.60084/mp.v1i2.60.
25. Abdullah, R., Abustan, I., and Ibrahim, A. N. M. (2013). Wastewater treatment using bentonite, the combinations of bentonite-zeolite, bentonite-alum, and bentonite-limestone as adsorbent and coagulant, *International Journal of Environmental Sciences*, Vol. 4, No. 3, 379–391.
26. Lala, A., Marlina, M., Yusuf, M., Rivansyah Suhendra, Maulydia, N. B., and Muslem, M. (2023). Reduction of Microbial Content (Escherichia coli) in Well Water Using Various Processes: Microfiltration Membranes, Aeration and Bentonite Adsorption, *Heca Journal of Applied Sciences*, Vol. 1, No. 1, 24–29. doi:10.60084/hjas.v1i1.17.
27. Zare Farjoudi, S., and Alizadeh, Z. (2021). A comparative study of total dissolved solids in water estimation models using Gaussian process regression with different kernel functions, *Environmental Earth Sciences*, Vol. 80, No. 17, 557. doi:10.1007/s12665-021-09798-x.
28. Khairunnas, K., and Gusman, M. (2018). Analisis pengaruh parameter konduktivitas, resistivitas dan TDS terhadap salinitas air tanah dangkal pada kondisi air laut pasang dan air laut surut di daerah pesisir pantai Kota Padang, *Bina Tambang*, Vol. 3, No. 4, 1751–1760.
29. Kaufhold, S., Dohrmann, R., Koch, D., and Houben, G. (2008). The pH of aqueous bentonite suspensions, *Clays and Clay Minerals*, Vol. 56, No. 3, 338–343.