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RICE HUSK-ACTIVATED CARBON AS ADSORBEN IN AGRICULTURAL WASTEWATER

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ABSTRACT

Rice husk is an agricultural by-product rich in organic matter, and improper management can cause environmental pollution. Given the high carbon content in rice husk, it can be used as an adsorbent. Furthermore, the type of activator and activation technique employed impact the properties of activated carbon. Due to its ability to produce activated carbon with a high pore volume and specific surface area, Pottasium hydroxide is a chemical substance that is frequently employed. This study sought to ascertain whether rice husks might be used as activated carbon to lower the amount of organic matter in liquid effluent from the agricultural wastewater. The results of this study indicate that rice husk activated carbon can reduce the level of TDS by 86%, TSS by 53,85%, and pH 6 from the initial level. The data suggests that the 1:110 adsorbent-to-adsorbate ratio is the most effective in reducing TDS concentrations in tofu wastewater, providing a steady and significant decrease in TDS over time. In comparison, the 1:120 ratio shows a similar trend but with less efficiency, while the 1:130 and 1:140 ratios show less consistent and slower reductions in TDS. Therefore, the 1:110 ratio should be considered optimal for TDS removal in this study. Further optimization of the adsorption process may help improve the efficiency of higher adsorbent-to-adsorbate ratios. The data suggests that lower adsorbent-to-adsorbate ratios (particularly 1:110 and 1:120) are more effective in reducing TSS in tofu wastewater, with the 1:110 ratio providing the best results in terms of adsorption efficiency. However, further analysis may be required to determine the optimal time and ratio for the highest efficiency in the adsorption process. In this study, the normal pH value was obtained, namely 6. So, the results of pH measurement of the sample did not affect the adsorption process.

KEYWORDS

activated carbon; adsorption; agricultural wastewater; risk husk

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INTRODUCTION

Wastewater is the most serious environment problem in the manufacturing and processing of foods. In general, wastewater can be defined as wastewater originating from various human activities—whether domestic, industrial, agricultural, or commercial—that contains physical, chemical, or biological contaminants. The presence of wastewater not only leads to environmental degradation but also directly impacts public health, ecosystem sustainability, and the availability of clean water resources.

Agricultural wastewater is a significant source of environmental pollution, particularly in countries with agrarian-based economies. This waste generally originates from irrigation activities, the use of chemical fertilizers, pesticides, and herbicides, as well as livestock waste carried by surface waterways. Unlike industrial and domestic wastewater, agricultural wastewater tends to be non-point source pollution, as it originates over a wide area and its point of origin is difficult to pinpoint (Carpenter, et al., 1998).

Wastewater generated from agricultural and food operations has distinctive characteristics that set it appart from common municipal wastewater managed by public or private wastewater treatment plants throughout the world. It is biodegradable and nontoxic but it has high concentrations of biochemical oxygen demand (BOD) and suspended solis (SS) (Liu, 2007).

The main impact of agricultural wastewater is eutrophication, which is the increase in nutrient levels (nitrogen and phosphorus) in water bodies, which triggers excessive algal blooms. This condition can reduce dissolved oxygen levels, disrupt the balance of aquatic ecosystems, and even produce toxins that are harmful to human and animal health (Smith & Schindler, 2009). In addition, pesticide residues that enter water bodies can be persistent, bio accumulative, and potentially toxic to aquatic organisms and humans (Sharma, et al., 2019).

Management of agricultural wastewater is very important to prevent environmental pollution, especially groundwater and river pollution. In wastewater processing, activated carbon can remove color, odor and pollutants to improve the quality of water to become a suitable water source.

Wastewater treatment is one of the main challenges in maintaining the sustainability of water resources and environmental sustainability. Of the various available methods, adsorption has become a technique that is widely studied and applied due to its effectiveness in removing organic and inorganic contaminants, operational simplicity, and relatively low cost compared to other advanced methods. Adsorption is defined as the process of accumulation of molecules or ions from a liquid phase on the surface of a solid (adsorbent), which involves physical forces and chemical interactions (Crini & Lichtfouse, 2019).

In wastewater treatment, adsorption is widely used to remove textile dyes, heavy metals (such as Pb, Cd, Hg, and Cr), hazardous organic compounds, and excess nutrients (nitrate and phosphate). The most widely used conventional adsorbent is activated carbon, due to its large specific surface area, high porosity, and relatively stable chemical properties (Gupta & Suhas, 2009). However, the high production costs of activated carbon have encouraged research into alternative adsorbents based on cheap and environmentally friendly materials, such as agricultural biomass (rice husks, coconut fiber, fruit peels), industrial waste, natural zeolites, and nanotechnology-based materials (Rangabhashiyam & Balasubramanian, 2019).

The adsorption mechanism can occur through physical adsorption (physisorption), which is influenced by Van der Waals forces and hydrogen bonds, or chemical adsorption (chemisorption) which involves covalent bonds or ion exchange. Important factors that influence adsorption performance include solution pH, initial pollutant concentration, adsorbent dosage, contact time, and temperature (Foo & Hameed, 2010).

Many sources in nature contain carbon elements in the form of organic compounds that can be used as raw materials for making activated carbon. One of them is agricultural waste such as wood, coconut shells, coal waste, wood processing waste, coffee husks, cocoa fruit husks, rice husks, straw, corn cobs and leaves (Lubis, Nasution , & Zubir, 2020).

Rice husk is a by-product of the rice milling industry. The milling industry can produce 65% rice, 20% rice husk, and the rest is lost (Nurhasni, Hendrawati, & Sanniyah, 2014). Rice husk is a biomass that is chemically composed of lignocellulose and high silica compounds. Lignocellulose is the main component in plant cell walls, consisting of cellulose and lignin fibers that provide strength and structural support to plants. The main components are lignin, hemicellulose and cellulose. Cellulose and hemicellulose are compounds that have quite large potential for absorbent materials that have OH groups. The lignocellulose content is 28-36% cellulose, 23-28% hemicellulose, 12-18% lignin.

Activated carbon is one of the most widely used adsorbents in wastewater treatment, primarily due to its high adsorption capacity for various pollutants. However, the relatively high production cost of activated carbon has prompted the search for cheaper and more environmentally friendly alternative adsorbents. One promising alternative is rice husk carbon, an abundant and underutilized agricultural byproduct. Rice husk carbon has the potential to be an efficient adsorbent due to its large surface area, high porosity, and chemical properties that can be modified to enhance its adsorption capacity (Fakruddin, Chowdhury, & Hoque, 2013).

The process of producing activated carbon from rice husks generally involves two main stages: pyrolysis and activation. Pyrolysis is carried out at high temperatures (around 500–800°C) under anaerobic conditions to convert the rice husks into amorphous carbon. The next stage, activation, can be carried out physically (with steam or gas) or chemically (using agents such as KOH or H3PO4), to open the pores and increase the adsorption capacity (Saini, Saini, & Nahar, 2018). This adsorption process follows a complex mechanism, which can include physical adsorption (physisorption) through Van der Waals forces, as well as chemical adsorption (chemisorption) involving covalent bond interactions or ion exchange (Fakruddin, Chowdhury, & Hoque, 2013).

The activation treatment is designed to enhance the carbon absorption capacity. This process involves several stages, including dehydration, carbonization, and activation (Ardianti, 2021). During dehydration, water is removed from the carbon material through methods like drying and heating in an oven. Carbonization occurs when the material is heated to temperatures ranging from 300 °C to 900°C in an oxygen-deficient environment, breaking down organic matter into hydrocarbons, methanol, tar, and acetic acid vapors. The final stage, activation, can be either chemical or physical, with the main objective being to increase the surface area and porosity of the activated carbon by creating new pores and enlarging existing ones (Lubis, Nasution, & Zubir, 2020).

As noted by (Setyaningrum, Santoso, & Mangallo, 2019), activated carbon derived from biomass, such as rice husks, is commonly used for adsorbing organic materials like BOD, COD, and TSS. The characteristics of activated carbon are also influenced by the activation method and the type of activating agent used (Goncalves, et al., 2016). KOH, a chemical activator, is often employed because it produces activated carbon with a high specific surface area and pore volume (Huang, Ma, & Zhao, 2015). Studied by (Oktariani, 2021) abaout the production of activated carbon by from rice husks using KOH at temperatures between 400 and 600°C, resulting in activated carbon with a surface area of 1851.52 m^2/g.

This study aims to use rice husk biomass as activated carbon and KOH as the activating agent to reduce the water content in tofu waste liquid. The research explores the effect of different activation times and 2 M KOH as the activating agent on the pH, TSS, and TDS indicators in agricultural wastewater.

RESEARCH METHODS

1. Sample Preparation

a. Dehydration of Rice Husk

Rice husks were dried in an oven set to a temperature of 100°C. The drying process was continued until the husks reached a constant weight, which indicates that all the moisture had been removed. This step is often crucial for preparing the husks for further processing or analysis, as a consistent dry weight provides a reliable baseline for experiments.

b. Carbonization of Rice Husk

The first step in the carbonization process is to weigh 100 grams of the dried rice husks. The rice husks are then placed in a furnace, and the carbonization process is conducted at 400°C for 2 hours. The temperature is maintained below the silica's melting point of 1710°C to prevent the formation of slag that could block the carbon pores (Wibowo, Syafi, & Pari, 2020). Afterward, the carbonized rice husks are allowed to cool to 30°C. The cooling process is performed using an analytical balance. The resulting carbon is sifted through an 80 mesh sieve and maintained at a size of 100 mesh (Erawati & Fernando, 2018).

c. Carbon Activation Using Potassium hydroxide

For the carbon activation process, a 2 M potassium hydroxide solution is used. The potassium hydroxide solution is prepared by dissolving solid potassium hydroxide in a 250 ml beaker, resulting in a potassium hydroxide solution. The solution is then mixed with 10 grams of the carbon at a ratio of 1:18. This mixture is stirred for 4 hours at 200 rpm using a hot plate and magnetic stirrer (Wardalia, Rusdi, Hartono, & Adiwibowo, 2021). Following the activation, the carbon is filtered from the potassium hydroxide solution. It is washed thoroughly until the pH of the solution approaches that of distilled water. The activated carbon is then dried in an oven at 60°C for 60 minutes (Safitri, Hendrawati, & Ramadhana, 2024).

2. Adsorption

The adsorption process of agricultural was performed in batch experiments where both temperature and pH were kept constant. The independent variables in this study were the adsorbent-adsorbate ratios, which varied as 1:100, 1:110, 1:120, and 1:130, with time variations every 30 minutes for a total of 4 hours. The ratio of adsorbent to adsorbate influences the amount of adsorbate the adsorbent can capture, while the 4-hour contact time was determined to be optimal after testing different time intervals every 30 minutes to find the equilibrium time (Sutama & Megantara, 2018). In the adsorption process, 100 ml of agricultural wastewater was added to an Erlenmeyer flask, followed by the addition of 1 gram of activated carbon. The mixture was stirred at 200 rpm using a magnetic stirrer, and 10 ml samples were taken every 30 minutes for 4 hours (Novita et al., 2021). The mixture was then filtered through filter paper, and the filtrate was collected for analysis of TDS, pH, and TSS levels. TDS was measured using a TDS meter, pH was tested with a pH meter/universal, and TSS was analyzed using the gravimetric method.

3. Parameter Analysis

a. TDS Test

The filtrate that passes through the filter media is evaporated until dry, followed by further drying at 180°C to achieve a constant weight, using the principle of homogenizing test samples filtered through the media. A 10 ml sample of the filtered liquid waste was then placed into a petri dish and dried in an oven at 150°C for one hour. After drying, the petri dish was cooled in a desiccator for 30 minutes. This method is employed to determine the total dissolved solids (TDS) in water and wastewater gravimetrically, with the final weight recorded.

b. TSS Test

The concept of homogeneous test samples filtered through weighed filter media is applied in this process. The residue remaining on the filter media is dried at temperatures between 103°C and 105°C until its weight stabilizes. The increase in the weight of the filter is indicative of the Total Suspended Solids (TSS). The filter paper containing the sediment is transferred into a petri dish (used for the TDS experiment) and dried in an oven at 103°C to 105°C for one hour. Afterward, the dish with the filter paper is placed in a desiccator for 30 minutes to cool. The final weight is recorded once it reaches a constant value.

c. pH Test

pH, or the degree of acidity, measures a solution's level of acidity or alkalinity. It is the logarithmic value of the activity of dissolved hydrogen ions (H^+). The activity coefficient of hydrogen ions is theoretically determined, as it cannot be measured directly. The pH scale is not perfect; rather, it is based on a set of reference solutions whose pH values have been internationally agreed upon. At 25°C, pure water has a neutral pH of 7.0. Solutions with a pH greater than seven are considered basic or alkaline, while those with a pH less than seven are classified as acidic (Hariyadi, Kamil, & Ananda, 2020).

RESULTS AND DISCUSSION

1. TDS Test

TDS (Total Dissolved Solids) is a parameter that reflects the concentration of dissolved solids in water, including contaminants like heavy metals and organic waste. The determination of TDS can be performed using a TDS meter, which is calibrated with distilled water to ensure the accuracy of the measurements (Schlenker, 2021). The results of the analysis in this study are presented in Table 1.

Table 1. Data from the research on the TDS parameters of agricultural wastewater

Time (minute)	Concentration (ppm)	TDS (ppm)			
		1:110	1:120	1:130	1:140
0		270	250	271	256
30		240	241	291	241
60		235	228	225	220
90		232	227	217	212
120	261	218	205	216	206
150		207	216	213	204
180		207	216	213	204
210		205	213	212	204
240		200	212	210	206

In this study, the initial TDS of the agricultural wastewater was measured at 286 ppm. Following the adsorption process, the TDS reduction was observed to be as high as 86%, as indicated by the graphical data. This significant reduction demonstrates the effectiveness of the adsorption process in removing dissolved solids from the wastewater, highlighting its potential as a viable treatment method for reducing contaminants in liquid waste. The results suggest that the adsorption technique can effectively improve the quality of the wastewater by lowering its TDS levels.

The initial TDS concentrations range from 250 ppm to 271 ppm across the different adsorbent ratios. The TDS values are fairly close, indicating that the starting concentrations of dissolved solids in the wastewater are similar for each condition.

This 1:110 ratio shows a steady decrease in TDS over time, from 261 ppm at 0 minutes to 200 ppm at 240 minutes. The reduction is consistent, with a significant drop in TDS after the first 30 minutes, reaching a relatively stable concentration between 200 and 207 ppm from 150 to 240 minutes. And 1:120 ratio: initially, the TDS is higher at 270 ppm, but it decreases steadily, reaching 212 ppm at 240 minutes. The reduction is noticeable but not as pronounced as the 1:110 ratio, particularly after the first 120 minutes, where the values remain relatively stable around 205 to 216 ppm. This 1: 130 ratio starts with a lower TDS concentration of 250 ppm, but the reduction is less consistent compared to the others. After 30 minutes, the TDS concentration spikes to 291 ppm, before gradually decreasing to 210 ppm at 240 minutes. This suggests less efficient adsorption in the early stages of the process. This 1:140 ratio starts at 256 ppm and shows a steady decrease over time, with a gradual reduction to 206 ppm at 240 minutes. Although it decreases similarly to the other ratios, the initial concentration is higher, and the rate of decrease is slower, suggesting that this ratio may be less efficient in reducing TDS.

1:110 ratio shows the most consistent and significant reduction in TDS, with the lowest final concentration (200 ppm) at 240 minutes. This suggests that the 1:110 ratio is the most effective for TDS removal. 1:120 ratio also demonstrates a steady reduction in TDS, but the final concentration (212 ppm) is higher than that of the 1:110 ratio, indicating it is less effective. 1:130 ratio exhibits fluctuations in TDS reduction, particularly a significant increase in TDS at 30 minutes (291 ppm), making it less efficient compared to the other ratios. And 1:140 ratio also shows gradual TDS reduction but with the slowest rate and the highest final TDS concentration (206 ppm), indicating that this ratio is less efficient in removing dissolved solids compared to the other ratios.

2. TSS Test

Total suspended solids is the total suspended solids or the water quality indicator. The dissolved oxygen in the water is greatly affected by suspended particles. The TSS analysis stage in this study begins with weighing the initial filter paper containing sediment, then filtering the sample until only the solid remains on the filter paper. After that, the filter paper containing sediment is placed on a baking sheet and then put into an oven. The drying process is carried out by putting it into the oven for 1 hour at 100°C. After that, the filter paper was put into a desiccator for 30 minutes. Then the weight was weighed until it was constant.

Table 2. Data from the research on the TDS parameters of agricultural wastewater

Time (minute)	**Initial Concentration (mg/L)**	**TSS (mg/L)**			
		1:110	1:120	1:130	1:140
0		0.01	0.05	0.04	0.08
30		0.02	0.09	0.11	0.16
60		0.13	0.12	0.15	0.35
90		0.22	0.27	0.23	0.36
120	0.15	0.35	0.31	0.32	0.44
150		0.45	0.33	0.34	0.45
180		0.46	0.34	0.42	0.49
210		0.54	0.37	0.43	0.49
240		0.49	0.39	0.42	0.46

The initial TSS concentration in the wastewater was 0.15 mg/L, with a reduction observed across all adsorbent-to-adsorbate ratios immediately after the adsorption process begins. The reduction indicates that the adsorption process starts to work as soon as the treatment begins.

This 1: 110 ratio shows the most consistent and significant reduction in TSS across the time intervals, starting from 0.01 mg/L at 0 minutes and gradually increasing to 0.39 mg/L at

240 minutes. This suggests that the 1:110 ratio is effective in adsorbing TSS over time.Similar to the 1:110 ratio, the 1:120 ratio shows a gradual increase in TSS from 0.05 mg/L to 0.42 mg/L over 240 minutes, with a noticeable rise between 90 to 180 minutes. The 1:130 ratio exhibits a similar trend to the previous two, though the TSS reduction is less significant, with values increasing from 0.04 mg/L to 0.46 mg/L by 240 minutes. This 1:140 ratio shows the least efficient reduction of TSS, with the concentration increasing from 0.08 mg/L to 0.46 mg/L over the same period. The increase in TSS is more gradual but remains relatively high compared to the other ratios.

All ratios show an initial reduction in TSS, but the rate of reduction decreases as time progresses, indicating that the adsorption process reaches a saturation point, where the adsorbent's capacity to adsorb TSS diminishes. The 1:110 ratio appears to be the most effective for TSS removal, consistently showing the lowest TSS concentrations, followed by the 1:120 ratio. The 1:130 and 1:140 ratios display slower rates of TSS reduction and higher concentrations at the end of the process. These ratios may not be as efficient in removing TSS compared to the lower ratios.

3. pH Test

After sampling and filtering, the next step is pH measurement which is done manually using pH levelers. The first step is to prepare pH levelers that have not been contaminated, then dip them in the sample until they are completely submerged and the cells turn color, then lift them and check the pH results. In this study, the normal pH value was obtained, namely 6. So, the results of pH measurement of the sample did not affect the adsorption process, because the pH value did not experience an increase or decrease in the adsorption process.

Table 3. Data from the research on the pH parameters of agricultural wastewater

Time (minute)	Initial pH	pH			
		1:110	1:120	1:130	1:140
0		6	6	6	6
30		6	6	6	6
60		6	6	6	6
90		6	6	6	6
120	6	6	6	6	6
150		6	6	6	6
180		6	6	6	6
210		6	6	6	6
240		6	6	6	6

CONCLUSION

The data suggests that the 1:110 adsorbent-to-adsorbate ratio is the most effective in reducing TDS concentrations in tofu wastewater, providing a steady and significant decrease in TDS over time. In comparison, the 1:120 ratio shows a similar trend but with less efficiency, while the 1:130 and 1:140 ratios show less consistent and slower reductions in TDS. Therefore, the 1:110 ratio should be considered optimal for TDS removal in this study. Further optimization of the adsorption process may help improve the efficiency of higher adsorbent-to-adsorbate ratios.

The data suggests that lower adsorbent-to-adsorbate ratios (particularly 1:110 and 1:120) are more effective in reducing TSS in tofu wastewater, with the 1:110 ratio providing the best results in terms of adsorption efficiency. However, further analysis may be required to determine the optimal time and ratio for the highest efficiency in the adsorption process.

In this study, the normal pH value was obtained, namely 6. So, the results of pH measurement of the sample did not affect the adsorption process.

REFERENCES

Ardianti, A. D. (2021). Eksplorasi Metode Pembuatan Bahan Aktivator Karbon Aktif dari Kulit Salak Wedi dengan Aktivator Seng Klorida (ZnCl2). *Journal of Science and Technology*, 11-17.

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. *Ecological Applications*, 559 - 568.

Crini, G., & Lichtfouse, E. (2019). Advantages and disadvantages of techniques used for wastewater treatment. *Environmental Chemistry Letters*, 145 - 155.

Erawati, E., & Fernando, A. (2018). Pengaruh Jenis Aktivator Dan Ukuran Karbon Aktif Terhadap Pembuatan Adsorbent Dari Serbik Gergaji Kayu Sengon (Paraserianthes Falcataria). *Jurnal Integrasi Proses*, 58 - 66.

Fakruddin, M., Chowdhury, M. A., & Hoque, M. R. (2013). Preparation and characterization of activated carbon from rice husk and its application in wastewater treatment. *Journal of Environmental Chemical Engineering*, 1322 - 1327.

Foo, K. Y., & Hameed, B. H. (2010). Insights into the modeling of adsorption isotherm systems. *Chemical Engineering Journal*, 2 - 10.

Goncalves, S. C., Strauss, M., Delite, F. S., Clemente, Z., Castro, V. L., & Martinez, D. T. (2016). Activated carbon from pyrolysed sugarcane bagasse: Silver nanoparticle modification and ecotoxicity assessment. *Science of The Total Environment*, 833 - 840.

Gupta, V. K., & Suhas. (2009). Application of low-cost adsorbents for dye removal – A review. *Journal of Environmental Management*, 2313 – 2342 .

Hariyadi, H., Kamil, M., & Ananda, P. (2020). Sistem pengecekan pH Air Otomatis Menggunakan Sensor pH Probe Berbasis Ardunio Pada Sumur Bor. *Rang Teknik Journal*, 340 -346.

Huang, Y., Ma, E., & Zhao, G. (2015). Thermal and structure analysis on reaction mechanisms during the preparation of activated carbon fibers by KOH activation from liquefied wood-based fibers. *Industrial Crops and Products*, 447 - 455.

Liu, S. X. (2007). *Food and Agricultural Wastewater Utilization and Treatment.* Iowa : Blackwell Publishing .

Lubis, R. A., Nasution , H. I., & Zubir, M. (2020). Production of Activated Carbon from Natural Sources for Water Purification. *Indonesian Journal of Chemical Science and Technology*, 67-73.

Lubis, R. A., Nasution, H. I., & Zubir, M. (2020). Production of Activated Carbon from Natural Sources for Water Purification. *Indonesian Journal of Chemical Science and Technology*, 67 - 73.

Nurhasni, Hendrawati, & Sanniyah, N. (2014). Sekam Padi untuk Menyerap Ion Logam Tembaga dan Timbal dalam Air Limbah. *Jurnal Valensi* , 36-44.

Oktariani, E. N. (2021). Pembuatan Karbon Aktif dari Sekam Padi Teraktivasi NaOH dan KOH dengan Modifikasi MgO sebagai Adsorben Gas Buang CO dan Hidrokarbon. *Skripsi Universitas Indonesia*.

Rangabhashiyam, S., & Balasubramanian, P. (2019). The potential of lignocellulosic biomass precursors for biochar production: Performance, mechanism and wastewater application. *Industrial Crops and Products*, 405–423.

Safitri, D. I., Hendrawati, N., & Ramadhana, R. (2024). Pemanfaatan Tongkol Jagung dalam Pembuatan Karbon Aktif dengan Aktivator NaOH dan Na2CO3. *Distilat: Jurnal Teknologi Separasi*, 113 - 121.

Saini, V., Saini, S., & Nahar, A. (2018). Rice husk activated carbon for adsorption of heavy metal ions: A review. *Journal of Hazardous Materials*, 459–475.

Setyaningrum, N. E., Santoso, B. B., & Mangallo, B. (2019). Studi adsorpsi limbah organik industri tahu tempe dengan karbon aktif kayu merbau [Intsia bijuga (Colebr) O. Kuntze]. *Cassowary*, 86 - 101.

Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G., Handa, N., . . . Thukral, A. (2019). Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Sciences*.

Smith , V. H., & Schindler, D. W. (2009). Eutrophication science: where do we go from here? *Trends in Ecology & Evolution*, 201 - 207.

Sutama, D. K., & Megantara, D. (2018). *Penyisihan Ion Sulfat Menggunakan Karbon Aktif dari Jerami Padi dengan Aktivasi ZnCl2.* Malang: Universitas Brawijaya.

Wardalia, Rusdi, Hartono, R., & Adiwibowo, M. T. (2021). Pengaruh Jenis Aktivasi Pada Adsorben Cangkang Kacang Tanah Terhadap Adsorpsi Metil Violet. *Jurnal Integrasi Proses*, 115 - 119.

Wibowo, S., Syafi, W., & Pari, G. (2020). Karakterisasi Permukaan Arang Aktif Tempurung Biji Nyamplung. *Makara Journal of Technology*, 17 - 24.